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Research and Innovation Action

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D2.1 – System of integrated multi-scale and multi-thematic performance indicators for the assessment of urban challenges and NBS

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Organisation name of lead contractor for this deliverable: G4C		
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	Authors	G4C and see contributions of partners table

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PU	Public	X
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Document history

History			
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5	12/15/2017	ALL	Consolidated version for review
6	12/21/2017	ALL	Final Version
7	07/23/2018	ALL	Improved version
8	11/02/2018	G4C, METU	New version following the review report comments

List of updates:

- Update of quality and layout for correct funding reference in footer of document.
- Short description of the expert elicitation method
- Update of UC 10
- Update future prospects and needs
- Structuring of Executive Summary + Lessons learned

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Glossary

Acronym	Full name
A	
AAPCV	Annual amount of pollutants captured by vegetation
AC	Adaptive Comfort
ACC	Accessivity
AES	Availability ES
ANS	Adjusted Net Saving
ABNA	Annual Budget of Natural Assets
AQElong	Air quality indicators: long term health effects
AQEshort	Air quality indicators: short term health effects
ARDfuels	Abiotic resource depletion – Fossil fuels
ARDmetalmineral	Abiotic resource depletion – Metal and Mineral
AS	Areal Sprawl
AT	Air temperature
AWC	Absolute Water Consumption
AWW	Agricultural water withdrawal
B	
BAF	Biotope Area Factor
BEN	Buildings Energy needs
BI	Bodily integrity
BN	Betweenness

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C

C&DW	Construction and demolition waste
CAQI	Common Air Quality Index
CAP	Capabilities
CC	Crime counts
CED	Cumulative Energy Demand
Cfer	Chemical fertility of soil
CGS	Connectivity of green spaces
CO_2	Annual carbon sequestration

D

DIPSB	Direct and indirect public spending on bioeconomy
DJ	Distributional justice
DPIC	Domestic Property Insurance Claims

E

EAQLVcity	Exceedence of Air quality limit value – city scale
EAQLVlocal	Exceedance of air quality limit value – local scale
EcoF	Ecotoxicology factor
EE	Energy Efficiency
ENNH	Effects of night noise on health
ERP	Efficiency of valorisation as a result of recycling processes
EIWS	Energy Intensity of Water Supply
EPTvar	Evapotranspiration variation
ES	Energy Security
EUA	Energy use in Agriculture

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F

FAV	Variation of flooded area

G

GEN	Gentrification
GHG	Greenhouse gas
GVAEGS	Gross Value Added in the local Environmental Good & Services sector HIM Heat induced mortality

H

HPI	House Pricing Index

I

IAS	Number of invasive alien species

K

KPI	Key Performance Indicator

L

Lden	Day-evening-night noise level
Lnight	Night noise level
LPB	Labour productivity of bioeconomy
LUsom	Land use related to Soil organic matter changes

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M

MCI	Material Circulatory Indicator
MRT	Mean radiant temperature

N

N4C	Nature4Cities
NBS	Nature Based Solutions
NDMP	Number of deaths and missing people
NDVI	Normalized Difference Vegetation Index
NPIRE	Number of people injured, relocated and evacuated
NVATRBB	N° of VAT registered bioeconomy business

P

PA	Place attachment
PAI	Population Annoyance Index
PALHB	Potential of areas likely to host biodiversity
PI	Performance Indicator
PC	Perceived crime
PCFPV	Per Capita Food Production Variability
PCFS	Percentage of citizens feeling safe
PCFSV	Per Capita Food Supply Variability
PET	Physiological equivalent temperature
PFvar	Peak flow variation
PGV	Percentage of gender violence
PH	Perceived health
PIB	Private investment on bioeconomy

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PJ	Procedural justice
PMV	Predicted mean vote
PSL	Land Use and associated impacts on biodiversity
PT	Perceived temperature
PV	Percentage of victimization

Q

QOL	Quality of life

R

RACER	Relevant – Accepted – Credible – Easy - Robust
REC	Recognition
RES	Responsibility
RME	Raw Material Efficiency
RNPS	Ratio of Native Plant Species
ROL	Rate of landfilling
ROR	Rate of recycling
RRMW	Recycling rate of municipal waste
RRR	Total runoff/Total rainfall ratio

S

SBA	Soil biological activity
SC	Social capital
ScF	Soil classification Factor
SCr	Soil Crusting
Sct	Soil contamination

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SDIH	Shannon Diversity Index of Habitats
SI	Segregation index
SMP	Soil macro porosity
SOM	Soil Organic Matter
SPI	Sustainable Practices Index
SQ	Soil quality
SR	Soil respiration
SWG	Specific waste generation
SWI	Soil water infiltration
SWR	Soil water reservoir for plants
SWS	Soil water storage

T

T	Task
TCS	Thermal Comfort Score
TLO	Thermal load of outstreaming body
TROvol	Total runoff volume
TRFvol	Totall rainfall volume

U

UC	Urban Challenge
UGSP	Urban Green Space Proportion
UPI	Urban Performance Indicator
UPIP	Urban Performance Indicator Pool
USC	Urban Sub-Challenge
UTCI	Universal thermal climate index

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W

WDT	Water detention time
WE	Water efficiency
WI	Water intensity
WP	Work packages
WQ	Stormwater quality
WS	Water security
WSc	Water scarcity

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Executive Summary

Purpose & methodologies

The aim of the task 2.1 in Nature4Cities project is to propose a system of integrated multi-scale and multi-thematic urban performance indicators (UPI) for the assessment of urban challenges (UC) and NBS. This report provides a comprehensive book of reference for UPI regarding NBS. First it presents the UC framework that has been considered in order to develop a clear and coherent indicator system, then the methodology that was used to identify and analyse an extensive set of UPIs, as well as a first attempt to select a list of Key Performance Indicators (KPIs). The partner's expertise in terms of UCs was first compiled based on an intern preliminary survey in order to build expert teams for each UC. In relation with WP1, a comprehensive literature review on UCs has been conducted in order to structure an appropriate UC framework for WP2 works. Among others, the EKLIPSE report was base for the final UC selection.

Key findings & Conclusions

Finally, five main topics, containing eleven UC and 26 urban sub-challenges (USC), were defined. This UC framework covers NBS impacts on Climate Issues, Water Management, Air Quality, Green Space Management and Biodiversity, Urban Regeneration, Resource Efficiency, Public Health and Well-being, Environmental Justice and Social Cohesion, Urban Planning and Governance, People Security and Green Economy. After defining a relevant UC framework structure, expert groups started investigating each UC. They focused on identifying and evaluating a core set of indicators for each UC. Based on the expert groups' knowledge and literature reviews, a total of 110 UPI was compiled. This Urban Performance Indicator Pool (UPIP) was further analysed with the RACER evaluation method to identify relevant KPIs for each UC and USC. This selection of KPIs, from the initial comprehensive indicators set and based on the RACER criteria, is a first attempt at identifying a set of KPIs for our UC framework. The results of this selection will be questioned and contrasted later on with a selection based on expert knowledge that will be performed in Task 2.2. This first selection of KPIs is an input for the Task 2.2 which is going to provide an expert modelling toolbox for the UC framework. Furthermore, it will also be considered by WP3 and WP4. (WP1 > T1.7)

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The results, in kind of KPI selection and methodologies, also take part as knowledge base within EU Task Force II working groups. There is a further specific related connection with the Naturvation project, by the commonly hold Story Corner for NBS case studies and assessment at EUGIC 2017 in Budapest, where the NBS assessment framework was presented also by a Poster.

Lessons learned & EC expectations

The main lessons learned are, that it's often not easy, to separate a specific NBS impact to only one single UC as well as to a single level of scale. The cross-scale impacts at the level of object have to be examined more in detail. There is also a need for deeper future research regarding the relation of the impact of NBS design with all the impacts, they produce and thus contributing specifically to certain UC. Last but not least, the field of NBS-related actions is a very wide and multidisciplinary one, why it's not easy to cover all urban challenges at the same level and expertise.

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1 Introduction

This chapter presents the underlying purpose of the Task and Deliverable, the contribution of each partner and the structure of the document. It also introduces the work process and the relations with other work packages.

1.1 Purpose

The aim of the Task is to define a relevant framework of UCs and to set up a multi-scale and multi-thematic UPI system to quantify the impacts of NBS on these UCs. Out of a comprehensive UPIP, a selection criteria based on the RACER evaluation is proposed and applied in order to obtain a list of KPIs.

1.2 Structure of the document

The document is structured as follows:

- Chapter 1: establishes the purpose and structure of the document
- Chapter 2: presents the UC framework.
- Chapter 3: introduces the used methodology.
- Chapter 4: shows the UC factsheets including USC
- Chapter 5: contains the UPIP regarding UC
- Chapter 6: shows the summarized results of the RACER evaluation
- Chapter 7: treats the KPI selection
- Chapter 8: draws conclusions on the overall content of this report.
- Chapter 9: structures the references
- APPENDIX: contains deep challenge research and all UPI and RACER evaluation FACTSHEETS as well as a summarized table with the main contribution information related to each UPI

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1.3 Contribution of partners

The following table (*Table 1*) presents the contribution of each partner to the task 2.1 through their contributions to the different sections of this report.

Table 1: Contribution of partners

PARTNER	CONTRIBUTION
G4C	Responsible for coordination of deliverable, ToC, section 1, 2, 3, 4.1, 4.7, 5, 6, 7, 8, Appendix II
MUTK	Responsible for 4.9. Contributions to ToC and 4.5. Review of the deliverable.
SZTE	Contributions to 4.1. and 4.3. Review of the deliverable.
IFSTTAR/UN	Responsible for 4.2. Contributions to 4.5 and 4.7. Review of the deliverable.
AO	Responsible for 4.4 and 4.5. Contributions to 4.1, 5 and 7. Review of the deliverable.
ARG	Contributions to 4.2.
CER	Contributions to 4.1 and 4.6. Review of the deliverable.
CAR	Responsible for 4.3. Contributions to 4.2. Review of the deliverable.
EKO	Responsible for 4.6. Contributions to 4.3 and 4.11. Review of the deliverable.
P&C	Contributions to 4.4.
NBK	Contributions to 4.3 and 4.6. Review of the deliverable.
TEC	Responsible for 4.11. Contributions to 4.9.
ACC	Contributions to 4.6 and 4.10. Review of the deliverable.
RINA/DAPP	Contributions to 4.6.
R2M	Contributions to 4.11.
CMM	Review of the deliverable.
CAN	Review of the deliverable.
SZGE	Review of the deliverable.
AH	Review of the deliverable.
LIST	Responsible for 2.1. Contributions to 4.10. and 4.11. Review of the deliverable. Appendix I
METU	Responsible for 4.10. Contributions to 4.8. Review of the deliverable.
CLR	Contributions to 4.9.
IIL	Contributions to 4.8.
TRS	Contributions to 4.4.
DW	Responsible for 4.8.

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1.4 Process of work and relation to other tasks and WPs

The WP2 objective is to provide a system for the assessment of the urban performance of NBS. The urban performance assessment consists in assessing the impacts of NBS on a range of urban challenges proceeding from processes such as impacts on climate mitigation and adaptation, water management, green space management (including biodiversity), air/ambient quality, public health and well-being. Most of these impacts are direct impacts of NBS on local urban challenges.

A first step consists in selecting urban challenges and defining a set of indicators (Task 2.1). In order to carry out the assessment, it is essential to set up a range of performance indicators (multi-scalar and multi-thematic) which are capable of evaluating complex urban challenges and integrated projects implementing NBS. The detailed assessment refers to both urban challenges and NBS. That is possible if the indicators' set is defined in a way that allows the evaluation of the components of urban challenges, and also the impact of NBS. As an example air quality as an urban challenge can be characterized by the concentration of pollutants in the air. On other hand the concentration of pollutants as an indicator is also capable of describing the effect of a certain NBS in the project area considering no other changes in the area of intervention.

WP2 (task 2.2) will provide an "expert modelling toolbox" to address performance indicators' calculation on a service basis (this compilation of existing expert modelling tools won't be integrated in the final platform). These expert modelling tools will also be applied on archetypal NBS projects representative from the NBS typology defined in WP1 in order to enrich the N4C NBS database with performance criteria. Finally, to ensure the implementation of the NBS urban performance assessment within N4C platform, a "Simplified Urban Assessment tool" (SUA tool) will be derived from the results of the above-mentioned application of the expert tools on archetypal NBS projects.

The selected indicators might be used also by other Tasks of WP2, WP3, and 4 together with additional indicators required at those WPs. Thus the Task serves as an input to T. 2.2 (Expert Modelling Toolbox), WP 3 (Environmental Assessment) and WP 4 (Socio-Economic Assessment).

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2 Urban Challenges (UC's) and NBS

Cities are nowadays dealing with highly complex and increasing urban challenges (UC). WP2 aims at facilitating the multi-thematic performance assessment of NBS projects in order to respond to major urban challenges. Thus urban challenges with an integrated point of view were analysed and identified within the partner consortium, based on a comprehensive literature review.

2.1 Framework of UC's

A comprehensive literature review regarding urban challenges was performed within the ongoing PhD thesis from BABI ALMENAR (2020) and linked with WP 1 and WP 2. This subsection and the linked Appendix I content is a literally extract from that thesis:

To keep the information relevant to current urban challenges, the revision was focused on documents and reports mainly published after 2007. In addition, the literature review targeted three types of documents (see Appendix I - UC Literature review for the detailed list):

A - EU Initiatives, projects and reports;

B - Urban planning reports of cities around the world: Sustainability Plans, Resilient Strategies, and Urban development concepts;

C - Scientific literature on urban science & planning.

The selection of documents was done by performing a series of queries in Google and Google Scholar (only for scientific papers) using different combinations of the following keywords:

- urban
- challenges
- priorities
- key issues
- strategic
- resilience.

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In the case of urban planning reports, this was combined with names of cities and a revision of the website section of urban planning departments of 60 cities. The scientific research and the specific research for cities permitted to identify documents from the "100 Resilient Cities" initiative of the Rockefeller Centre.

For EU reports, for the same type of document only the most up to date version was considered. The EU reports act as the main frame for the identification of initial UC of interest. Since, N4C is framed in an EU context it should be coherent with documents and similar initiatives that already identified the key UC for cities of the European Union.

The selection of scientific papers permitted to see if there is a divergence between the UC acknowledged by EU initiatives and the scientific community or if certain challenges have more weight in one or other type of document. It also allowed the extension of the spatial scope to the rest of the world and the identification of urban challenges of global interest. This could be relevant if N4C looks for a future compatibility/integration of our research with other international initiatives. The revision of urban planning reports of cities around the world, introduced the perspective of the own cities. This revision was focused on sustainability plans, resilience strategies and urban development concepts. It was not only focused on European cities to facilitate also the identification of challenges of global interest. In addition, these document permitted the refinement of identified urban challenges and an initial characterisation of sub-challenges.

Once the selection of documents was done, a list of stated UC or urban priorities was collected by type of document. The UC or urban priorities that we could not relate in any way with Nature-based solutions or their implementation models (governance, business and financial models) were disregarded and not included in the list. In addition, each document refers to similar UC in different ways or introduces challenges related to specific scales, but linked to more general UCs. Therefore, there was not a straightforward list of UC and a posteriori interpretation and aggregation of the UC identified in the list was necessary. A plenty of different existing frameworks were analysed, summarized and structured together. To try to keep the structure as simple as possible, the EKLIPSE framework was adduced to be the base for that. Further the gathered challenges were filtered regarding the urban context. For the sake of clarity and workability, the consortium decided to keep the number of challenges at a maximum number of twelve.

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The classification of challenges is slightly different to the one of EKLIPSE. Some of the challenges of EKLIPSE have been considered linked between them or sub-challenges in this classification. Other challenges such as coastal resilience have not been considered relevant for all the cities and were not included as a general challenge. In any case, the list proposed here and their sub-challenges are highly compatible with the ones of EKLIPSE, what facilitates exchange of information between both initiatives.

This classification intends to recognize explicitly the existing main groups of urban challenges, reduce overlapping of sub-challenges, and to facilitate its posterior operability. Also, all the main groups of challenges identified here are relevant globally, and not only at European level. Nevertheless, the specific subdivision is inherently subjective and all the overlaps could not be resolved. In many cases, sub-challenges of climate change can be related to the ones of many other classes (e.g. energy, water security & management) or to consequences obtained from improving them. In other cases, a decision has been made and certain sub-challenges have been assigned to what was considered the most relevant challenge.

The following sub-sections explains briefly each challenge and their first-level sub-challenges. An extended list of challenges, sub-challenges of different levels can be found in Appendix I. The second-level and third-level sub-challenges of that list are just exemplary (Babi Almenar, 2020).

2.2 Topics

To have a clear and coherent structure, the drafted challenges were finally pooled to five different main topics (Table 2): climate, environment, resource, social and economy.

Table 2: Framework of Assessment Topics

CLIMATE
ENVIRONMENT
RESOURCE
SOCIAL
ECONOMY

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2.3 Scales – Urban Planning Tools

A requirement for the indicator finding process was, to find multi-scalar performance indicators. UC must be investigated and assessed at three different scales in line with the practice of urban planning:

- City Scale: refers to city level, usually based on a country basis (from a few kilometres to several kilometres)
- District/Neighbourhood scale: refers to a particular region, district or neighbourhood level which means a larger subset of a city or a space with specific characteristics (from a few hundred metres to several kilometres)
- Object Scale: refers to building and open space level with local characteristics (from a few meters to several hundred metres) (Barbano et al., 2015).

2.4 Urban Challenges (UC's)

The table below (Table 3) shows the simplified UC framework within the main topics for the N4C project, based on a wide and comprehensive literature-review. The five topics include eleven UC and 24 urban sub-challenges (USC).

Table 3: Framework of Urban Challenges

TOPICS	URBAN CHALLENGES (UC)
CLIMATE	1 | Climate issues
	2 | Water management and quality
ENVIRONMENT	3 | Air quality
	4 | Biodiversity and urban space
	5 | Soil management
RESOURCE	6 | Resource efficiency
SOCIAL	7 | Public health and well-being
	8 | Environmental justice and social cohesion
	9 | Urban planning and governance
	10 | People security
ECONOMY	11 | Green economy

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A factsheet was produced to present each UC. Each UC factsheet covering the relation to the topic, a short description and a description of the sub-challenges. – Further the relation between potential actions and expected impacts within each challenge is considered. The sheet also contains consequently a summary of the related indicators. Keywords as well as references top the detailed analysis.

2.5 Urban Sub-challenges (USC's)

The wordcloud (Figure 1) and table below (*Table 4*) show the overall UC framework from Topics to urban sub-challenges (USC). A description of each USC is presented in the respective UC Factsheet in Chapter 5.

Figure 1: Wordcloud of Nature4Cities' urban challenges (UC) and sub-challenges (USC) framework

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Table 4: Urban Challenges framework; topics, urban challenges (UC) and sub-challenges (USC)

TOPICS	URBAN CHALLENGES (UC)	URBAN SUB-CHALLENGES (USC)
CLIMATE	1 | Climate issues	1.1 | Climate mitigation
		1.2 | Climate adaption
	2 | Water management and quality	2.1 | Urban water management and quality
		2.2 | Flood management
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale
		3.2 | Air quality locally
	4 | Biodiversity and urban space	4.1 | Biodiversity
		4.2 | Urban space development and regeneration
		4.3 | Urban space management
	5 | Soil management	5.1 | Soil management and quality
RESOURCE	6 | Resource efficiency	6.1 | Food, energy and water
		6.2 | Raw material
		6.3 | Waste
		6.4 | Recycling
SOCIAL	7 | Public health and well-being	7.1 | Acoustics
		7.2 | Quality of Life
		7.3 | Health
	8 | Environmental justice and social cohesion	8.1 | Environmental justice
		8.2 | Social cohesion
	9 | Urban planning and governance	9.1 | Urban planning and form
		9.2 | Governance in planning
	10 | People security	10.1 | Control of crime
		10.2 | Control of extraordinary events
ECONOMY	11 | Green economy	11.1 | Circular economy
		11.2 | Bioeconomy activities
		11.3 | Direct economic value of NBS

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3 Methodology

Once the UC framework has been consolidated and agreed on, we have followed a five steps methodology (Figure 2) in order to built and document a system of urban performance indicators for NBS:

- Set-up of expert groups
- Deep literature reviews
- Documentation of indicators' factsheets
- Evaluation of UPI through RACER criterions
- Weighted scoring on RACER sub-criterions as an attempt to select KPIs

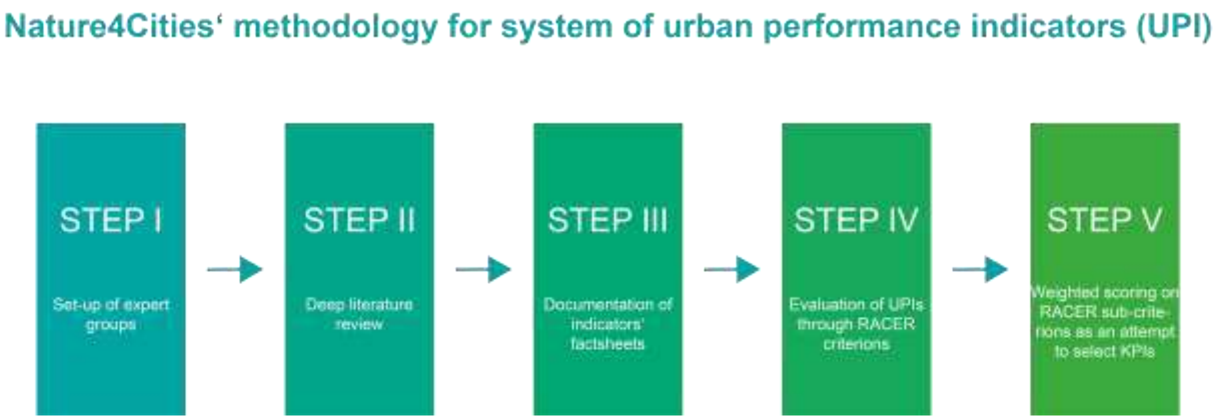

Figure 2: Nature4Cities' methodology for system of urban performance indicators (UPI)

3.1 Set-up of expert groups

In the beginning and in linkage with T 2.2 a Preliminary survey, regarding the partners' expertise and knowledge respectively already used expert models was done to ascertaining and collecting existing partners' knowledge and experiences regarding UCs and indicators (see example Table 5).

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Table 5: Example of the Preliminary survey for partner knowledge inquiry by SZTE

Within the preliminary survey all partners, involved in Task 2.1 and 2.2 have been consulted (Table 6). The main profile of the experts are background expertise for climate issues, water management, biodiversity, energy and economy. Further some expertises for specific urban challenges and issues got elicited within the survey (Figure 3 and Table 6).

Thus, beside a wide and comprehensive field of expertise, the results out of the preliminary survey show basically a nearly full-covering of all Topics with the partner consortium's expertise with the exception of the topics Air quality and Public health and well-being, which were not covered by specialists. At the same time prevalent respective knowledge's for certain UC's were occurring. Thus the focus within the partner consortium was set to the main areas of expertise. The following wordcloud (Figure 3) and table (Table 6) are summarizing and illustrating the N4C Partners expertise regarding NBS impact evaluation and deriving the focus areas of challenges.

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Figure 3: Result of preliminary survey: Wordcloud of partners expertise with main focus on climate and resource/energy issues (larger size means higher expertise)

Table 6: Results of the Preliminary survey for partner knowledge (adapted to final challenges)

PARTNER KNOWLEDGE based on preliminary survey	TOPIC	CLIMATE		ENVIRONMENT				ENERGY	SOCIAL				ECONOMY
	URBAN CHALLENGE	Climate issues	Water management	Air quality	Biodiversity and Urban Space	Soil management	Acoustics	Resource	Public Health and Well-being	Environmental Justice and Social Cohesion	Urban Planning and Governance	People Security	Green Economy
	G4C	x	x		x			x					x
	SZTE	x						x					
	CER	x						x					
	AO	x	x		x	x							
	EKO	x			x			x					x
	ARG	x	x										
	DW							x					
	MUTK	x				x		x		x	x		
	UN/IFSTARR		x		x	x	x		x				
	ACC	x						x					
	NBK	x		x				x					
	DAPP							x					
	DW									x	x		
	TRS				x								
	CAR			x									
	P&C				x								
	TEC										x		x
	R2M												x
	LIST							x					x
	ILL									x			
	METU												
	CLR												
	EUT												

Based on the Preliminary survey and the background expertise of each partner, expert teams were set up in the following, which got responsibility for a single UC in the further Task process. Each Partner was assigned to one or two expert teams, which is composed out of (at least) three partners with one leader.

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Table 7: Expert groups partner's allocation

TOPICS	URBAN CHALLENGES (UC)	EXPERT GROUP PARTNERS
CLIMATE	**1 | Climate issues**	**G4C**, SZTE, CER
	2 | Water management and quality	**IFSTAR**, ARG, CAR
ENVIRONMENT	**3 | Air quality**	**CAR,** NBK, EKO, SZTE
	4 | Biodiversity and urban space	**AO**, P&C, TRS
	5 | Soil management and quality	**AO,** MUTK, IFSTAR
RESOURCE	**6 | Resource efficiency**	**EKO**, DAPP, NBK, CER, ACC
SOCIAL	**7 | Public health and well-being**	**G4C,** DW, IFSTAR, AO
	8 | Environmental justice and social cohesion	**DW**, METU, ILL
	9 | Urban planning and governance	**MUTK**, TEC, CLR
	10 | People security	**METU,** ACC, LIST
ECONOMY	**11 | Green economy**	**TEC,** LIST, R2M, EKO

3.2 Deep literature review

Within the expert teams the specific UC received a thorough examination and analysis containing the necessary information's, based on partners' expertise and a further deep literature review regarding the specific UC and related UPIs in the relevant field. Specific Keywords and acknowledged literature are listed in the related factsheets.

3.3 Documentation of indicators' factsheets

The objective of T 2.1 was, to create a system and set of meaningful but tailored indicators to assess urban challenges and NBS. Nowadays the term indicator is a frequently used but still ambiguous terminology, especially in the field of ecological and environmentally planning. There are occurring different application approaches and concepts regarding environmental indicator evaluation as well as understandings between policy and science (e.g. indicator, index, data, …) (Haase et al. 2014, Heink et al. 2010, OECD 2003).

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Due the missing of a generally valid definition for the term indicator, the consortium decides to agree on a clear definition, based on a further indicator-specific literature review, and to find selection criteria for using indicators to avoid problems based on different understandings.

The process to find a list or pool of UPIs for NBS evaluation was based on a detailed analysis containing following parameters shown in
Figure 4.

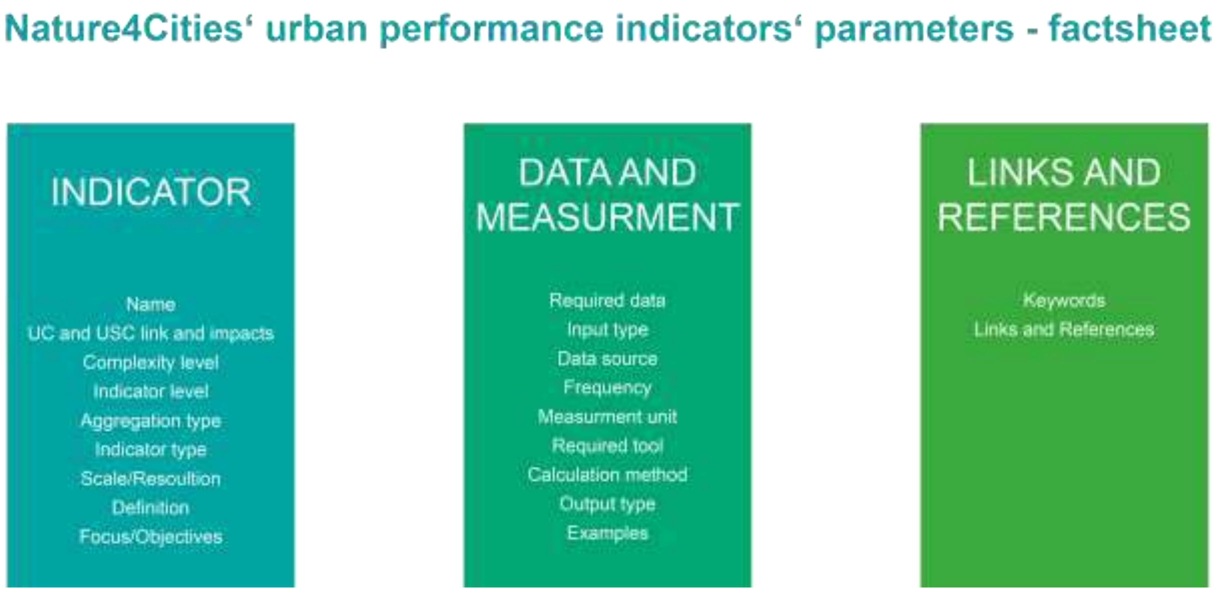

Figure 4: Nature4Cities' urban performance indicators' analysis parameters - factsheet

Figure 5 shows the defined indicator system and the relations between parts. The INPUT for the Urban Performance Indicator Pool (UPIP) is obtained from partners' knowledge and literature review and lead to URBAN PERFORMANCE INDICATORS (UPI) which are related to Urban Challenges (UC) and NBS impacts. The UPIP is a collection of a range of UPI, whence Key Performance Indicators (KPI) can be selected.

To streamline the list of KPIs a RACER criteria evaluation was developed. The documentation of the particular indicators is done by so-called FACTSHEETS, which contain indicator specific information. Indicators needed to cover three main scales of urban planning (object, neighbourhood, city).

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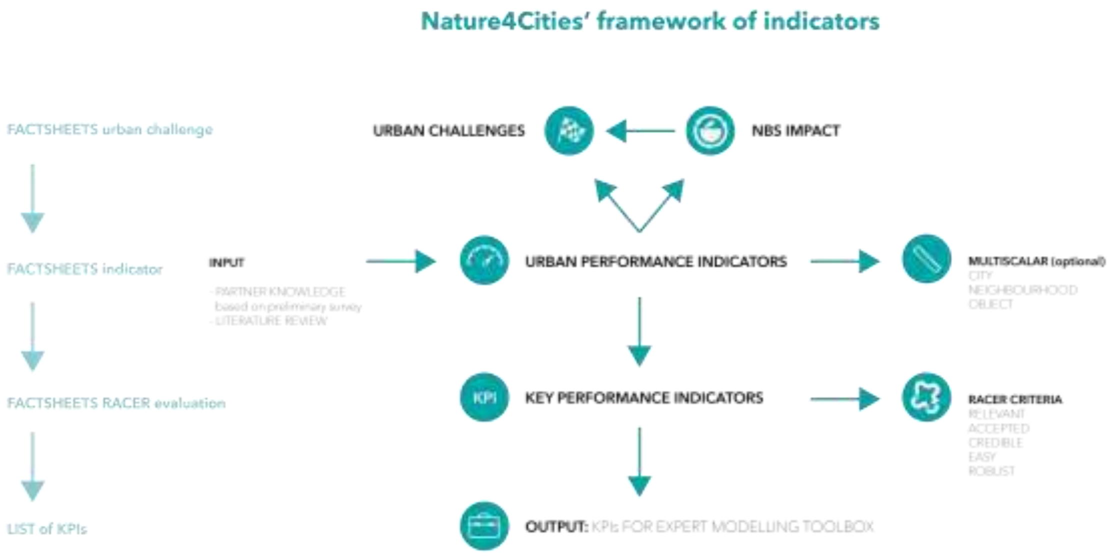

Figure 5: Framework of indicators

For a common understanding we've furtherone defined a straight indicator hierarchy (Figure 6) based on appropriate literature references *(BIO Intelligence Service 2012; Science for Environment Policy 2015)* and own adaptations (intern background knowledge of an indicator approach of the EU-H2020 Project OptEEmAL) for the specific case.

It all starts by a so-called PARAMETER, which is a property, that can be measured or observed. A collection of a couple of PARAMETERS, that have been measured or observed is following a DATA SET. This kind is usually the source of specific data, used by typical environmental indicators. Furtherone we've distinguished among three different indicator levels. A 1st level INDICATOR is thus a value derived from PARAMETER(S) or DATA SET, which points to, provides information about, and/or describes the state of a phenomenon, environment or area. If a 1st level INDICATOR is proceeded further into a equation or model, he gets into the next level and is getting a 2nd level INDICATOR. If this one is furtherone used again in a equation or model, he's getting into the next level, 3rd level INDICATOR, and theoretical ongoing.

INDICATOR DEFINITION AND HIERARCHY

PARAMETER	a property that is measured or observed
DATA SET	a collection of PARAMETERS that have been measured; usually the source of the specific data used by indicators
1st LEVEL INDICATOR	a value derived from PARAMETER(S), which points to, provides information about, and/or describes the state of a phenomenon/environment/area
2nd LEVEL INDICATOR	1st LEVEL INDICATOR proceeded into furhter equation or model
3rd LEVEL INDICATOR	2nd LEVEL INDICATOR proceeded into furhter equation or model

Figure 6: Framework of indicators – Indicator Hierarchy

Additionally, to the definition for coherence, some examples were shared, discussed and improved at that time (

Figure 7), to show the hierarchy system by means of examples.

	EXAMPLES	
PARAMETER	air temperature	sealed area
DATA SET	air temperature, radiation, wind, relative humidity	sealed and unsealed area
1st LEVEL INDICATOR	MRT	sealing grade
2nd LEVEL INDICATOR	PET	—
3rd LEVEL INDICATOR	PET Thermal Sensation Scale	

Figure 7: Framework of indicators – Indicator Hierarchy examples

For each indicator a FACTSHEET was produced, which contains the relation to the UC, Topic and USCs, the complexity level, indicator level, aggregation, type, scale, again a short description as well as objectives. And further informations regarding data and measurement as well again keywords and literature references.

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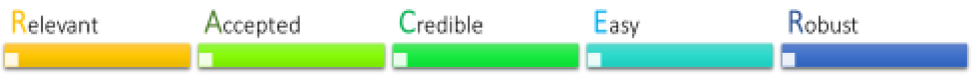
3.4 Evaluation of the UPI through RACER criterions

Find KPIs out of the UPIP, the consortium decided to follow the RACER framework. It was specified by the EC's Impact Assessment Guidelines, to assess the value of scientific tools for use in policy making (Lutter et al., 2008). It's an evaluation framework developed for assessing the value of scientific tools for use in policy making. RACER is an acronym for:



Relevant	= closely linked to the objectives to be reached
Accepted	= by staff, stakeholders, and other users
Credible	= accessible to non experts, unambiguous and easy to interpret
Easy	= feasible to monitor and collect data at reasonable cost
Robust	= not easily manipulated

Figure 8: RACER criteria framework (Science Communication Unit, University of the West of England, Bristol 2012)

The RACER framework and its sub-criteria have been adapted to our specific case, based on different literature papers *(Science Communication Unit, University of the West of England, Bristol 2012 and BIO Intelligence Service, Institute for Social Ecology and Sustainable Europe Research Institute 2012).* The base for the evaluation is a framework with three sub-criteria within each RACER category, summing up altogether to 15 issues (see Table 8, Table 9 and Table 11).

Each categorie and sub-criterion has to be answered descriptive in a sufficient way and thus colour coded in Green, Yellow or Red colour code (as can be seen in Table 8) within a factsheet. The RACER Evaluation Factsheet contains thus a specified and deep set of clear questions (see Table 8 and Table 9) by having the same significance and value for each RACER criterion.

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Table 8: Case-adapted RACER Evaluation Factsheet I

Factsheet RACER Evaluation

INDICATOR	
NAME	**Name of Indicator**
TOPIC	**Name of Topic**
URBAN CHALLENGE	**Name of Urban Challenge**
SUB-CHALLENGE	**Name of Sub-Challenge**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

RELEVANT
R1: Linkage to the project aim: Is the indicator capable of describing initial planning problems?
R2: Policy support for policies: Is the indicator related to specific policies and/or objectives?
R3: Comparability: Is the methodology designed to provide data comparable to and usable together with existing datasets? Is it possible – with reasonable effort – to standardise the methodology, in order to provide fully comparable results?

ACCEPTED
A1: Policy makers: Has the indicator been applied/tested in the development or assessment of policies?
A2: Practitioners: Does the indicator have the potential to be or is used by an urban planner in operational urban planning praxis?
A3: Other stakeholders: Is the indicator accepted by other stakeholders (e.g. described in one or several peer-reviewed publications in recent years)?

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Table 9: Case-adapted RACER Evaluation Factsheet II

CREDIBLE
C1: Unambiguous results: Do the indicator results convey a clear, unambiguous message? This relates to interpretation by political decision makers? Does the general public accept/understand the indicator, what it is?
C2: Transparency: Has the indicator a clear methodology?
C3: Documentation of assumptions and limitations: Are the underlying data, calculation methods and assumptions fully disclosed, interpretable and reproducible, in order to ensure a uniform application in all EU member states?

EASY
E1: Availability of data to calculate the indicator: Does the methodology require inputs of data that has already been collected (in best case in electronic form) or which still has to be generated? Is it possible to update it easily?
E2: Technical feasibility: Is the indicator simple enough to be carried out using software and expertise appropriate to the scale of application and the typical capabilities of the institution doing the calculations? Can it be applied using standard software and hardware or does it require purchasing special equipment? Are the inputs and the calculation methodology clearly defined to avoid ambiguity and consequent error in implementation?
E3: Reproducibility: Is it possible to apply the indicator in numerous (similar but different) cases? Has it been used in different circumstances and delivered reasonable results?

ROBUST
R1: Data quality: Does the indicator use robust real data and estimation procedures which serve for all declared purposes?
R2: Sensitiveness: Is there an assessment of the uncertainty of the produced data included in the methodology? Is an error estimation or calculation procedure an integral part of the study, is there an explicit sensitivity testing approach provided, or is the uncertainty of the produced data only described in general terms?
R3: Scale: Is the indicator tracking NBS-impacts on more scales?

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3.5 Weighted scoring on RACER sub-criterions as an attempt to select KPIs

The objective is to propose a reduced set of KPIs covering the whole urban sub-challenges and compatible with urban planning praxis. In that respect we have decided to base our selection of KPIs on the RACER indicator evaluation system.

Figure 9: Task 2.1 KPI framework

The KPIs should be obtainable directly by measurements or should be modelled using easily available input data. The KPI selection approach is in relation to the thematical importance of the scope and dimension of the specific sub-challenge and ensures a comprehensive evaluation of NBS regarding the defined UC’s and USC’s by choosing contentwise full covering KPI’s.

Therefore, the methodology leads to a quantitative analysis of the urban performance indicators, existing in form of evaluation points. The legend below shows the RACER classification for the RACER sub-criterions, composed of three defined classes with a colour code and weighted points with linked criterions (see Table 10).

Table 10: RACER Evaluation Classification Legend

Legend:

2 points	criterion completely fulfilled
1 point	criterion partly fulfilled
0 points	criterion not fulfilled

Further for each RACER criterion three relevant RACER sub-criteria got defined (see Table 11), to have a equilibrium among the RACER evaluation criterions. Combined with the weighted points (see Table 10), the total points for the evaluation can sum up too maximum 30 for each UPI.

Table 11: RACER Evaluation Criterions and sub-criterions

RELEVANT			ACCEPTED			CREDIBLE			EASY			ROBUST		
R1: Linkage to project aim	R2: Policy support for policies	R3: Comparability	A1: Policy makers	A2: Practioners	A3: Other Stakeholders	C1: Unambiguous results	C2: Transparency	C3: Documentation of assumptions	E1: Availability of data	E2: Technical feasibility	E3: Reproducibility	R1: Data quality	R2: Sensitiveness	R3: Sensitiveness

Finally, a summary table (see Chapter 6) shows the result of the RACER evaluation in a clear matrix. For the KPI choosing process the combined approach of RACER evaluation results with expert knowledge was used. To cover all sub-challenges, the basis regulation was defined within the Partner consortium to choose at least one UPI, the best RACER evaluation rated one, from each USC. The number of choosen KPIs is further in relation to the number of the collected and allocated UPIs for each USCs and thus depending on the focus of the partner's expert knowledge. The more recorded UPIs in the USCs, the more KPIs were choosen out of them. The final decision of KPI selection is based on profound expert knowledge and documentated judgement in favour of more meaningful and challenging-covering KPIs.

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4 Urban challenges (UC's) FACTSHEETS

Based on the methodology, a FACTSHEET has been written for each UC, containing a description of the challenge, potential actions and expected impacts, followed by a short indicator-list containing appropriate indicators split up for each sub-challenge. In the following sections (5.1 to 5.11) the related UCs and USCs are analysed detailly with this common factsheet.

4.1 UC 1 | Climate Issues

1 | CLIMATE ISSUES

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.1 | Climate mitigation
		1.2 | Climate adaption

INFORMATIONS	
DESCRIPTION UC	The quality of life in European cities and in most of the world is threatened by a number of factors including increasing pollution levels, urban heat islands, flooding and extreme events related to climate change, as well as decreased biodiversity (Grimm et al., 2008). These can have detrimental effects for human health and well-being. At the same time, cities are a large source of carbon emissions. The importance of action on carbon mitigation and greenhouse gas control at the urban level was addressed at the COP21 in Paris, highlighting that as the world becomes more urbanized, local action is becoming increasingly important (UNFCCC, 2016). For example, the European Commission's Covenant of Mayors (www.covenantofmayors.eu) obliges European cities to establish an Action Plan to reduce their carbon emissions by over 20%, including by using NBS and through the sustainable management of green space. Each city will need to aim for carbon-neutral urban development. Climate resilience is based on two interacting concepts: • **Climate adaption** • **Climate mitigation**

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In the case of NBS, which involve elements of ecosystems, the two concepts are closely linked as any adaptation of an ecosystem can further influence the mitigation potential (e.g. by sequestering carbon in vegetation), with an overall dramatic effect on climate resilience (Calfapietra et al., 2015; Van Vuuren et al., 2011). One of the major issues in implementing NBS for urban climate resilience and in understanding their potential impact and effectiveness is related to the scale of intervention. Action on climate mitigation can span the micro level of a single building, the meso level of a district or whole city or country and the macro level of the entire planet, though it has essentially a macro (global) scale effect through affecting global concentrations of greenhouse gases. Climate adaptation is more often planned and implemented at the meso (national) to micro (local) level, and the impacts are also at these levels. NBS can contribute to climate adaptation, such as through improved water management.

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1.1 | CLIMATE MITIGATION

INFORMATIONS	
DESCRIPTION USC	Climate mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazard of climate change to human life, property. The International Panel on Climate Change (IPCC) defines mitigation as: *"An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001a)."*

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Increasing the area of** (or avoiding the loss of) **green space, particularly wetlands and tree cover,** for both direct and indirect carbon storage.	• Carbon sequestration in vegetation and soil (Davies et al., 2011; Pataki et al., 2006). • Reducing the temperature at meso or microscales, thus decreasing the energy demand for cooling, especially in warmer climates, and reducing associated carbon emissions (Akbari, 2002).
• **Maximizing the net sequestration of carbon** through species selection and management practices i.e. improving mitigation as well as choosing species that are adapted to future conditions.	• Climate change mitigation and carbon storage by vegetation, including carbon stored in soil (Davies et al., 2011; Pataki et al., 2006). • Securing long-term carbon storage in vegetation and soil and avoid carbon emissions from land-use changes (global impact).

INDICATORS	
• **CO_2 - Carbon storage and sequestration in vegetation and soil** (Davies et al., 2011; Demuzere et al., 2014).	• Tonnes of carbon removed or stored per unit area per unit time (Zheng et al., 2013), total amount of carbon (tonnes) stored in vegetation (Davies et al., 2011). • Comparison with calculations of carbon consumption of equivalent non-NBS actions (e.g. through Life Cycle Assessment). • Allometric forest models of carbon sequestration, developed using proxy data obtained from Lidar data (Giannico et al., 2016). • Growth rates derived from Forest Inventory Analysis (Zheng et al., 2013).
• **GHG – Avoided GHG emissions**	• The total amount of Greenhouse gas emissions avoided as a result of implementation of specific NBS. • Comparison with calculations of carbon consumption of equivalent non-NBS actions (e.g. through Life Cycle Assessment). • Close relation to energy consumption at building scale. • Calculation of avoided GHG emissions (Pan et al., 2016). • Improve comfort in buildings and at street level through increased energy savings at building and street level by the insulating effect of plants (Alexandri and Jones, 2008; Zinzi and Agnoli, 2011; Malys, 2016).

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1.2 | CLIMATE ADAPTION

INFORMATIONS	
DESCRIPTION USC	Climate adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences. The IPCC defines adaptation as the*, "adjustment in natural or human systems to a new or changing environment. Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2011a)."*

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Increasing the area of** (or avoiding the loss of) **vegetation and particularly tree cover.** • **Increasing green walls and roofs** to cool down the city through outdoor energy management using shading and the latent heat of evapotranspiration of plants and soils.	• Maximize cooling effect by evapotranspiration and shading, thus reducing local temperatures and ameliorating heat island effects and heat stress (Alexandri and Jones, 2008; Fioretti et al., 2010; Kazmierczak, 2012). • Reducing wind speed and thus wind chill in cold climates. • Mitigation of thermal hot spots • Decreasing air temperature (Doick et al, 2014) • Decreasing air temperature (Hathway and Sharples, 2012; Theeuwes et al, 2013)

INDICATORS	
• **AT – Air temperature**	• Decrease in mean or peak daytime local temperatures (°C) (Demuzere et al., 2014). • Heatwave risks (number of combined tropical nights (>20°C) and hot days (>35°C)) following Fischer, Schär, 2010, cited by Baró et al. (2015).
• **TLO - Thermal load of out-streaming body** (GREEN**PASS**®, 2016)	• Describes the difference (Delta K/C°) between the hourly average In- and Out-flow Air temperature of an area on the height of 1.8 m (standardized human) over the day (typical summer day).
• **AC - Adaptive Comfort (Indoor)-** (Nichol 2002, 2012).	• Takes into account the ways that people's perceptions of their environment change based on seasonal expectations of temperature and humidity as well as their capacity to control the conditions in a space (Nichol 2002, 2012).

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• **TCS - Outdoor Thermal Comfort Score**	• Calculation of Thermal Comfort Score outdoor (GREEN**PASS®**)
• **PET – Physiological equivalent temperature**	• Calculation of human thermal comfort (physiological equivalent temperature) e.g. ENVIMET, Rayman, Solene
• **UTCI – Universal thermal climate index**	• Calculation of human thermal comfort (universal thermal climate index) e.g. ENVIMET, Rayman, Solene
• **MRT – Mean radiant temperature**	• Calculation of human thermal comfort (mean radiate temperature) e.g. ENVIMET, Rayman, Solene
• **PT – Perceived temperature**	• Calculation of human thermal comfort (perceived temperature) e.g. RaymanPro
• **PMV – Predicted mean vote**	• Calculation of human thermal comfort (predicted mean vote) e.g. ENVIMET, Rayman, Solene
• **β - Bowen ratio**	• Caluclation of Bowen ratio (ratio between sensible and latent heat).

LINKS AND REFERENCES

KEYWORDS	• Climate Change • Climate Change Adaption • Climate Change Mitigation • Greenhouse Gas • GHG • CO_2 sequestration • Urban Heat Island • UHI • Microclimate • Thermal comfort • PET - Physiological equivalent temperature • UTCI - Universal thermal climate index • MRT - Mean radiant temperature • PMV – Predicted mean vote • TCS – Thermal comfort score • Building energy consumption

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4.2 UC 2 | Urban Water Management and quality

2 | URBAN WATER MANAGEMENT AND QUALITY

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | URBAN WATER MANAGEMENT AND QUALITY	2.1 | Urban water management and quality
		2.2 | Flood management

INFORMATION	
DESCRIPTION UC	The quality of life in European cities and in most of the world is threatened by a number of factors including increasing pollution levels, urban heat islands, flooding and extreme events related to climate change, as well as decreased biodiversity (Grimm et al., 2008). These can have detrimental effects for human health and well-being. Urban areas are characterized by impervious surfaces that strongly modify the water cycle, compared to natural surfaces (Fletcher et al, 2013): decreased groundwater, increased surface runoff, higher stormwater pollution fluxes and lower evapotranspiration. If urban water management was mainly first focused on conveyance of water away from cities (Burian & Edwards, 2002), in the last decades it adopted an approach driven by multiple objectives (Fratini et al, 2012). Nature Based Solutions used in urban water management, help to get closer to a natural water cycle. They are usually based on increasing storage, infiltration and/or evapotranspiration processes. Thus they can **mitigate floods** by source stormwater storage, they lead to a **more sustainable urban water management** by favouring groundwater recharge and increasing urban vegetation area and they also can contribute to mitigate UHI by increasing evapotranspiration. Urban water management challenges are usually examined at the catchment scale that can be compared to the neighborhood scale for climate issues, for example. Actually, for urban hydrology issues, discharge, the main monitored physical variable, is a spatially integrated variable. But urban water management challenges can also be studied at micro-scale, as the NBS scale, by monitoring the effective water stored. Evaluation of mixed scenarios of NBS at the city scale can also allow to avoid negative joint effects or to promote positive ones (Gunawardena et al, 2017).

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2.1 | URBAN WATER MANAGEMENT AND QUALITY

INFORMATIONS	
DESCRIPTION USC	Since the last decades, urban water management has been more interested in environment protection and urban sustainability. European legislation with the EU water framework Directive adopted in 2000 participated to the awareness of stakeholders. Water pollution and water resources are now at the heart of topics of urban water management. Imperviousness of urban surfaces and human activities lead to decreased groundwater recharge impacting water resource, increased surface runoff leading to more frequent and more intense floods, higher stormwater pollution fluxes potentially impacting groundwater quality or urban river quality, lower evapotranspiration favouring the urban heat island phenomenon. Nature based solutions allow to mitigate such effects by modifying the urban water cycle. Thus, increasing vegetated areas leads to higher water infiltration and evapotranspiration. Groundwater recharge can then be improved and water outflows from the sewer network to the river can be limited.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Increasing the area of vegetation**	• Decreasing of the runoff volumes (Khan et al, 2012; Yilmaz et al, 2016) • Increasing of evapotranspiration volume (Chapman and Horner, 2010, Yilmaz et al, 2016) • Increasing groundwater resource (Brander et al, 2004)
• **Increasing water storage**	• Increasing of evapotranspiration volume (Hathway and Sharples, 2012)
• **Decreasing water pollution**	• Decreasing the pollutant load of the stormwaters to comply the water quality standards of the european WFD (Sage et al, 2015)

INDICATORS	
• **EPTvar - Evapotranspiration variation**	• increase of evapotranspiration as a consequence of increase interception or infiltration, leading to lower surface runoff
• **SWS - Soil water storage**	• increase infiltration can lead to lower surface runoff. It can also contribute to water storage at larger time scale for water resource purposes (irrigation of vegetation during dry season, to support evapotranspiration)
• **PFvar - Peakflow Variation**	• Increase flowrate (peakflow) reduction due to a given rain event by NBS catchment
• **WQ - Stormwater quality**	• Improvement of the water quality leaving systems to comply the thresholds of the Water Framework Directive

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2.2 | FLOOD MANAGEMENT

INFORMATIONS	
DESCRIPTION USC	Urban areas are characterized by impervious surfaces that strongly modify the water cycle, compared to natural surfaces (Fletcher et al, 2013). The increased surface runoff and the higher speed transfer of water at the surface and into the pipes, lead to more intense and more frequent flow peaks. Nature Based Solutions used for flood management can help to limit surface runoff by favoring infiltration. They can also help to store water in order to move back and decrease the peak time. Thus they can mitigate flood. Urban flood management challenges are usually examined at the catchment scale and at the event scale. Then, the discharge in the river or the pipes can be used to evaluate the peak flows. For flood challenges, the flooded areas are also a good indicator.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Increasing the area of vegetation** and permeable surfaces	• minimizing negative impacts of rainfall events, floods
• **Decreasing the possible impacts of flood event**	• Identifying and reducing the impacts of rainfall events, floods

INDICATORS	
• **TROvol - Total runoff volume**	• Increasing infiltration (Davis et Al, 2009) • Increasing total runoff volume through NBS catchment
• **TRFvol – Total rainfall volume**	• Increasing infiltration (Davis et Al, 2009) • Increase the level of drainage for an urban area, using permeable hard surfaces and increasing the use of vegetation to reduce runoff and floods. • The combination of NBS can reduce runoff as well as take advantage of the rainfall.
• **RRR - Runoff/rainfall ratio**	• Rainfall / runoff response (Blume et Al, 2010)
• **FAV - Variation of flooded area**	• Flood variation and soil nutrient content in floodplain vegetation communities in the Okavango Delta. (Tsheboeng et Al, 2013)
• **WDT - Water detention time**	• Increasing infiltration (Davis et Al, 2009) • Increasing possible flood hazards protection through NBS ability

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LINKS AND REFERENCES

KEYWORDS	• sustainable urban water management • urban flood management • potential thermal control • evapotranspiration • stormwarter pollution • runoff • soil water storage
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4.3 UC 3 | Air Quality

3 | AIR QUALITY

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | AIR QUALITY	3.1 | Air quality at district/city scale
		3.2 | Air quality at local scale

INFORMATION	
DESCRIPTION UC	The quality of life in European cities and in most of the world is threatened by a number of factors. The drivers include increasing pollution levels, urban heat islands, flooding and extreme events related to climate change, as well as decreased biodiversity[1]. These can have detrimental effects for human health and well-being. **Air quality is also a major concern worldwide**, **particularly in urban areas**, due to its direct consequences on human health, plants, animals, infrastructure and historical buildings (among others). In the political agenda, air quality issues can be coupled with climate change mitigation policies as described in Challenge 1, since many actions aimed at air quality improvement (such as reducing fossil fuel combustion because emissions contains both CO_2 and other GHG gases and pollutants directly affecting health and other issues) involve a concurrent reduction of GHG emissions. NBS based on the creation, enhancement, or restoration of ecosystems in human-dominated environments also exploit the synergy between ecosystem processes that regulate pollutants and CO_2 in the atmosphere. Vegetation affects air quality mainly through the removal of air pollutants (PM10, NO_2, O_3) through dry deposition, although certain species can also emit biogenic volatile organic compounds (BVOC), which are ozone precursors. However, vegetation can also reduce the air temperature, which reduces the emission of BVOCs and slows down the creation of secondary pollutants such as ozone[2,3] or vegetation could be selected to reduce at minimum this kind of emissions[4]. Despite their limited contribution compared to the overall production of pollutants and GHG emissions at the city level, measures to tackle air quality by enhancing green infrastructure can be

[1] Grimm, N.B., Faeth, S.H., Golubiewski, E.N., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global change and the ecology of cities. Science 319, 756–760.
[2] Wang, Y., Bakker, F., de Groot, R., Wortche, H., Leemans, R., 2015b. Effects of urban trees on local outdoor microclimate: synthesizing field measurements by numerical modelling. Urban Ecosyst. doi:10.1007/s11252-015-0447-7.
[3] Calfapietra, C., Fares, S., Manes, F., Morani, A., Sgrigna, G., Loreto, F. 2013. Role of biogenic volatile organic compounds (BVOC) emitted by urban trees on ozone concentration in cities: a review. Environmental Pollution 183, 71-80.
[4] Grote et al., 2016. Functional traits of urban trees: air pollution mitigation potential. Front Ecol Environ 2016; doi:10.1002/fee.1426.

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considered a good investment due to the number of co-benefits that they produce and their contribution to amenity value over time[5] but with a limited impact at district or city scale. **Green infrastructures are beneficial but they do not represent a solution to completely remove air pollution from cities.** We should keep in mind that trying to reduce the concentration of a pollutant once it is already diluted is much more inefficient than when acting directly on the source. However, NBS could be used to treat local problems by placing vegetation systems[6] (with a proper design) near to high traffic roads as capture or barrier to "protect" dense hedges, hospitals, schools, etc. Finally, the effectiveness of green infrastructure-based strategies to meet environmental policy targets can vary greatly across pollutants. PM removal potential should not be neglected in urban policy-making. Other pollutants should be addressed by different methods/technologies to reach detectable effects.

Some of the traits that are beneficial for air pollution mitigation may act in opposite directions for specific services: for instance, uptake capacity increases air quality but decreases plant health, while other traits such as a large leaf area help cool the environment and at the same time reduce air pollutants. It should also be mentioned that ecosystem services are sometimes indirectly related, for example by modifying the microclimate and thus energy consumption, which then reduces anthropogenic emissions. The complexity of the matter has prevented holistic investigations for specific cities or regions, although model approaches that integrate at least some aspects are already available[7].

[5] Baró, F., Haase, D., Gómez-Baggethun, E., Frantzeskaki, N., 2015. Mismatches between ecosystem services supply and demand in urban areas: A quantitative assessment in five European cities. Ecol. Indic. 55, 146–158. doi:10.1016/j.ecolind.2015.03.013

[6] Ahu Aydogan Akseli, Gabriel Tardos, Elizabeth J. Biddinger, "Granulation of Growth Media for Indoor Air Purification Utilizing Botanically-Based Systems", Indoor Air 2016.

[7] Nowak DJ, Crane DE, Stevens JC et al (2008) A ground-based method of assessing urban forest structure and ecosystem services. Arboric Urban For 34(6):347–358.

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3.1 | AIR QUALITY AT DISTRICT/CITY SCALE

INFORMATIONS	
DESCRIPTION USC	**Air quality is also a major concern worldwide**, **particularly in urban areas**, due to its direct consequences on human health, plants, animals, infrastructure and historical buildings (among others). The improvement of air quality in cities is a complex problem. It depends on a large number of factors such as amount and type of traffic, location or weather. The role of the NBS in this regard is limited and can be considered as a small aid to other measures with much greater impact such as the reduction of traffic levels. The indicators selected for this SC have been aimed at knowing the global situation of the city and being able to evaluate in a general way how is the air quality in the city and its possible effects on human health.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Planting trees around the city.** • in private domestic gardens; • along the streets; • in urban parks.	▪ Improved air quality (mesoscale impact) (Baró et al., 2014). ▪ Reduction of air pollutants through increased deposition[8,9,10].
• **Definition of a customized program on tree/green infrastructure species for each city.**	▪ Urban trees help to improve air quality by facilitating widespread deposition of various gases and particles through the provision of large surface areas as well as through their influence on microclimate and air turbulence. However, many of these trees produce wind-dispersed pollen (a known allergen) and emit a range of gaseous substances that take part in photochemical reactions – all of which can negatively affect air quality. The degree to which these air-quality impacts are manifested depends on species-specific tree properties: that is, their "traits". ▪ The suitability of a tree species for a particular combination of demands is highly case-specific, street, district, urban and metropolitan.
• **Other solutions with less impact on air quality but with many associated co-benefits. Green roofs and walls, green barriers, etc.**	▪ Reduction of air pollutants through deposition.

[8] Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D.J., Terradas, J., 2014. Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. Ambio 43, 466–479. doi:10.1007/s13280-014-0507-x.

[9] Bealey, W.J., McDonald, a G., Nemitz, E., Donovan, R., Dragosits, U., Duffy, T.R., Fowler, D., 2007. Estimating the reduction of urban PM10 concentrations by trees within an environmental information system for planners. J. Environ. Manage. 85, 44–58. doi:10.1016/j.jenvman.2006.07.007

[10] Grote et al., 2016. Functional traits of urban trees: air pollution mitigation potential. Front Ecol Environ 2016; doi:10.1002/fee.1426.

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INDICATORS	
• **CAQI - Common Air Quality Index** (www.airqualitynow.eu)	▪ District/Urban scale ▪ Data required.
• **AAPCV - Annual amount of pollutants captured by vegetation** [11]**.**	▪ Street, Urban and Metropolitan scale. ▪ Modelling and data needed.
• **EAQLVcity - Exceedance of air quality limit value – City scale in urban areas.** EU Indicator codes: CSI 004.	▪ The indicator shows the fraction of the urban population that is potentially exposed to ambient air (1) concentrations of pollutants (2) in excess of the EU limit value set for the protection of human health. ▪ It could be adapted to urban scale.

[11] Bottalico, F., Chirici, G., Giannetti, F., De Marco, A., Nocentini, S., Paoletti, E., Salbitano, F., Sanesi, G., Serenelli, C., Travaglini, D., 2016. Air pollution removal by green infrastructures and urban forests in the city of Florence. Agric. Agric. Sci. Procedia 8, 243–251. doi:10.1016/j.aaspro.2016.02.099.

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3.2 | AIR QUALITY AT LOCAL SCALE

INFORMATIONS	
DESCRIPTION USC	At the local or street level, it is easier to locate places with worse air quality in the city for various reasons. Sometimes, in these places there are buildings such as schools or sports facilities where air quality should be especially cared. There are NBS that can help improve air quality locally or act as a barrier to air pollution from a large source. For these cases, it is believed that the installation of NBS may be of special interest and therefore indicators have been proposed that could be used to evaluate their impact. However, there are not too many examples of its use in practice.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Planting trees around the city.** ▪ in private domestic gardens; ▪ along the streets; ▪ in urban parks.	▪ Reduction of air pollutants through increased deposition[12,13,14].
• **Installation of green bio-filters in urban static sources of pollutants:** ▪ City Tunnels extraction chimney. ▪ Underground car parks extraction chimney.	▪ Reduction of air pollutants at pollutant sources. Novel developments.
• **Placing well-design vegetation barriers close to a road/street**	▪ Dilution of emissions with clean air from aloft is crucial; the vegetation should thus preferably be low and/or close to surfaces. ▪ Proximity to the pollution source increases concentrations of air pollutants and thus deposition; vegetation should be close to the source. ▪ Air passing above, and not through, vegetation is not filtered; barriers should be high enough and porous enough to let the air through, but solid enough to allow the air to pass close to the surface[15].
• **Definition of a customized program**	▪ Urban trees help to improve air quality by facilitating widespread deposition of various gases and particles through

[12] Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D.J., Terradas, J., 2014. Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. Ambio 43, 466–479. doi:10.1007/s13280-014-0507-x.

[13] Bealey, W.J., McDonald, a G., Nemitz, E., Donovan, R., Dragosits, U., Duffy, T.R., Fowler, D., 2007. Estimating the reduction of urban PM10 concentrations by trees within an environmental information system for planners. J. Environ. Manage. 85, 44–58. doi:10.1016/j.jenvman.2006.07.007

[14] Grote et al., 2016. Functional traits of urban trees: air pollution mitigation potential. Front Ecol Environ 2016; doi:10.1002/fee.1426.

[15] Janhäll, S.2015. Review on urban vegetation and particle air pollution - Deposition and dispersion. Atmospheric Environment 105, 130-137.

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on tree/green infrastructure species for each city.	the provision of large surface areas as well as through their influence on microclimate and air turbulence. However, many of these trees produce wind-dispersed pollen (a known allergen) and emit a range of gaseous substances that take part in photochemical reactions – all of which can negatively affect air quality. The degree to which these air-quality impacts are manifested depends on species-specific tree properties: that is, their "traits". ▪ The suitability of a tree species for a particular combination of demands is highly case-specific, street, district, urban and metropolitan.

INDICATORS

● **Direct capture of pollutants at local scale.**	▪ As shown in the EKLIPSE report and in many references, the amount of pollutants that can be trapped by vegetation is very low compared to the amount that is emitted in a city. However, NBS could address air quality improvements in micro spaces but no indicators or metrics are found in the literature. It could be proposed a new methodology based on long-time passive measurements of PM and/or O3 for specific areas with or without NBS. Modelling and data needed.
● **EAQLVlocal - Exceedance of air quality limit value – Local scale** EU Indicator codes: CSI 004.	▪ The indicator shows the fraction of the urban population that is potentially exposed to ambient air (1) concentrations of pollutants (2) in excess of the EU limit value set for the protection of human health. ▪ It could be adapted to urban scale.

LINKS AND REFERENCES

KEYWORDS	● Urban ● Air quality ● Vegetation ● Deposition ● Dispersion ● Particle matter ● Ozone ● Air pollutants ● Air Quality Index ● Pollen ● Other ecosystem services
LINKS AND REFERENCES	• Grimm, N.B., Faeth, S.H., Golubiewski, E.N., Redman, C.L., Wu, J., Bai, X., Briggs, J.M., 2008. Global change and the ecology of cities. Science 319, 756–760. • Wang, Y., Bakker, F., de Groot, R., Wortche, H., Leemans, R., 2015b. Effects of urban trees on local outdoor microclimate: synthesizing field measurements by numerical modelling. Urban Ecosyst. doi:10.1007/s11252-015-0447-7. • Calfapietra, C., Fares, S., Manes, F., Morani, A., Sgrigna, G., Loreto, F. 2013. Role of biogenic volatile organic compounds (BVOC) emitted by urban trees on ozone concentration in cities: a review. Environmental Pollution 183, 71-80. • Grote et al., 2016. Functional traits of urban trees: air pollution mitigation potential. Front Ecol Environ 2016; doi:10.1002/fee.1426.

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- Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D.J., Terradas, J., 2014. Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. Ambio 43, 466–479. doi:10.1007/s13280-014-0507-x.
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4.4 UC 4 | Biodiversity and urban space

4 | BIODIVERSITY AND URBAN SPACE

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | BIODIVERSITY AND URBAN SPACE	4.1 | Biodiversity
		4.2 | Urban space development and regeneration
		4.3 | Urban space management

INFORMATION	
DESCRIPTION USC	The major part of urban areas are actually strongly anthropized or in the dense urban environment and this is where almost 70% of human beings are expected to live by 2050 (Burghardt et al., 2015; Morel et al., 2017). Also, there are a number of significant factors that are converging and forcing a re-examination of the way cities are planned, designed and lived in (James et al., 2009). One of this way is to reconsider the management of the urban areas in using more green or natural spaces. The terms green space and open space are often used interchangeably (Swanwick et al., 2003). In order to address the confusion that may occur, clear definitions are needed. Swanwick et al., (2003) suggested that urban areas are made up of the built environment and the external environment between buildings. The external environment, in their model, is composed of two distinct spaces: "grey space" and "green space". Grey space is land that consists of predominantly sealed, impermeable, "hard" surfaces such as concrete or tarmac. Green space land, whether publicly or privately owned, consists of predominantly unsealed, permeable, "soft" surfaces such as soil, grass, shrubs, trees and water (Jim, 2004). In effect, urban green spaces provide an array of benefits, or ecosystem services, that support our physical, psychological, and social health. In many cases, however, these benefits are not equitably distributed across diverse urban populations. Actually, many research projects are made on the ecosystem services provided by urban green space, the flora and the fauna. Especially: (1) the connections between cultural ecosystem services and social determinants of health and (2) the interest of the cultural ecosystem services as nature-based health amenities to promote social equity (Jennings et al., 2016). These green spaces harbour a biological diversity. Rich or poor, urban ecosystems contribute to the living environment of the cities. These ecosystem's health and functioning mechanisms are at the origin of all services humans can benefit from the urban external environment. Many urban areas contain sites of significant nature conservation value such as wetlands, grassland or and ancient woodlands, which can often be of local, regional or national

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importance. However, urban landscape is more often characterised by fragmented sites, which only have local community importance such as gardens, allotments, churchyards and school grounds. The remaining biodiversity in these urban areas can be found in small remnant pockets of habitat that have intense development pressure on them due to their urban nature. Actually, it exists different solutions for a good, sustainable and resilient management of the urban area, more especially the green space:

- Understanding and managing the connections between the different urban spaces in avoiding environments ruptures (scale of object) (Micand and Larramendy, 2014)
- Enhancement of biodiversity in urban ecosystems can have a positive impact on the quality of life and ducation of urban dwellers and thus facilitate the preservation of biodiversity in natural ecosystems (Savard et al., 2000)
- Conservation of connexion to reduce isolation of sites and allow their integration in a network of ecological continuity (Micand and Larramendy, 2014)
- Implementing sustainable management practices so as the potential of urban ecosystems can be expressed, both as ecological dynamic equilibriums and ecosystem services providers.

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4.1 | BIODIVERSITY

INFORMATIONS	
DESCRIPTION	Biodiversity has been defined in various ways (Salwasser, 1990) but the term has generally been used in a very comprehensive manner meaning the variability of life (composition, structure and function). Biodiversity can be represented as an inter-locked hierarchy of elements on several levels of biological organization (Noss, 1992). Since the term `biodiversity' transcends all levels of life from genes to communities and all spatial and temporal scales (Noss, 1990; Savard, 1994), it has generated a lot of confusion and misunderstanding (Lautenschlager, 1997). However, when understood and used properly biodiversity concepts can provide a useful framework for conservation efforts (Savard, 1994).

POTENTIAL ACTIONS	EXPECTED IMPACTS
● Maintain or restore connexions between semi-natural areas at the city scale	● increase in biodiversity within urban semi-natural areas
● Give priority to NBS design that favour spontaneous biodiversity and native species	● increasing in resilient areas ● avoiding management problem due to invasive species

INDICATORS	
● **UGSP - Urban Green Space Proportion** (Badiu et al., 2016; Cochard et al., 2017)	● This indicator represents the ratio of the natural areas per the total area. The different input paramters can be derived from land use and land cover geodatabases at different scales.
● **SDIH – Shannon diversity index of habitats –** (Cornelis and Hermy, 2004; Whitford et al., 2001)	● Indicates the proportion of bare, turf grass, rough grassland and herbs, shrubs, trees and of built environment
● **IAS - Number of invasive alien species** (Kohsaka et al., 2013; Lososová et al., 2012)	● “Invasive Alien Species (IAS) are animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative consequences for their new environment. They represent a major threat to native plants and animals […]” http://ec.europa.eu/environment/nature/invasivealien/index_en.htm)
● **PALHB - Potential of areas likely to host biodiversity** (Direction Régionale de l’Environnement Nord-Pas-de-Calais. 2008; AUAT., 2015)	● This indicator enables to highlight the natural areas susceptible to accommodate a higher level of biodiversity due to their size and shape. Moreover, the use of a Digital-Height-Model (DHM) can make it possible to highlight the mineralized areas (such as city squares for example).

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• **RNS - Ratio of Native Plant Species** (Kohsaka et al., 2013; Lososová et al., 2012)	• The ratio between the number of native plant species and the total plant species richness (total number of species). Native species are naturally present in the considered biogeographical area.
• **PSL - Land Use and associated impacts on biodiversity**	• Potential species loss (PSL) represents the loss of regional species due to the land occupation, the relative abundance of those species within that area and the overall global thread level for the affected species. The indicator covers five taxonomic groups; birds, mammals, reptiles, amphibians, and vascular plants. The taxonomic groups can be analysed separately or can be aggregated to represent the Potentially Disappeared Fraction (PDF) of species. Land use types covered by the method include intensive forestry, extensive forestry, annual crops, permanent crops, pasture, and urban land.

LINKS AND REFERENCES

KEYWORDS	• Accessibility • Connectivity • Urban green space • Exotic and invasive species • Indigenous species of vegetation • Green cover • Green spaces / open spaces • biodiversity • Plant communities structure • richness • Native species (or indigenous species) • Naturality • Land use • Ground cover • Sustainable management practices
LINKS AND REFERENCES	• Atkinson, R. 2003. Domestication by cappuccino or a revenge on urban space? Control and empowerment in the management of public spaces. Urban studies, 40(9), 1829-1843. • Badiu, D.L., Iojă, C.I., Pătroescu, M., Breuste, J., Artmann, M., Niță, M.R., Grădinaru, S.R., Hossu, C.A., Onose, D.A., 2016. Is urban green space per capita a valuable target to achieve cities' sustainability goals? Romania as a case study. Ecol. Indic., Navigating Urban Complexity: Advancing Understanding of Urban Social – Ecological Systems for Transformation and Resilience 70, 53–66. doi:10.1016/j.ecolind.2016.05.044 • AUAT. (2015). Pour une approche globale du fonctionnement écologique potentiel des territoires, 8. • Becker, G. M. R., & Mohren, R. (1990). The Biotope Area Factor as an Ecological Parameter. Landschaft Planen & Bauen, Berlin. Available: http://www. stadtentwicklung. berlin. de, 24. • Brown, R.D., Vanos, J., Kenny, N., Lenzholzer, S., 2015. Designing urban parks that ameliorate the effects of climate change. Landsc. Urban Plan. 138, 118–131. doi:10.1016/j.landurbplan.2015.02.006 • Burghardt, W., Morel, J.L., Zhang, G.-L., 2015. Development of the soil research about urban, industrial, traffic, mining and military areas (SUITMA). Soil Sci. Plant Nutr. 61, 3–21. doi:10.1080/00380768.2015.1046136

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systémique

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4.2 | URBAN SPACE DEVELOPMENT AND REGENERATION

INFORMATIONS	
DESCRIPTION USC	Urban space development can be defined as the voluntary action of the urban planners to organize and equip the space in the city. This definition highlights two main concepts: organizing and equipping. Organize is defined as the concept to introducing order according to a plan planned in advance. Urban planning is often presented through only one of its dimensions: legal (procedures), technical (urban engineering), urbanistic (form) or financial (balance sheets). It is unusual for these different aspects are interconnected. The concept of system provides us with the means to attempt this liaison, to try to consider urban planning as a whole. Indeed, the systemic analysis is a suitable method for describing complex phenomena with multiple elements and interdependencies (Vilmin, 1999).

POTENTIAL ACTIONS	EXPECTED IMPACTS
• Create, enlarge, fit out and connect and improve green spaces by implanting NBS (Kazmierczak and Carter, 2014; Raymond et al., 2017)	• Improve the connectivity and functionality of green infrastructure (Brown et al., 2015; Raymond et al., 2017)
• Make use of innovative, interdisciplinary planning methods for green space co-design and co-implementation, including development of innovative social models for long-term positive management (e.g. Citizen Engagement for Health) (Derkzen et al., 2015; Raymond et al., 2017)	• Increased stakeholder awareness and knowledge about NBS and ecosystem services, as well as citizen participation in the management of NBS (Filibeck et al., 2016; Raymond et al., 2017)

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INDICATORS	
• **BAF – Biotope Area Factor** (Huang et al., 2015)	• The BAF is calculated by dividing the amount of surface area available for nature and vegetation by the total surface area considered. Each type of soil / ground cover / land use is affected a coefficient related to its potential for vegetation growth & nature implementation (e.g. sealed surface = 0; semi-permeable = 0.3; green wall = 0.5; green roof = 0.7; in-ground plantations = 1). Thresholds and goals can then be determined based on the expected performance or current land use / urban planning objectives (e.g. the City of Berlin expects BAF to be produced for each new project – the result must be between 0.3 and 0.6, depending of the project's nature). The BAF takes values between 0 and 1. It increases with in-ground planted areas.
• **CGS - Connectivity of green spaces** (Direction Régionale de l'Environnement Nord-Pas-de-Calais. 2008; AUAT., 2015)	• This indicator enables to assess natural habitats best connected to each other on the study area. It takes into account the fragmentation of the habitat. Thus, this indicator will help to know where to focus efforts, where to improve the connectivity (where it is the lowest) and where to maintain green spaces in priority (where connectivity is the highest because these areas are more favourable to species) → decision-making tool. The efforts to be made will depend on the objectives of each city.
• **LUsom – Land use related to soil organic matter**	• This indicator illustrates the changes in the Soil Organic Matter (SOM) content based on land occupation and transformation. Also the indicator states the "ecosystem quality" depending on the changes of land occupation or transformations without any geographical specificity.
• **NDVI - Land use mix (Normalized Difference Vegetation Index)**	• enhanceing access to major green spaces

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4.3 | URBAN SPACE MANAGEMENT

INFORMATIONS	
DESCRIPTION USC	Several notation grids exist in France regarding sustainable green space management practices. They stem mainly from labels and certifications. The 'EcoJardin' label already provides such a tool to evaluate management practices at the object's scale. In this case, numerous criteria are assessed, resulting in individual evaluation / notation and an overall score, after examination of which the label is given or not (Micand and Larramendy, 2014). It is then proposed to gather different such grids '(EcoJardin', 'EcoQuartier', 'Terre Saine' + other outside of France?) to propose a notation grid specific to the N4C project and complementary with the other indicators (Faure et al., 2016). The aim of this would be to provide easy evaluation of several criteria, to obtain an aggregated score describing the overall sustainability of the management practices. Identified sources have been tested and validated in France, and have been used for several years now. They even stand as references in their fields. Work is needed to select the criteria of interest from source, check applicability to other countries, and stabilizing a notation method satisfactory for the project.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• define and implement sustainable management plans • use or build an ecolabel / notation grid (e.g. EcoJardin) • promote ecoconception practices (Larramendy et al., 2014)	• decrease use of chemicals (fertilizer and pesticides), fuels / energy, water… • ensure that sustainable practices are being carried on • set & share guidelines for sustainable management and green spaces' ecoconception

INDICATORS	
• **SPI - Sustainable practices indicator** (Faure et al., 2016; Micand and Larramendy, 2014).	Indicates the level of acceptance of sustainable solutions.

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4.5 UC 5 | Soil management

5 | SOIL MANAGEMENT

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | SOIL MANAGEMENT	5.1 | Soil management and quality

INFORMATION	
DESCRIPTION UC	Cities play an important role in their respective local, regional and national economies, acting as the power-house for their wider economic systems (Buck et al., 2005). They have sustained industrial and commercial development everywhere (Dogan and Kasarda, 1988; Hall, 2000). Governments across Europe have developed their own responses to socio-spatial polarisation within cities, initiated at the national, regional or local levels, according to the particular context (Carpenter, 2006). In this context, different solutions are made and investigated to remedy this situation. It is possible to cite green and blue spaces with urban areas that are being increasingly recognized for their capacity to not only support biodiversity conservation (Goddard et al., 2010), but also to generate additional environmental, economic, and social benefits (Haase et al., 2014; Kabisch et al., 2015). In the urban areas, the soils are most of time stripped, filled, mixed, compacted and supplemented with artificial materials, soil profiles are strongly modified, leading to high spatial and vertical heterogeneity (Meuser, 2010). At the same time, a strong spatial heterogeneity characterizes the urban soil at the urban environment from physical, chemical and biological aspects (Morel et al., 2005; Béchet et al., 2009). This heterogeneity can be explained by a wide range of applications (support for buildings, road infrastructure, recreational areas, kitchen gardens and parklands) (Blanchart et al., 2017). However, the structure of the urban soil is frequently altered from a pedo-geochemical point of view (Joimel et al., 2016). In effect, these soils could either lost their structures and constitutions (aggregation) because of (1) compaction due to traffic and (2) the presence of large particles natural and/or anthropogenic sourced, which contain a high pollutant content as opposed to agricultural soils (El Khalil et al., 2008; Nehls et al., 2013).

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5.1 | SOIL MANAGEMENT AND QUALITY

INFORMATIONS	
DESCRIPTION USC	Soil management is required and essential to improve the quality of the soil in the urban area. Urban construction requires prior knowledge of the quality of soil and subsoil, generally acquired through a set of diagnostics (lithology, geotechnics, physico-chemistry ...). The capitalization of these data, often collected and exploited by different actors, is a major stake in a logic of implementation of a consistent, reasoned and sustainable use of the subsoil for planning purposes. It involves the use of techniques and tools adapted to the urban context, through optimized management using specific tools (compilation into databases, interpretation of data, taking into account uncertainties, etc.) and visualization means. It is necessary to sustain the information in a usable format and make it available and accessible. Today, more and more, it also involves the use of innovative procedures to promote their social acceptability vis-à-vis the users of the city.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Planting trees:** o **In private domestic gardens** (Davies et al., 2011) o **Along the streets** (Baro et al., 2014) o **In urban park** (Yin et al., 2011	• Reduce the erosion causing by water run-off, wind speed (losing soil matter)
• **Reducing the human activity on the urban soil (covering of soil by building or soil sealing)** (Huber et al., 2008)	• Increase in soil organic matter • Reduce the waterproofing phenomena essentially due to a huge urbanization • Limit the stormwater runoff
• **Building green areas (green roof)** (Bouzouidja et al., 2016)	• Limit the storm water impact by the substrate (retention in the pores)
• **Maintaining existing natural area**	• Maintain the existing biodiversity of soils (macro-fauna, meso-fauna and micro-fauna) and reduce erosion
• **Using phytoremediation solution (Braud et al. 2009)**	• Limit local contamination and diffuse contamination by reducing heavy metals and inorganic contaminants, biocides and persistent organic pollutants • Reduction of use chemical treatments to reduce organic contaminants (Levin et al., 2017) • preservation of biodiversity
• **Convert the urban brownfield to NBS areas** (Mathey et al., 2015; Raymond et al., 2017)	• Increase surface of green space for resident • Increase cultural richness and diversity in urban areas, as well as improve ease of movement of people • Limitation of contamination expansion by dusts, leaching by infiltration waters

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INDICATORS	
• **SWI - Soil water infiltration** (Yilmaz et al. 2016)	• **SWI** represents the capacity of the soil to let water draining into the soil
• **SR - Soil respiration –** (Anderson and Domsch, 1978; Miao et al 2017)	• **SR (biological activity)** represents respiration rates of soil microbes, fauna and roots
• **SBA - Soil biological activity** (Keuskamp et al. 2013)	• **SBA (decay of 2 types of plant material)** represents the rate of decomposition of 2 different organic matter quality mainly by microbes
• **SMP** - **Soil macroporosity** (Yilmaz et al. 2016)	• **SMP** represents the capacity of the soil to provide air for root respiration
• **SCr - Soil Crusting** (Šimanský et al. 2014)	• **SCr** is a consequence of soil getting a poor aggregation capacity/stability. A crust at the soil surface is created, limiting water infiltration and favouring water runoff. In the context of the urban area, most of time, the soils have a bad level of aggregation. In addition, urban soil are generally poor in organic matter, one of the building element of soil structure that reduce soil crusting risk. Moreover, soil compaction by people or other anthropogenic activity disrupt soil structure and favor soil crusting
• **Sct - Soil contamination** (Huber et al. 2008)	• **Sct** is the diffuse and the point source soil contamination by inorganic contaminants (trace metals, metalloids, radionuclides...), by nutrients and pesticides, by persistent organic pollutants, by soil acidifying
• **Cfer - Chemical fertility of soil –** (Damas and Rossignol, 2009, Vidal-Beaudet et al. 2016)	• **Cfer** relates to the mineral nutrition of plants via the concepts of biodisponibility of elements, deficiencies, toxicities and equilibria
• **EcoF - Ecotoxicology factor** – (Damas and Rossignol, 2009, Vidal-Beaudet et al. 2016)	• **EcoF** is based on (i) an evaluation of the concentration of pollutants for which an effect is measured in 50% of a population (EC50) and (ii) the time needed for 50% of a pollutant disappears (DT 50)
• **ScF - Soil classification** (IUSS, 2014)	• **ScF** (**type/nature of soil -** Soil classification) is the overall characterization of soil used to define at local (object) scale, the type of soil that is going to be used as NBS support and to define potential improvement of soil quality, at neighbourhood or city scale, helpful in urban planning to have an overview of the land-use potential of surfaces
• **SOM - Soil Organic Matter** (Šimanský et al., 2014)	• **SOM** is a crucial parameter of soil biological, chemical and physical quality. All soil properties are highly depending on this parameter (soil aggregation, soil nutrients, soil decomposers…)
• **SWR - Soil water reservoir for plants** (Bouzouidja et al., 2016; Ylimaz et al., 2016)	• **SWR** represents the capacity of the soil to provide water for plant uptake compared with a control soil or soil reference (absence of human pressure or impact).

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LINKS AND REFERENCES	
KEYWORDS	● Aeration ● Contamination ● Drainage ● Ecotoxicity ● Fertility ● Humidity ● Infiltration ● Nutrients ● Plant water uptake ● Porosity ● Runoff ● Soil ● Transpiration ● Water stress
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4.6 UC 6 | Resource efficiency

6 | RESOURCE EFFICIENCY

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | RESOURCE EFFICIENCY	6.1 | Food, Energy and Water
		6.2 | Raw materials
		6.3 | Waste
		6.4 | Recycling

INFORMATION	
DESCRIPTION UC	Resource Efficiency Indicators are classified as Environmental Indicators that assess the water-energy-raw materials relation with respect to the various Sustainable Development Goals, namely; Ensure access to affordable, reliable, sustainable and modern energy for all (Goal 7), promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (Goal 8), Ensuring sustainable consumption and production patterns (Goal 12). The scope of the Resource Efficiency here is set as Food-Energy-Water nexus, waste efficiency, raw material efficiency, life cycle indicators and energy efficiency for Nature based Solutions. Food-Energy-Water nexus analyses the interconnections existing not only in natural resources but also among different levels or scales of assessment; between local and global processes of resources use, and between social and economic aspects of a society, highlights the complex issues involved in addressing these challenges in ways that also make effective use of the possible changes resulting from new policies or new interventions. Waste efficiency covers the non-hazardous waste generated, hazardous waste produced and by-products and recyclable portion of the total waste amount. Life cycle indicators are used to carry out quantitative assessments for different aspects of environmental issues. LCA indicators are quantified either for the product or the production process, use a wider and holistic scope covering the life cycle of the product or process. ISO 14040/44 clearly states that, first; the selection of impact categories, category indicators and characterization models shall be both justified and consistent with the goal and scope of the LCA and second, the selection of impact categories shall reflect a comprehensive set of environmental issues related to the product system being studied. Energy efficiency, is a fundamental aspect in resource efficiency. Key energy-related issues include dependency on fossil fuels, greenhouse gas emissions, energy security and dependency as well as cost. Promoting energy efficiency not only cuts fuel dependency but also can reduce costs and greenhouse gas emissions. Energy indicators play a crucial part in monitoring the mid-term and long-term shift towards a low-carbon economy in the EU. For this reason, energy indicators are a part of every sustainability indicator set currently in use globally.

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6.1 | FOOD, ENERGY AND WATER

INFORMATIONS	
DESCRIPTION USC	Water, energy and food are inextricably linked. Water is an input for producing agricultural goods in the fields and along the entire agro-food supply chain. Energy is required to produce and distribute water and food: to pump water from groundwater or surface water sources, to power tractors and irrigation machinery, and to process and transport agricultural goods (UN, 2017). FAO recognizes the FWE nexus as a new approach to support food security and sustainable agriculture. In this context, the Water-Energy-Food Nexus has emerged as a useful concept to describe and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic and environmental goals (FAO, 2014).

POTENTIAL ACTIONS	EXPECTED IMPACTS
• Use NBS to support the local production of food such as urban farming	• Decrease in transportation energy use, food security benefits
• Water efficient NBS design	• Water efficiency via urban elements that require less water for operation
• Use NBS to support energy security/the on site efficiency and production of energy such as biofaçades	• Energy security
• Replace conventional systems with energy efficient NBS in waste management, water management etc.	• Less operating energy costs and consumption via the use of living matter
• Provide building insulation with NBS such as green façades and roofs with high insulation value, instead of conventional materials	• More life cycle efficient insulation systems that also help energy efficiency
• Reduce GHG emissions at building scale by reducing the building energy consumption	• t $CO_{2\text{-eq}}$ /y saved for heating / cooling buildings.

INDICATORS	
• **EE - Energy Efficiency**	Energy Efficiency represents the percent change of the consumed energy with respect to the fuel demand per capita or per selected time frame to the baseline levels. This indicator can be used in both generation and consumption or demand processes. Considering the scale, i.e. city scale, municipal energy consumption and energy performance from built environment can be extrapolated in order to estimate the consumption/performance output of the cities.

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	Furthermore, taking generation of energy into consideration, renewable sources are of concern for NBS. The focus related to the energy challenges set is on appropriate combination of local renewable energy production with the related NBS.
• **ES - Energy security**	European Commission defines energy security as the combination of import dependency-primary sources and specific energy consumption.
• **EIWS - Energy intensity of water supply**	This indicator represents the quantity of energy to supply one cubic meter of water to urban areas with regards to the energy-water relation.
• **EUA - Energy use in agriculture**	Energy use in agriculture points the energy-food relation by illustrating the percent ratio of the energy consumed for agricultural purposes from the total energy demand.
• **PCFPV - Per capita food production variability**	The per capita food production variability compares the variations of the food production across countries and time.
• **PCFSV - Per capita food supply variability**	This indicator compares the changes of the food supply across countries and time. Furthermore, this indicator is included in the FAO's annual State of Food Insecurity in the World report.
• **WS - Water security**	The urban water security index includes the water supply coverage, wastewater treatment and urban flooding. In addition to these sub-indices several adjustment factors are used in order to represent urban growth rate and river basin health.
• **AWW - Agricultural water withdrawal**	This indicator illustrates the water-food relation in terms of the percent agricultural water withdrawal of total withdrawal as the agricultural practices consumes significant amount of the water relative to the total water consumption.
• **BEN – Building energy demand**	NBS can have thermal impacts on buildings' energy consumptions (for cooling in summer and heating in winter). These impacts are measured from the difference in their consumption/needs.
• **Cumulative energy demand**	The aim of a related NBS is to decrease the total energy consumption of both renewable and non-renewable sources. For that aim Cumulative Energy Requirements Analysis (CERA) is used to evaluate the energy use throughout the life cycle of a good or a service. The method takes both direct uses and indirect (or grey) consumption of energy.
• **WS – Water scarcity**	The AWARE method assesses the relative potential of water deprivation, to either humans or ecosystems. The indicator in the AWARE method builds on the assumption that the less water remaining available per area, the more likely another user will be deprived (Boulay et al. 2016).
• **AWS – Absolute water consumption**	This indicator presents the average annual value calculated by the aggregation of two values: • Indoor water use • External water use
• **WE - Water efficiency**	Water efficiency is reducing water wastage by measuring the amount of water required for a particular purpose and the amount of water used or delivered.
• **WI - Water intensity**	Water Use Intensity– is all water sources divided by the building surface, including outdoor surface. The ratio between water intake and a defined unit of production.

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6.2 | RAW MATERIAL

INFORMATIONS	
DESCRIPTION USC	Raw materials including ferrous and non-ferrous metals and fuels are being consumed continuously in all daily operations in order to satisfy the ever-growing demand for new products and services. Raw materials not only creates pressure on the environment in the form of resource depletion but also leads to creation of waste. For this reason, particularly non-renewable natural resources need to be utilized sparingly and overstraining renewable resources should be avoided. Furthermore, in order to minimize both impacts, it is necessary to shift from consumption of primary (virgin) materials to secondary (valorized) materials.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• Use natural components/naturally sourced materials as NBS instead of raw materials with higher impact.	• Less primary/virgin raw material consumption and less exploitation of environment for acquisition of primary raw materials
• Increased proportion of softscape in urban design	• Less construction material consumption for urban space, which can be associated with high embedded emissions

INDICATORS	
• **RME - Raw material efficiency**	• This indicator illustrates the percent change of consumed non-metallic minerals, metal ores, biomass and fossil energy carriers per capita to the baseline levels. The objective of the indicator is to give a percent change value in primary raw material consumption per capita as a result of strategic implementation of NBS.
• **ARDfuels – Abiotic depletion-fossil fuels**	Abiotic depletion-fossil fuels covers the depletion of the fossil energy resources as recommended by JRC and the indicator is based on CML characterisation method. CML offers an approach considering the Lower Heating Value (LHV) in MJ per kg or m3 of fossil fuel used. Using LHV illustrates that fossil fuels are substitutable.
• **ARDmetalmineral – Abiotic depletion of metals**	Abiotic depletion of metals (CML) only includes metal and mineral resources (separated from fossil fuels) as recommended by JRC and is based on the CML characterisation method. The characterisation factor for the indicator is Abiotic Depletion Potential (ADP) which is expressed as a reference element equivalent of Antimony (Sb).

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6.3 | WASTE

INFORMATIONS	
DESCRIPTION USC	An unavoidable outcome of raw material consumption and production is waste generation. The sheer number of products entering the market poses yet another challenge. Demographic changes, like an increase in the number of one-person households, also affect the amount of waste we generate (EEA, 2016). It has become a more and more pressing issue over time due to unsustainable production and consumption patterns. Waste is not only an environmental problem but also an economic problem, where waste generation is strongly linked with raw material consumption and recycling. Cities are sources of concentrated waste generation, which makes this topic an important sub challenge.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• Use NBS that generate less waste than alternative conventional systems	• Improved waste efficiency via substituting conventional systems with NBS that generate less waste
• Use waste as input to NBS such as fertilizer/waste remediation via natural systems	• Improved circularity via the use of NBS to dispose of waste while reusing it as nutrition etc.

INDICATORS	
• **SWG - Specific Waste Generation**	Specific Waste Generation illustrates the annual municipal solid waste generated per capita. Also, considering the fact that the amount of the municipal solid waste produced is strongly correlated with the loss of materials, i.e. landfilled portion of the total solid waste, the specific waste generation is significant in related NBS.

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6.4 | RECYCLING

INFORMATIONS	
DESCRIPTION USC	Turning waste into a resource by 2020 is one of the key objectives of the EU's Roadmap to a Resource Efficient Europe. Recycling and efficiency of recycling is closely related to raw material consumption and waste generation. The recycling processes offer an alternative solution to over consumption of primary raw materials and long-term environmental impacts of waste disposal. The promotion of recycling, which covers reuse and recovery as well, is also important for establishment of circular economy models. Overall in the EU, an increasing amount of waste is recycled and a decreasing amount is sent to landfills. For municipal waste, the share of recycled or composted waste in the EU-27 increased from 31 % in 2004 to 41 % in 2012 (EEA).

POTENTIAL ACTIONS	EXPECTED IMPACTS
● Use of recycled products in combination with NBS implementations	● Reduce and improve the use of waste and by-products ● Improve recycling efficiency

INDICATORS	
• **ERP - Efficiency of valorisation as a result of recycling processes**	This indicator measures the efficiency of the recycling process used to produce the recycled feedstock (for specific materials and recycling processes). **Efficiency** of the recycling process 0-99%, while reuse is assumed to have an efficiency of 100%.
• **ROL - Rate of landfilling**	The indicator is defined as the rate of waste landfilled (directly or indirectly) in a country per year, excluding major mineral wastes, dredging spoils and contaminated soils.
• **ROR - Rate of recycling**	Recycling indicator will allow measuring how much of the waste that is generated is recycled Recycling of waste is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations

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LINKS AND REFERENCES	
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4.7 UC 7 | Public health and well-being

7 | PUBLIC HEALTH AND WELL-BEING

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | PUBLIC HEALTH AND WELL-BEING	7.1 | Acoustics
		7.2 | Quality of Life
		7.3 | Health

INFORMATION	
DESCRIPTION UC	The urban environment significantly affects the health and well-being of residents (Barton and Grant, 2006). NBS are supposed to improve the health and well-being of urban residents through the provision of ecosystem services by urban green spaces (Keniger et al., 2013). Many of the climate regulation ecosystem services address threats to environmental health posed by urbanization and climate change (Haase et al., 2014). Today noise is a major societal problem with a proven impact on health (hearing impairment, development of cardiovascular problems, stress, insomnia, etc.), particularly in urban and peri-urban areas where the noise sources are numerous and varied. *„A majority of the EU population is estimated to be exposed to outdoor road traffic noise levels above the threshold suggested by WHO for onset of negative health effects (Hosanna, 2014).“* NBS, like e.g. Green roofs and walls can help to significantly reduce noise in urban environment (Science for Environment Policy, 2013). Nature-based solutions can contribute to a range of positive psychological and physiological outcomes. Studies have shown the positive effects of urban green spaces on urban residents through psychological relaxation and stress relief (Roe et al., 2013; Ward Thompson et al., 2012) and enhanced opportunities for physical activity (Sugiyama and Ward Thompson, 2007). Studies have also identified positive health associations between distance to urban green spaces and potential health benefits, suggesting that being in proximity to urban green spaces (Maas et al., 2006) and viewing greenery (Dravigne et al., 2008; Ulrich, 1984; Ulrich, 2002) have positive health effects. Additional benefits include reduced depression (Bratman et al., 2015a) and improved mental health (Hartig et al., 2014; van den Berg et al., 2015; Vries et al., 2003); reduced cardiovascular morbidity and mortality (Gascon et al., 2016; Tamosiunas et al., 2014); improved pregnancy outcomes (Dadvand et al., 2012); and reduced obesity (Kim et al., 2014) and diabetes (Maas et al., 2009). Urban green space also provides

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	opportunities for exploratory behaviour in children and Improved functioning of the immune system (Kuo, 2015; Lynch et al., 2014). However, urban green spaces can also be related to negative health outcomes, such as allergic reactions, or vector-borne diseases, because of increased exposure to allergenic pollen or increased disease vectors in urban green environments (Bai et al., 2013; Calaza-Martinez and Iglesias-Díaz, 2016; Cariñanos and Casares-Porcel, 2011). In addition, physical activity or play in green spaces may also be associated with increased risk of injuries particularly with children (Kendrick et al., 2005). These potential detrimental effects may be addressed through the adequate design, maintenance and management of urban green spaces and species selection (Lõhmus and Balbus, 2015).
OBJECTIVES	• Reduce negative health effects through NBS implementation. • Improve Public Health and well-being

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7.1 | Acoustics

INFORMATIONS	
DESCRIPTION USC	Acoustic is an important topic because noise has dramatic health impacts: The World Health Organization (WHO) states that "*Excessive noise seriously harms human health and interferes with people's daily activities at school, at work, at home and during leisure time. It can disturb sleep, causes cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behavior. Traffic noise alone is harmful to the health of almost every third person in the WHO European Region. One in five Europeans is regularly exposed to sound levels at night that could significantly damage health*".

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Decrease of noise level through NBS implementation** • **NBS Implementation**	• Positive impact of NBS on urban soundscape (Watts, Chinn, et Godfrey 1999; Watts, Pheasant, et Horoshenkov 2001; F. Yang, Bao, et Zhu 2011; Hong Seok Yang, Kang, et Choi 2012; H.S. Yang et al. 2013; H.S. Yang, Kang, et Cheal 2013 • Positive health impact (Science for Environment Policy, 2013)

INDICATORS	
• ***L_{DEN}*** **- Day-evening-night noise level**	***L_{DEN}*** is a daily equivalent sound pressure level
• **L_{NIGHT} - Night noise level**	**L_{NIGHT}** is the average sound pressure level over one night.
• **ENNH – Effects of night noise on health**	The ENNH describes the following health effects from the acoustic indicator **L_{NIGHT}** and thus the night noise level in urban areas (dB). The night-level indicator (**L_{NIGHT}**) is designed to assess sleep disturbance. The WHO-Night Noise Guidelines (2009) discusses in great detail the relations between, noise, sleep quality and health.
• **PAI – Population Annoyance Index**	The PAI describes the following health effects from the acoustic indicator ***L_{DEN}*** and thus the night noise level in urban areas (dB). The day-evening-night–level indicator (***L_{DEN}***) designed to assess annoyance. European threshold ***L_{DEN}***: High Noise level: 55 decibels (dB) (EEA, 2014)

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7.2 | QUALITY OF LIFE

INFORMATIONS	
DESCRIPTION USC	WHO defines Quality of Life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns. It is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment (WHOQOL, 1995; Parra et al., 2010; Muldoon et al. 1998).

POTENTIAL ACTIONS	EXPECTED IMPACTS
• NBS access	• Improvement of Quality of Life

INDICATORS	
• **QOL – Quality of Life**	Indicates the global level of perceived Quality of Life

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7.3 | HEALTH

INFORMATIONS	
DESCRIPTION USC	Further extreme weather events such as heat waves, exacerbated by the urban heat island (UHI) effect, cause premature death and illnesses (Basagaña et al., 2011; Xu et al., 2016). The UHI-effect is most significant in high-density built-up areas with impermeable surfaces and a low proportion of green space (Oke, 1973; Rizwan et al., 2008). Urban trees and vegetation provide climate regulation services as they reduce the UHI-effect through evapotranspiration, and shading and can thus prevent heat related morbidity, and mortality (Chen et al., 2014). NBS may reduce exposure to environmental pollution through mitigating the UHI (Alexandri and Jones, 2008; Bowler et al., 2010a) and reducing air pollution (Baró et al., 2014) and noise (Madureira et al., 2015).

POTENTIAL ACTIONS	EXPECTED IMPACTS
• NBS access	• Improvement of Public Health

INDICATORS	
• **PH - Perceived health**	Perceived health is a subjective measure of overall health status. Individuals' self-assessment of their health may include aspects that are difficult to capture clinically, such as incipient disease, disease severity, physiological and psychological reserves, and social function. Studies have demonstrated that this is a reliable and valid measure, associated with functional decline, morbidity and mortality.
• **HIM - Heat induced mortality**	The HIM indicates the number of deaths associated with temperatures above the 75th percentile of daily mean temperature during summer months (Apr-Sep). Relative risks extracted from a European multi-city study (de' Donato et al. 2015) are used to describe the effect of high temperatures on mortality.
• **AQEshort – Air quality indicators: short term health effects**	The ASE estimates the number of preterm deaths due to ozone short-term exposure in urban areas (O_3). (WHO 2013a)
• **AQElong – Air quality indicators: long term health effects**	The ALE estimates the number of deaths in age group 30+ associated with long-term exposure to urban background levels of PM2.5 and NO2. Relative risks based on recommendations from WHO HRAPIE Project (WHO, 2013b) regarding PM2.5 and UK COMEAP (2015) regarding NO2.

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LINKS AND REFERENCES	
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4.8 UC 8 | Environmental Justice and Social Cohesion

8 | ENV. JUSTICE AND SOCIAL COHESION

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES	SUB-SUB-CHALLENGES
SOCIAL	8 | ENVIRONMENTAL JUSTICE AND SOCIAL COHESION	8.1 | Environmental justice	8.1.1. | Recognition
			8.1.2. | Procedural Justice
			8.1.3 | Distributional justice
			8.1.4 | Capabilities
			8.1.5 | Responsibility
		8.2 | Social cohesion	

INFORMATION	
DESCRIPTION UC	The environmental justice concepts allows to evaluate and assess **procedural** and **distributional** impacts of NBS-type of solutions in urban environments. It allows for addressing both the quality of the process and its outcomes (who benefits from the NBS). A pre-condition for procedural justice is the **recognition** of diverse needs and interests, but also attention to **capabilities** to participate and the room to assume (rather than be allocated) **responsibility**. Since NBS are planned for and implemented in a specific local context, the extent to which these build on or improve the quality of existing local social networks is also important to consider. Addressing the social context through the concept of **social cohesion** allows to address, next to the justice elements which also bear on social cohesion, **social capital** is a main indicator, which refers to the value that social networks have (to those that are part and to those that are bystanders (Putnam in Jenson 2012:9).

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8.1 | ENVIRONMENTAL JUSTICE

INFORMATIONS	
DESCRIPTION USC	Environmental justice is a concept that has evolved over the past years towards become increasingly suitable for evaluative purposes (Schlossberg 2004; Davoudi and Brooks 2014). Using a broad concept, it encompasses social justice, but does so in relation to the **distribution** of *environmental* goods and bads across time, space and social groups. A distinction is made between different dimensions of environmental justice. In the process from designing an intervention (NBS) until after its implementation and maintenance, questions about **recognition** of diversity refer to the acknowledgement of diverse voices, with particular attention to vulnerable groups that are prone to exclusion (e.g. migrants, women, children, elderly, people with disabilities, people suffering from deprivation). Put the other way around, a lack of recognition of diverse needs undermines the quality of the participatory process and undermines possibilities for a fair distribution. The quality of the participatory process is furthermore determined by **procedural justice**, which relates to the clarity, transparency of the rules that govern the processes and thereby affect the extent to which a process is considered fair. Equally relevant is the extent to which **capabilities** and resources are sufficiently present among stakeholders to be able to voice concerns and/or to participate, and to shape ones lives. **Responsibility** refers to the role stakeholders can and want to adopt at individual or collective levels, and this is affected by e.g. institutional context, physical and mental abilities, social norms and cultural values (Davoudi and Brooks 2014). As the above points out, we can in fact distinguish between 5 interrelated **sub-sub-challenges,** for which we need to formulate indicators in order to be able to assess them. The relevance of each of these 5 is briefly described in relation to the process of realizing an NBS; in the assessment of the impact of an NBS; and in relation to the maintenance of an NBS. In the beginning, an assessment of the starting situation in terms of geographical disparities in environmental impacts in each urban area where an NBS is being planned or developed, is important. Depending on the specific urban context and available data, it's beneficial to assess disparities in the distribution of environmental impacts across sections of the population before implementation of an NBS. For instance, socio-demographic information could be coupled to environmental information for specific locations (e.g. districts; neighbourhoods). Next, the (impact) of the NBS on specific locations can be assessed, whereby it becomes clear if the NBS on an urban scale, diminishes or increases disparities. Socio-demographic indicators could relate to indicators that the EPA has defined for cities in the U.S. (https://www.epa.gov/environmentaljustice): • % of low income people in a particular area • % of people under age of 5 in a particular area • % of people above age 64 a particular area

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- % of minorities (if that is relevant in relation to deprivation) a particular area
- % of other vulnerable groups a particular area
- % of linguistically isolated people a particular area
- % of people with low education
- % of people unemployed

The EPA combines these indicators with environmental indicators.

An approach used in the UK that could also be used in connection to environmental indicators is the multiple deprivation index with attention to domains such as income, employment, health deprivation and disability, education skills and training, barriers to housing and services, crime, living environment. For each of these domains, indicators have been developed in order to be able to map deprivation in areas (http://www.simonpoulter.co.uk/iod/iodpdf/odpm_urbpol_029534.pdf).

- Rather than suggesting a particular approach for assessing the starting situation in each urban context, we suggest for each urban area to make use of the data and methods of structuring and mapping these that are already in use and available to assess how people from different socio-economic status are distributed across an urban area, if possible complemented with environmental impact data, so that it becomes clear what the starting situation is before an NBS is planned for.

- That then serves as a starting point that will enable the relevant stakeholders to start filling in the checklist questions – for which additional research and interactions will be necessary – enabling them to ascertain that the NBS will not further increase inequalities but rather try to counter these.

Recognition of diversity:

- <u>In the process of realising an NBS</u>, having acknowledged and invited the diversity of perspectives, needs and social groups that affect and/or are affected by this process and its outcome, with particular attention to vulnerable groups (e.g. children, migrants, women, lowly educated groups, etc).
- <u>In assessing the impact of an NBS</u>, addressing how it affects (caters for the needs of) these diverse groups of stakeholders and social groups or individuals.
- <u>With regard to further maintenance of the NBS</u>: ensuring that diverse stakeholders' needs and interests are taken into account

Procedural justice:

- <u>In the process of realising an NBS,</u> having clarified (and made the information available and accessible) the procedures or rules of the game to all stakeholders and (potential) participants to process.
- <u>In assessing the impact of a realised NBS,</u> assessing to what extent the process towards realising this NBS has been considered as 'fair' by relevant stakeholders
- <u>With regard to further maintenance of the NBS</u>: ensuring clarity also with regard to the process of maintenance of the NBS

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	Distributional Justice: ● In the process of realising an NBS: having ensured an equitable distribution of co-benefits and costs, and ensuring that existing unequal distributions are not exacerbated (e.g. through gentrification or increased feelings of unsafety for particular groups) ● In assessing the impact of a realised NBS: assessing how this NBS and the (co-)benefits and costs that this NBS generates accrue to diverse (social) groups and stakeholders and assessing the impact in terms of changing existing unequal distributions (e.g. with attention to gentrification or increased feelings of unsafety for particular groups) ● With regard to further maintenance of the NBS: ensuring that distributional impacts are taken into account in and continue to be taken into account. **Capabilities:** ● In the process of realising an NBS: having ensured that all stakeholders and participants to the process have been enabled to fulfil this role (by providing understandable and accessible information in time; by ensuring that the discussions respect difference; by providing support, training and coaching if needed in order to enable those not used to these processes to participate; by using not only text and words, but also images and visualisations, stories etc). ● In assessing the impact of a realised NBS: assessing to what extent this NBS has any impact on existing capabilities in its direct environment, i.e. how this NBS supports people and communities to shape their own lives and flourish ● With regard to further maintenance of the NBS: ensuring that those interested in maintenance receive sufficient support and coaching to fulfil this role. **Responsibility:** ● In the process of realising an NBS: having ensured that in the process towards this NBS, people have had the choice to take the responsibility that they saw fit form themselves (enabling people to take responsibility without allocating such responsibilities) ● In assessing the impact of an NBS: assessing what responsibilities people have adopted and how. With regard to further maintenance of the NBS: ensuring that those involved in the further maintenance of the NBS have chosen to be involved (rather than being allocated this responsibility).
POTENTIAL ACTIONS	**EXPECTED IMPACTS**
● **Organising the process in such a manner that diverse types of knowledge, disciplinary**	- A larger diversity and number of people that benefit from the co-benefits of NBS and a diverse understanding of the benefits that NBS can bring for different groups (e.g. recreational space; playgrounds; meeting points; safe routes; source of income; etc.)

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perspectives and diverse value orientations which are all relevant to the particular NBS that is going to be realised, are invited (Raymond et al 2017)	(Recognition of diversity)
● **Organise a participatory process that starts with clarifying the rules that govern this participatory process, the extent and the goal of participation, and that clarifies what will be done with the inputs provided by the participants.**	- Creating, through transparency and accountability, legitimacy; ensuring that the process is likely to be regarded as fair by stakeholders (which also contributes to the acceptance of the outcome – a particular NBS) (Procedural justice)
● **Start the process by mapping the existing unequal distributions that may be affected by the NBS that is going to be realised, in order to find ways to counter a further increase in inequalities as part of the process**	● Having, in the end, and NBS designed, delivered and monitored in ways that reflect the needs and interests of typically excluded s ocial groups and through a process that redresses existing inequalities. (Distribution)
● **Build capacities of t ypically excluded gr oups to participate i n NBS design and decision-making processes. This can entail educational efforts but also coaching and skills in e.g. negotiation. (Rutt and Gulsrud, 2016;Krasny et al, 2013).**	● Active engagement of formerly excluded (or neglected) social groups in the design, delivery and management of NBS ● Capacity building: empowerment: more people are informed about NBS, gain new skills, build self-confidence and trust in others; building of respect between (social-cultural) groups ● Institutional capacity building by learning how to do this capacity-building and making it part and parcel of the processes of co-production of NBS (Capability)
● **Next to building capacities among diverse groups, inviting people to consider their role and responsibility (rather than being allocated**	● An increase in communities' and people's sense of ownership with regard to their direct (green) environment and with regard to the NBS in their surroundings ● A clarification in expectations about who is responsible for what, so that discussions can be held if there is disagreement (Responsibility)

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responsibility by others) in the process of planning for NBS, their implementation and maintenance.	

INDICATORS	Sub-Sub-challenge: Recognition of Diversity
DIV – Recognition: diversity of needs	- What diverse local stakeholders (including citizens) and needs can be identified? Some of these needs address the indicators PAT, BIN and CUL, LIV but there may be additional context- and/or segment specific needs.
PAT - Recognition: Place Attachment	- What diverse ways in which people value this particular place can be identified? (e.g. related to its history) - How has/can this be(en) taken into account in the NBS planning, implementation and maintenance?
BIN - Recognition: Bodily integrity	- What sort of safety concerns are relevant to consider in the planning, implementation and maintenance of the NBS? Bodily integrity relates to being able to move freely from place to place and to be secure against violent assault.
CUL – Recognition: Cultural services	- What cultural, educational and recreational services are relevant to consider and for which groups of (local) users? (e.g. meeting place; cultural activities and festivities, educational activities, walking, cycling, fishing, performing sports).
LIV – Recognition: Livelihood	- To what extent and in what manner are people dependend on this particular NBS for their livelihood? (e.g. food production; economic activity related to the NBS)

INDICATORS	Procedural Justice
PROC – Procedural justice: Formal procedures in planning and decision-making	- What are the formal (urban planning) procedures for the planning, implementation and maintenance of this NBS and how do these formal procedures allow for participation from local stakeholders including citizens? (e.g. formal consultation on ready-made plans)
PAR – Procedural justice: Participation in the process	- How have diverse groups, including citizens been involved in the process of planning and implementing this NBS? And in the maintenance? - To what extent have local stakeholders (including citizens) been invited to participate early in the process – e.g. in the choice of the location, the design and scope of the NBS, other aspects?
FAI - Procedural justice: Perceived process fairness	- Was there any contention about this area before the planning and implementation of this NBS? - If yes, what was this contention about and between which stakeholders? - Have any contentious issues risen during the proces of planning or implementing this NBS? - If yes, what are these issues and which stakeholders are involved in the contention? Is there any relation to previous contention or conflicts? If so, how and why? - To what extent has the process of developing this NBS been considered fair by the various stakeholders including citizens? - To the extent that the process is not considered fair by all stakeholders involved, what are the main points of criticism? Have these points been addressed in further discussions or negotiations?

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INDICATORS	Sub-Sub-challenge: Distributional justice
C&B – Distribution of costs and benefits	- How does the development of this NBS affect the current distribution of advantages and disadvantages in the city/urban area? - What costs, burdens, disbenefits does the development and maintenance of this NBS bring and for whom (which segments) are these? (e.g. safety issues; accessibility issues) - What (co-)benefits and advantages does the development and maintenance of this NBS bring and for whom? (may vary from clean air, safety, noise reduction, room to meet, recreate, play etc) - Is there a risk of an inequitable distribution of impacts?
AGR – Distribution: (Dis)agreement on cost-benefit distribution	- Are there points of (dis)agreement with regard to how costs and benefits are being distributed? If so, what are these point and who is in disagreement?
GEN – Distribution: Gentrification	- Does this NBS result (or is it expected to result) in a process of gentrification whereby the low-income residents are displaced in the longer term as a result of the increased property values that are a (partial) consequence of the NBS? - Have any stakeholders voiced concerns about this? If so, how, when and who?

INDICATORS	Sub-Sub-challenge: Capabilities
CBU – Capabilities: Capacity building	- Has relevant and understandable information been provided in time to all relevant stakeholders about the planning, implementation and maintenance of this NBS? - How have people that are less highly educated been enabled (e.g. through training, coaching, using visual rather than only textual means) to participate in the process around this NBS?
EXC – Capabilities: Exclusion due to lack of resources and capabilities	- To what extent do certain stakeholders risk to be excluded in the planning, implementation and maintenance of this NBS? - What is the lacking ability to participate related to? (think of age, language, negotriation skills, disabilities, lack of time and resources). How have these issues been addressed?
EMP – Capabilities: Empowerment of hitherto excluded groups	- How can hitherto excluded stakeholders (including citizens) be empowerd to participate in the planning, implementation and maintenance of this NBS? - What is (was) needed to achieve that? (Who is responsible, which stakeholders need to collaborate in order to empower these groups)?

INDICATORS	Sub-Sub-challenge: Responsibility
RES – Responsibility: own role and responsibility	- Which responsibilities do different stakeholders (including citizens) wish to adopt in the planning, implementation and maintenance of this NBS? - What do they need to be able to take the responsibility they would like to take?
EXP – Responsibility: expectations of each others' roles and responsibilities	- What expectations are there with regard to each stakeholders' role and responsibility in the planning, implementation and maintenance of this NBS? - Are the expectations in line with the role and responsiblity that stakeholders see for themselves?

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8.2 | SOCIAL COHESION

INFORMATIONS	
DESCRIPTION USC	The concept of social cohesion has no single straightforward definition and the ambiguity of the concept is widely acknowledged (see Jenson 2012 for a historical introduction to the concept). Social cohesion is a multiscalar concept (Jenson 2012) and indicators reflect local level rather than national level is chosen. Regina Berger-Schmitt (2002) decomposed the concept of social cohesion into two dimensions of **equality/justice** and **social capital**. As the issue of (environmental) justice is addressed already above the focus her will be on social capital dimension as the main indicator. Social capital refers to the value that social networks have (to those that are part and to those that are bystanders (Putnam in Jenson 2012:9). Empowerment, participation, associational activity and common purpose, supporting networks and reciprocity, collective norms and values, trust, safety and belonging are domains of social capital at the neighbourhood level (Forrest and Kearns 2001). These domains must be examined in order to understand the level of social cohesion at the local level.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• In addition to the above actions, see if (further) improvement is possible in terms of empowerment and participation, but also address supporting social networks and reciprocity, shared norms and values, trust, belonging, safety	- Improvements in structural dimensions like bonds with family and friends, being part of organised associations, integration in the wider community as well as in the more cognitive aspects like trust, feeling attached to the neighbourhood, practical help, tolerance and respect (Raymond et al 2017). - A (further) increase in social capital building, in relation to the realisation of NBS. (Social Cohesion)

INDICATORS	
Justice	➔ See above elaboration on environmental justice
SCA - Social capital	• In the process of realising an NBS: having ensured that in the process towards this NBS, attention is paid to the various aspects/domains of social capital so that social cohesion improves in the process of realising an NBS • In assessing the impact of an NBS: assessing how it further supports and improves social capital (e.g. consider collaboration; feelings of safety; feelings of belonging, an NBS as a local meeting point) • With regard to further maintenance of the NBS: ensuring that social cohesion is maintained of further strengthened in the maintenance of the NBS (e.g. NBS maintenance as empowerment; collective action; enhancing feelings of belonging and integration in the local community)

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LINKS AND REFERENCES	
KEYWORDS	• Recognition • procedural justice • participation • transparency • Distribution • Gentrification • Displacement • Inequality • Capabilities • Empowerment • Skills • Training • Responsibility • Social cohesion • social capital • participation
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4.9 UC 9 | Urban Planning and Governance

9 | URBAN PLANNING AND GOVERNANCE

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | URBAN PLANNING AND GOVERNANCE	9.1 | Urban planning and form
		9.2 | Goverance in planning

INFORMATION	
DESCRIPTION UC	The challenge of urban planning is all about triggering new solutions for sustainable and liveable urban environment. Urban planning addresses several issues faced in the cities: environmental, societal and economic issues too. The objective of the challenge Urban Planning and Governance is to evaluate the effectiveness of using nature-based solutions when tackling the consequences of intentional and unintended urban transitions. Urban planning is a tool of governance, that has been always driven by political forces, on the other hand in accordance with responsible innovation, the opinion of city users (residents, those who work in the city and visitors too) needs to be taken into account. The tools of participatory planning enable urban planners and decision makers to engage people in the urban planning process and consider their needs. Nature-based solutions are a good topic to be communicated towards the citizens. Urban planning also addresses a lot of environmental issues: such as the quality of built environment, infrastructure needs, energy supply, food security, water and waste management. They are issues addressed in other urban challenges in this framework. In this UC, we focus on urban form as a result of urban planning. Indeed, urban form is a key element of all of the previous questions and also defines the possibilities and barriers of implementing NBS. Urban planning is also an economic question. It is essential to make interventions that are financially sustainable on the long term. Therefor we also propose one indicator focusing on spending on nature-based solutions. The toughness is, that while there are several indicators for sustainable cities (EU: Indicators for Sustainable Cities, 2015), the effectiveness of urban planning is usually mainly measured through the impact it has created in cities.

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9.1 | URBAN PLANNING AND FORM

INFORMATIONS	
DESCRIPTION USC	Urban form is defined as the physical characteristics that make up built-up areas, including the shape, size, density and configuration of settlements. Urban form evolves as a result of urban planning; however this is a constantly developing circumstance. There are places that are subject of particular attention: such as historical cities, city centres and places of heritage. Urban form can be considered at different scales: regional, urban, neighbourhood, block and street. Urban form evolves constantly in response to social, environmental, economic and technological developments; planning, housing and urban policies; and health, transport and economic policies (Williams, 2014). Urban form is directly related to NBS in numerous ways. For example, the implementation of nature-based solutions are basically determined by the geometric facilities, that is the urban fabric. Urban form implies issues such as territorial balance and integration, the growth of metropolitan areas, urbanization of suburban villages, and thus the extension functional urban areas, resulting severe mobility issues, and of course energy and emission-related problems, etc. All these problems are linked with NBS in either a direct or an indirect way, however, we can only evaluate the direct impacts correctly. Using 3 indicators we evaluate urban form and the connections to NBS: Areal sprawl, Betweenness and Accessibility. All three indicators measure the effectiveness of urban planning in tackling urban form related issues and can assess the effectiveness of NBS to tackle negative trends.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Increase ecological connectivity across NBS sites and residential areas**	• Greater ecological connectivity across urban regeneration sites, and across scales.
• **Create green areas for recreation in a regular spatial pattern through the city.**	• Enhance quality of life by better accessibility of green areas (mainly with recreational function) • Increased the amount and the accessibility of green open space for residents. • Reduce urban sprawl because of a better acceptance of urban density
• **Assess urban form sustainability in urban planning process**	• In favouring urban plans that are putting emphasis on: - creating a compact and sustainable form, - ensuring the renaturing of the cities - giving space for nature and its ecosystem services.
• **Set up and conserve natural environment in the fringes of the city**	• Stopping space consuming developments, but favouring a compact city, multicentre urban form. Nature-based solutions are highly relevant from compact urban form point of view. Compactness can be also achieved with the balanced availability of green spaces and ecosystem services.

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INDICATORS	
• **AS - Areal sprawl**	measure the severity of the sprawl of a city
• **BN - Betweenness**	measure the spatial organization of the urban fabric
• **ACC - Accessibility**	measure the spatial organization of green spaces in relation to the residential areas.

LINKS AND REFERENCES	
KEYWORDS	• Urban planning • Sustainable urban form • Territorial balance and integration • Growing metropolitan areas • Compactness
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9.2 | GOVERNANCE IN PLANNING

INFORMATIONS	
DESCRIPTION USC	Governance has the power to manifest society's values and needs through urban planning, and for sure it is securing the framework of planning. One can easily realize the importance of urban planning and design, a tool of implementing decisions of the governance. Focusing on NBS, the situation is not very different either. Society has a demand for a healthy, climate-friendly, energy-efficient, secure, etc. urban environment; therefor governance should aim to react on urban transitions in a sustainable way. Summing up, appropriate urban governance applied to urban planning ensures a socially sustainable pattern within the city. That implies not only the engagement of the relevant stakeholders in particular decisions but also the harmonized distribution of different social groups within the city (that is: preferably avoiding segregation or gentrification). Urban planning and governance is a rather complex process therefore the evaluation also needs a compound method. As the planning and governance system varies in European countries, the methodology of evaluations should also differ, which wouldn't make a harmonized system.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Provide more liveable environment by NBS**	• Segregation seems to be a double ended weapon when thinking of nature-based solutions. On one hand we see, that urban areas and neighbourhoods that are rich with pleasant green spaces have higher real estate prices, therefore the residents are usually of the upper classes of society. On other hand, nature-based solutions should ensure social inclusion and reduce segregation. Segregation means the unequal access to amenities and liveable environment. Poorer strata tend to occupy less desirable places, hit more often by climatic issues and health-related problems. By offering more liveable environment by NBSs such negative effects can be remedied and liveability of an area can be improved. On the other hand offering such solutions could reduce the negative effects of segregation. (Kabisch, N., et al., 2016) NBS techniques may be applied to make a neighbourhood more liveable by e.g. reducing the heat island affect. Thus the tension arising from low quality environment lessens and reduces the willingness to leave the neighbourhood amongst those who could move to another, more desirable areas.
• **Create opportunities and facilitate cross-sectoral dialogue and partnership of different stakeholders**	• Legitimate different forms and systems of knowledge in participatory planning processes, empowering citizens/civil society, practitioners and policy stakeholder involvement in NBS projects.

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for NBS design, implementation and maintenance	• Social learning about the location and importance of different types of sociocultural values for NBS, enabling NBS to be designed in line with community aspirations and expectations. • Policy learning leading to more efficient design, delivery, and monitoring of NBS. • Inter-departmental collaboration leading to NBS designs for multi-functionality. • Improved co-ordination of NBS strategies within and across levels of governance.
• **Favour diversity in use, such as mix of people, mix of uses, appropriate densities and visual diversity (Biddulph, 2011);**	• Increased cultural richness and diversity in urban areas, as well as improved ease of movement. • Diversified utilization of green spaces, ensure common ground for different social groups

INDICATORS	
• **BBGM - Annual budget of natural assets management**	• NBS presumes a conscious planning and management of the green infrastructure of a city. The annual budget spent on green infrastructure management relative to the annual budget of a city reflects to importance of this asset. Due to the very “nature” of this infrastructure, it is a long-term investment that requires a persistent effort. For this reason, if we aspire to define an indicator to measure it, we need to consider at least a 10 years long period
• **SI – Segregation index**	• Segregation shows the spatial separation of different social strata in a given spatial area

LINKS AND REFERENCES	
KEYWORDS	• Urban governance • Segregation, social balance • Urban fringes • Financially sustainable urban natural assets management

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4.10 UC 10 | People Security

10 | PEOPLE SECURITY

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | PEOPLE SECURITY	10.1 | Control of crime
		10.2 | Control of extraordinary events

INFORMATION	
DESCRIPTION UC	This challenge mainly focuses on how NBS contexts cope with increasing security issues in urban contexts. **Two threats, manmade (criminal) events and extraordinary events (such as natural disasters) are considered in this challenge.** In 1990s UNDP and Canadian Government introduced the notion of human security as an important challenge of our times. People security element for N4C project relates to the personal safety and refers to an individual's freedom from crime and violence (Bajpai 2000). We can think of different forms of crime in NBS contexts such as murder, rape, assault, robbery etc. There is a continuous tension between the natural environment and public use in urban areas (Luymens and Tamminga 1995). In urban contexts security is low as a result of lower levels of social cohesion (see UC 8.2) and informal social control (Bruinsma 2007). NBS, part of the city or neighborhood, are spaces managed and planned at material, infrastructural and social level (Luymes and Tamminga 1995). NBS as designed, planned and managed contexts provide control of crime in a neighborhood. Also control and management of people security leads to sustainability of the NBS. These real measures of crime reflect one side of the security challenge. Perceived risk of crime which influences quality of life constitutes the other side (Christmann and Rogerson 2004). People perceive risk of crime when crime exists or they think the possibility of crime to exist (Loukaitou-Sideris 2006). Perceptions of crime influence the people's motivation to consume an NBS. When the motivation decreases, people's activities in NBS contexts decrease resulting in sedentary lifestyles. These lack of motivation for consuming the NBS has negative impacts on social cohesion (sharing the same space with the community) and people's health due to inactivity. Another security issue is caused by extraordinary events like natural disasters (earthquakes, floods etc). People who died, relocated, evacuated, or injured must be identified to take necessary controls. Also value of insurance claims provide an economic measure for the effect of these events on the citizens' properties (Donelly et al 2004).

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10.1 | CONTROL OF CRIME

INFORMATIONS	
DESCRIPTION USC	Man-made events or crime occurring in NBS contexts create threats to personal security which refers to an individual's freedom from crime and violence (Bajpai 2000). We can think of different forms of crime in NBS contexts such as murder, rape, assault, and robbery. Crime counts in different categories of crime (Bella 2015) and percentage of victimization are important measures of crime. Even if crime does not exist, if people perceive the environment as unsafe then they prefer not to be there. NBS is a micro-locality in neighborhood resulting as a place where safety perceptions are managed in the neighborhood. This reflects to the safety perceptions of the neighborhood and also sustainability of the use of NBS. Perceived risk of crime serves a good indicator of control of crime subchallenge.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Control and Policing of the NBS**	• Establishing security through decrease in the frequency measures on the amount and types of crime, gender violence and victimization.
• **Designing and founding NBS which controls the possible cues of crime that can create perceived risk of crime**	• Decrease in the perceptions of crime • Increase in the activity in the context of NBS • Increase in the quality of life and well-being
• **Eliminating the cues that create perceived risk of crime such as empty or dark roads, broken windows, no policing**	• Decrease in the perceptions of crime • Increase in the activity in the context of NBS • Increase in the quality of life and well-being

INDICATORS	
• **CC/PCFS/PGV/PV - Frequency Indicators (victimization, gender violence, crime categories)**	• Number of different categories of events at street, neighbourhood, city and NBS level. • Average number of a specific category of event for a specific locality • Comparisons of amounts and different categories among different localities. • They can be used to design, revise, control NBS.
• **PC - Perceived Crime Measures**	• Perception of safety • Perception of crime • They can be used to design promotional or civic tools to create awareness on safety and security in public. For example, if older people feel less secure, using cues communicating safety in the design of NBS is possible.

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10.2 | CONTROL OF EXTRAORD. EVENTS

INFORMATIONS	
DESCRIPTION USC	In NBS contexts, in addition to man-made events or crime, extraordinary events can happen and influence the security of people. Natural disasters such as fire, earthquakes, floods constitute examples of such extraordinary events. In order to control this subchallenge, people who died, relocated, evacuated, or injured must be identified. Also value of insurance claims provide an economic measure for the effect of these events on the citizens' properties.

POTENTIAL ACTIONS	EXPECTED IMPACTS
• **Control and Policing of the NBS**	• Establishing security through decrease in the frequency measures on the amount and types of crime, gender violence and victimization.
• **Designing and founding NBS with less risk of extraordinary events**	• Decrease in the economic loss • Decrease in the death and injuries • Management of relocation or evacuation of people

INDICATORS	
• **DPIC - Value of Insurance claims**	• An economic measure of harmful effects of extraordinary events on people's properties.
• **NDMP/NPIRE - Frequency measures of negative effects of extraordinary events (deaths, missing people, number of people injured, relocated, evacuated)**	• This helps to measure the impact of NBS in the reduction of risks associated with extraordinary events.

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KEYWORDS	• Crime • Violence • Security • Human Security • Fear of Crime • Natural disaster mitigation
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11 | GREEN ECONOMY

Factsheet URBAN CHALLENGE

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	11 | GREEN ECONOMY	11.1 | Circular economy
		11.2 | Bioeconomy activities
		11.3 | Direct economic value of NBS

INFORMATION	
DESCRIPTION UC	The European Environment Agency (2017) defines Green Economy as one that generates increasing welfare while maintaining the environment that supports us. From a practical point of view, UNEP (2017) considers that a green economy is one whose *growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services.* Raymond et al (2017), in an EKLIPSE report state the value of NBS in the generation of co-benefits that can save money to residents and the government as well as create opportunities for "Green Businesses" and creation of "Green-collar jobs". Green Surge, a previous EU project on green infrastructure, linked green economy with green infrastructure and their supplied ecosystem services based on UNEP's approach. In a similar sense, we build up on UNEP's approach and take into consideration the work from Green Surge to develop this challenge and define subchallenges. Green Surge identifies four aspects that connects green economy with urban green infrastructure (UGI): economy competitiveness, business opportunities, economic efficiency, and investment in urban quality. Related to those aspects, they stress the contribution of UGI to attractive spaces (for resident, business, and labour force), social entrepreneurship, avoidance of costs, insurance values, and green accounting. With respect to the green accounting, they acknowledged the value of life cycle assessment approaches and techniques to assess benefits and costs. Despite Nature-based solutions (NBS) does not include only green infrastructure many of the identified elements applied to our case. This challenge intends to relate the contribution of NBS (direct and indirect) and their implementation to the enhancement of an inclusive green economy. In this sense, we identified three main aspects (or subchallenges) to consider: - Enhancement of a circular economy; - Enhancement of bioeconomy activities; - Direct economic value of NBS.

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Enhancement of the circular economy will be focused on assessing how NBS and their implementation could contribute to enhance energy and resources efficiency, including the reduction of waste, from an economic point of view. Enhancement of the bioeconomy activities will be focused on assessing how NBS and their implementation could contribute to empower the local economic sectors and industries that produce, manage or use biological resources, including biowaste. The direct economic value of NBS will assess the contribution of supplied ecosystem services into the real economy. In order to do that, the avoidance of cost, the insurance value, and the increase of assets value (e.g. properties) due to NBS impact will be considered.

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11.1 | CIRCULAR ECONOMY

INFORMATIONS	
DESCRIPTION USC	The circular economy goes beyond the traditional extractive industrial model and it aims to gradually decouple economic activity from the consumption of finite resources in order to reduce negative impacts. According to the Ellen Macarthur Foundation it is based on three principles: design out waste and pollution, keep products and materials in use and regenerate natural systems.

POTENTIAL ACTIONS	EXPECTED IMPACTS
Specification of more durable, longer lasting elements and components in the design phase of NBS projects	• This will reduce the generated amount of waste.
Design to ensure the recyclability of segregated materials	• This will increase the recycling rate and enhance the circular economy.

INDICATORS	
C&DW - Construction and demolition waste	• Measure of generated waste calculated per life cycle and project stage
MCI - Material Circularity Indicator	• Measure how restorative flows are maximized and linear flows minimized, considering also the length and intensity of the product use
RRMW - Recycling rate of municipal waste	• Measure of tonnage recycled from municipal waste divided by the total municipal waste generated in the same year, displayed in percent

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11.2 | BIOECONOMY ACTIVITIES

INFORMATIONS	
DESCRIPTION USC	Bioeconomy covers all the economic sectors and industries, including their service areas, that produce manage or use biological resources. As part of the green economy challenge, the bioeconomy sub-challenge is focused on assessing how NBS and their implementation could contribute to the empowerment of these economic sectors in the urban areas, by increasing the local production of biological resources or making a more efficient use of biowastes.

POTENTIAL ACTIONS	EXPECTED IMPACTS
Establish private-public partnerships agreements as part of the strategic implementation of productive NBS in urban areas	• Increase the added value of the local agroforestry sector by developing synergies with them. This will also propitiate increase of agroforestry business and employment in the sector.
Potentiate policies that encourage the use of biowaste and biomass from local urban areas (public or private) for energy production	• This will increase the amount of biomass used for energy purposes. This will reduce the amount of waste, enhance the bioeconomy sector and propitiate the increase of biomass and biofuel in the share of energy consumption

INDICATORS	
GVAEGS - Gross Value Added in the Local Environmental Good & Services Sector	• Measure of the value added by EGSS to the total economy with respect the total value of the other activities.
LPB - Labour productivity of bioeconomy	• The average amount of turnover generated by a person employed in the bioeconomy
NVATRBB - No. of VAT Registered Bioeconomy Business	• Measure of the increase of decrease in the bioeconomy business in the area after implementation of NBS in a strategic level

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11.3 | DIRECT ECONOMIC VALUE OF NBS

INFORMATIONS	
DESCRIPTION USC	Nature-based solutions need to demonstrate their value as economic input in cities to facilitate its mainstreaming in cities. As part of the green economy challenge, the Direct Economic Value of NBS assess the contribution of suppliec ecosystem services into the economy of cities by reducing costs or avoiding them, demonstration their insurance value (to mitigate economic impacts of extreme natural events) and increasing the value of private and public built assets, such as private residential properties.

POTENTIAL ACTIONS	EXPECTED IMPACTS
Encourage provision of new green urban spaces related to new urban developments	• This will increase the amount of green areas in the city and their benefits plus an increased economic gain obtained by the developers and the future landowners.
Enhance the provision of sustainable urban drainage solutions (SUDS). This is especially relevant in relation to flood risk areas	• This will decrease the damages on properties and people due to flooding events. Therefore reducing cost for public authorities, owners and insurance companies.
Enhance the provision of urban woodlands and streets trees	• This will increase the deposition of PM2.5., PM10 as well as the removal of O_3, NOx, CO, SO_2. At the same time will increase the carbon sequestration. From an economic point of view this will increase the value of close properties and reduce the damages from emissions on built assets and public health, avoiding economic costs.
Increase the public and private investment on NBS solutions by transferring benefits to the NBS initiators too (e.g. trough tax reductions)	• This will increase the willingness to invest on NBS solutions and will create jobs related to NBS development or management and reduce the future associated costs of companies.

INDICATORS	
ANS - Adjusted Net Saving (or Adjusted Net Saving including particulate emission damage)	• Adjusted net savings are derived from standard city accounting measures of gross savings by making four adjustments. First, estimates of fixed capital consumption of produced assets are deducted to obtain net savings. Second, current public expenditures on education are added to net savings (in standard national accounting these expenditures are treated as consumption). Third, estimates of the depletion of a variety of natural resources are deducted to reflect the decline in asset values associated with their extraction and harvest. And fourth, deductions are made for damages from carbon dioxide emissions and local pollution.

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HPI - The House Price Index	• Measure of the increase or decrease of value of the houses due to an implementation of NBS in the area with recreational, aesthetic or social value in general
DIPSB - Direct and indirect public spending on bioeconomy	• Direct public spending under grants, loans and incentives as well as indirect spending under promotion, procurement, R&D education for bioeconomy.
PIB - Private Investment on bioeconomy	• Private capital investment (plant and equipment, storage and distribution infrastructure), private R&D investment, and other investments.

LINKS AND REFERENCES

Keywords	• Bioeconomy • Circular Economy • Direct Use • Added Value • Environmental Goods and Services • Employment • Investment
Links and references	• European Environment Agency. 2017. [Link] : https://www.eea.europa.eu/themes/waste/green-economy/green-economy [Last Access: 21/09/2017] • UNEP. 2017. [Link]: https://www.unep.org/greeneconomy/what-inclusive-green-economy [Last Access: 21/09/2017] • Erik Andersson, Jakub Kronenberg, Rozalija Cvejić, Thomas Elmqvist , Marina Pintar. 2017. Deliverable D.4.1: Integrating green infrastructure ecosystem services into real economies. Green Surge – Report. • Raymond, C.M., Berry, P., Breil, M., Nita, M.R., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, D., Cardinaletti, M., Lovinger, L., Basnou, C., Monteiro, A., Robrecht, H., Sgrigna, G., Munari, L. and Calfapietra, C. (2017) An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford, United Kingdom

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5 Urban Performance Indicator Pool (UPIP)

The Urban Performance Indicator Pool (UPIP) collects and structures relevant UPIs related to the USCs, UCs and Topics. And is further linked and based on detailed UPI specifications. In the following tables (Table 12, Table 13, Table 14, Table 15 and Table 16) you can find the raw set of N4Cs UPIP, collected within T 2.1.

Discussion on quality indicators (2.1.4 and 5.1.12)

One of the reasons for implementing NBS is to preserve or restore the state of environment in the urban ecosystems. The deterioration in the state of environment and its improvement achieved through implementation of NBS can be measure by “quality indicators” representing the state of different environmental components. Quality indicators, therefore, become an integral part of the indicator system of any NBS related project. In N4C, these indicators are added to the indicator pool to represent environmental quality of three major media; air, water and soil. They are intended to be utilized depending on the medium/media whose quality is impacted as a result of NBS. The quality in a given medium is usually measured through analytical methods which are the basis for quality indicators. These analytical methods are well-established, robust and well-accepted, which is the reason why no RACER evaluation was carried out and these indicators are added directly to the streamlined KPI list of N4C. Only quality indicator for which RACER evaluation was done was Common Air Quality Index due to the fact that it is a composite indicator presenting the overall air quality in the city by combining different air quality parameters. At this moment, no parameters for water and soil quality was specified as the exact parameters would be revealed on a case-by-case basis.

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5.1 UPI - CLIMATE

Table 12: N4C Urban Performance Indicator Pool – CLIMATE

TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS
CLIMATE	1 CLIMATE ISSUES	1.1 Climate mitigation	1.1.1 | CO_2 - Annual carbon sequestration
			1.1.2 | GHG - Avoided GHG emissions
		1.2 Climate adaption	1.2.1 | AT - Air temperature
			1.2.2 | TLO - Thermal load of outstreaming body
			1.2.3 | AC - Adaptive Comfort (indoor)
			1.2.4 | TCS - Thermal Comfort Score (outdoor)
			1.2.5 | PET - Physiological equivalent temperature
			1.2.6 | UTCI - Universal thermal climate index
			1.2.7 | MRT - Mean radiant temperature
			1.2.8 | PT - Perceived temperature
			1.2.9 | PMV - Predicted mean vote
			1.2.10 | β - Bowen ratio
	2 WATER MANAGEMENT	2.1 Urban water management and quality	2.1.1 | EPTvar - Evapotranspiration variation
			2.1.2 | SWS - Soil water storage
			2.1.3 | PFvar - Peak flow variation
			2.1.4 | WQ - Stormwater quality
		2.2 Flood management	2.2.1 | TROvol - Total runoff volume
			2.2.2 | TRFvol - Total rainfall volume
			2.2.3 | RRR - Total runoff/Total rainfall ratio
			2.2.4 | FAV - Variation of flooded area
			2.2.5 | WDT - Water Detention Time

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5.2 UPI - ENVIRONMENT

Table 13: N4C Urban Performance Indicator Pool - ENVIRONMENT

ENVIRONMENT	3 AIR QUALITY	3.1 Air quality at district/city scale	3.1.1 | CAQI - Common Air Quality Index
			3.1.2 | EAQLVcity - Exceedance of air quality limit value – City scale
			3.1.3 | AAPCV - Annual amount of pollutants captured by vegetation
		3.2 Air quality locally	3.2.1 | EAQLVlocal - Exceedance of air quality limit value – Local scale
	4 GREEN SPACE AND BIODIVERSITY	4.1 Biodiversity	4.1.1 | UGSP - Urban Green Space Proportion
			4.1.2 | SDIH – Shannon Diversity Index of Habitats
			4.1.3 | IAS - Number of invasive alien species
			4.1.4 | PALHB - Potential of areas likely to host biodiversity
			4.1.5 | RNPS - Ratio of Native Plant Species
			4.1.6 | PSL - Land Use and associated impacts on biodiversity
		4.2 Urban space development and regeneration	4.2.1 | BAF - Biotope Area Factor
			4.2.2 | CGS - Connectivity of green spaces
			4.2.3 | LUsom – Land use related to Soil organic matter changes
			4.2.4 | NDVI - Normalized Difference Vegetation Index
		4.3 Urban space management	4.3.1 | SPI – Sustainable practices indicator
	5 URBAN REGENARATION AND SOIL	5.1 Soil manage-ment and quality	5.1.1 | Cfer - Chemical fertility of soil
			5.1.2 | EcoF - Ecotoxicology factor
			5.1.3 | SWI - Soil water infiltration
			5.1.4 | SBA - Soil biological activity
			5.1.5 | ScF - Soil classification Factor
			5.1.6 | SCr - Soil Crusting
			5.1.7 | Sct - Soil contamination
			5.1.8 | SMP - Soil macro porosity
			5.1.9 | SOM - Soil Organic Matter
			5.1.10 | SR - Soil respiration
			5.1.11 | SWR - Soil water reservoir for plants

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5.3 UPI - RESOURCE

Table 14: N4C Urban Performance Indicator Pool - RESOURCE

RESOURCE	6 RESOURCE EFFICIENCY	6.1 Food, energy and water	6.1.1 | EE - Energy Efficiency
			6.1.2 | ES - Energy Security
			6.1.3 | EIWS - Energy Intensity of Water Supply
			6.1.4 | EUA - Energy use in Agriculture
			6.1.5 | PCFPV - Per Capita Food Production Variability
			6.1.6 | PCFSV - Per Capita Food Supply Variability
			6.1.7 | WS - Water Security
			6.1.8 | AWW - Agricultural water withdrawal
			6.1.9 | BEN - Buildings Energy needs
			6.1.10 | CED - Cumulative Energy Demand
			6.1.11 | WSc - Water scarcity
			6.1.12 | AWC - Absolute Water Consumption
			6.1.13 | WE - Water Efficiency
			6.1.14 | WI - Water Intensity
		6.2 Raw Material	6.2.1 | RME - Raw Material Efficiency
			6.2.2 | ARDfuels - Abiotic resource depletion – Fossil fuels
			6.2.3 | ARDmetalmineral - Abiotic resource depletion – Metal and Mineral
		6.3 Waste	6.3.1 | SWG - Specific waste generation
		6.4 Recycling	6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes
			6.4.2 | ROL - Rate of landfilling
			6.4.3 | ROR - Rate of recycling

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5.4 UPI - SOCIAL

Table 15: N4C Urban Performance Indicator Pool – SOCIAL

SOCIAL	7 PUBLIC HEALTH AND WELL-BEING	7.1 Acoustics	7.1.1 | Lden - Day-evening-night noise level
			7.1.2 | Lnight - Night noise level
			7.1.3 | ENNH - Effects of night noise on health
			7.1.4 | PAI – Population Annoyance Index
		7.2 Quality of Life	7.2.1 | QOL - Quality of life
		7.3 Health	7.3.1 | PH - Perceived health
			7.3.2 | HIM - Heat induced mortality
			7.3.3 | AQEshort – Air quality indicators: short term health effects
			7.3.4 | AQElong – Air quality indicators: long term health effects
	8 SOCIAL JUSTICE AND COHESION	8.1 Environmental justice	8.1.1 | REC - Recognition
			8.1.1.1 | PA - Place attachment
			8.1.1.2 | BI - Bodily integrity
			8.1.1.3 | AES - Availability ES
			8.1.2 | PJ - Procedural justice
			8.1.3 | DJ - Distributional justice
			8.1.3.1 | GEN - Gentrification
			8.1.4 | CAP - Capabilities
			8.1.5 | RES - Responsibility
		8.2 Social cohesion	8.2.1 | SC - Social capital
	9 URBAN PLANNING AND GOVERNANCE	9.1 Urban planning and form	9.1.1 | AS – Areal Sprawl
			9.1.2 | BN - Betweenness
			9.1.3 | AC - Accessibiléity
		9.2 Governance in planning	9.2.1 | ABNC – Annual Budget of Natural Assets
			9.2.2 | SI – Segregation Index
	10 PEOPLE SECURITY	10.1 Control of crime	10.1.1 | CC - Crime counts
			10.1.2 | PC - Perceived crime
			10.1.3 | PCFS - Percentage of citizens feeling safe
			10.1.4 | PGV - Percentage of gender violence
			10.1.5 | PV - Percentage of victimization
		10.2 Control of extraordinary events	10.2.1 | DPIC - Domestic Property Insurance Claims
			10.2.2 | NDMP - Number of deaths and missing people
			10.2.3 | NPIRE - Number of people injured, relocated and evacuated

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5.5 UPI - ECONOMY

Table 16: N4C Urban Performance Indicator Pool - ECONOMY

ECONOMY	11 GREEN ECONOMY	11.1 Circular economy	11.1.1 | C&DW - Construction and demolition waste
			11.1.2 | MCI - Material Circulatory Indicator
			11.1.3 | RRMW - Recycling rate of municipal waste
		11.2 Bioeconomy activities	11.2.1 | GVAEGS – Gross Value Added in the local Environmental Good & Services sector
			11.2.2 | LPB - Labour productivity of bioeconomy
			11.2.3 | NVATRBB - N° of VAT registered bioeconomy business
		11.3 Direct economic value of NBS	11.3.1 | ANS - Adjusted Net Saving
			11.3.2 | HPI - House Pricing Index
			11.3.3 | DIPSB - Direct and indirect public spending on bioeconomy
			11.3.4 | PIB - Private investment on bioeconomy

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5.6 UPI – MULIT-SCALES

The following tables (Table 17, Table 18, Table 19, Table 20 and Table 21) show summarizing the multidimensionality and scales of the collected UPI, based on the Indicator Factsheets specifications. The RACER evaluation reveals further, that most of the UPIs can be in a kind adapted from city to object scales, which underlines the multiscalar applicability.

Table 17: N4C Urban Performance Indicator Pool – Scales – CLIMATE

TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS	CITY	NEIGHBOURHOOD / DISTRICT	OBJECT
CLIMATE	1 CLIMATE ISSUES	1.1 Climate mitigation	1.1.1 | CO2 - Annual carbon sequestration	X	X	X
			1.1.2 | GHG - Avoided GHG emissions	X	X	X
		1.2 Climate adaption	1.2.1 | AT - Air temperature	X	X	X
			1.2.2 | TLO - Thermal load of outstreaming body		X	X
			1.2.3 | AC - Adaptive Comfort (indoor)		X	X
			1.2.4 | TCS - Thermal Comfort Score (outdoor)	X	X	X
			1.2.5 | PET - Physiological equivalent temperature	X	X	X
			1.2.6 | UTCI - Universal thermal climate index	X	X	X
			1.2.7 | MRT - Mean radiant temperature	X	X	X
			1.2.8 | PT - Perceived temperature	X	X	X
			1.2.9 | PMV - Predicted mean vote		X	X
			1.2.10 | β - Bowen ratio			X
	2 WATER MANAGEMENT	2.1 Urban water management and quality	2.1.1 | EPTvar - Evapotranspiration variation	X	X	
			2.1.2 | SWS - Soil water storage	X	X	X
			2.1.3 | PFvar - Peak flow variation	X	X	X
			2.1.4 | WQ - Stormwater quality	X	X	X
		2.2 Flood management	2.2.1 | TROvol - Total runoff volume	X	X	X
			2.2.2 | TRFvol - Total rainfall volume	X	X	X
			2.2.3 | RRR - Total runoff/Total rainfall ratio	X	X	
			2.2.4 | FAV - Variation of flooded area	X	X	
			2.2.5 | WDT - Water Detention Time	X	X	X

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Table 18: N4C Urban Performance Indicator Pool – Scales - ENVIRONMENT

TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS	CITY	NEIGHBOURHOOD / DISTRICT	OBJECT
ENVIRONMENT	3 AIR QUALITY	3.1 Air quality at district/city scale	3.1.1 | CAQI - Common Air Quality Index	X	X	
			3.1.2 | EAQLVcity - Exceedance of air quality limit value – City scale	X	X	
			3.1.3 | AAPCV - Annual amount of pollutants captured by vegetation	X	X	
		3.2 Air quality locally	3.2.1 | EAQLVlocal - Exceedance of air quality limit value – Local scale		X	X
	4 GREEN SPACE AND BIODIVERSITY	4.1 Biodiversity	4.1.1 | UGSP - Urban Green Space Proportion	X	X	
			4.1.2 | SDIH – Shannon Diversity Index of Habitats		X	X
			4.1.3 | IAS - Number of invasive alien species		X	X
			4.1.4 | PALHB - Potential of areas likely to host biodiversity	X	X	X
			4.1.5 | RNPS - Ratio of Native Plant Species		X	X
			4.1.6 | PSL - Land Use and associated impacts on biodiversity	X	X	X
		4.2 Urban space development and regeneration	4.2.1 | BAF - Biotope Area Factor		X	X
			4.2.2 | CGS - Connectivity of green spaces	X	X	X
			4.2.3 | LUsom – Land use related to Soil organic matter changes	X	X	X
			4.2.4 | NDVI - Normalized Difference Vegetation Index	X	X	
		4.3 Urban space management	4.3.1 | SPI – Sustainable practices indicator	X	X	X
	5 URBAN REGENARATION AND SOIL	5.1 Soil management and quality	5.1.1 | Cfer - Chemical fertility of soil	X	X	X
			5.1.2 | EcoF - Ecotoxicology factor			X
			5.1.3 | SWI - Soil water infiltration			X
			5.1.4 | SBA - Soil biological activity			X
			5.1.5 | ScF - Soil classification Factor	X	X	X
			5.1.6 | SCr - Soil Crusting			X
			5.1.7 | Sct - Soil contamination	X	X	X
			5.1.8 | SMP - Soil macro porosity			X
			5.1.9 | SOM - Soil Organic Matter			X
			5.1.10 | SR - Soil respiration			X
			5.1.11 | SWR - Soil water reservoir for plants			X

Table 19: N4C Urban Performance Indicator Pool – Scales - RESOURCE

TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS	CITY	NEIGHBORHOOD/DISTRICT	OBJECT
RESOURCE	6 RESOURCE EFFICIENCY	6.1 Food, energy and water	6.1.1 | EE - Energy Efficiency	X	X	X
			6.1.2 | ES - Energy Security			X
			6.1.3 | EIWS - Energy Intensity of Water Supply	X		
			6.1.4 | EUA - Energy use in Agriculture	X		
			6.1.5 | PCFPV - Per Capita Food Production Variability	X		
			6.1.6 | PCFSV - Per Capita Food Supply Variability	X		
			6.1.7 | WS - Water Security	X	X	
			6.1.8 | AWW - Agricultural water withdrawal	X		
			6.1.9 | BEN - Buildings Energy needs		X	X
			6.1.10 | CED - Cumulative Energy Demand	X	X	X
			6.1.11 | WSc - Water scarcity	X	X	X
			6.1.12 | AWC - Absolute Water Consumption	X	X	X
			6.1.13 | WE - Water Efficiency	X	X	X
			6.1.14 | WI - Water Intensity	X	X	X
		6.2 Raw Material	6.2.1 | RME - Raw Material Efficiency	X		
			6.2.2 | ARDfuels - Abiotic resource depletion – Fossil fuels	X	X	X
			6.2.3 | ARDmetalmineral - Abiotic resource depletion – Metal and Mineral	X	X	X
		6.3 Waste	6.3.1 | SWG - Specific waste generation	X	X	X
		6.4 Recycling	6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes	X	X	
			6.4.2 | ROL - Rate of landfilling	X	X	X
			6.4.3 | ROR - Rate of recycling	X	X	X

Table 20: N4C Urban Performance Indicator Pool – Scales - SOCIAL

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Table 21: N4C Urban Performance Indicator Pool – Scales - ECONOMY

TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS	CITY	NEIGHBOURHOOD / DISTRICT	OBJECT
ECONOMY	11 GREEN ECONOMY	11.1 Circular economy	11.1.1 | C&DW - Construction and demolition waste		X	X
			11.1.2 | MCI - Material Circulatory Indicator	X		
			11.1.3 | RRMW - Recycling rate of municipal waste	X		
		11.2 Bioeconomy activities	11.2.1 | GVAEGS – Gross Value Added in the local Environmental Good & Services sector	X		
			11.2.2 | LPB - Labour productivity of bioeconomy	X		
			11.2.3 | NVATRBB - N° of VAT registered bioeconomy business	X		
		11.3 Direct economic value of NBS	11.3.1 | ANS - Adjusted Net Saving	X		
			11.3.2 | HPI - House Pricing Index	X	X	
			11.3.3 | DIPSB - Direct and indirect public spending on bioeconomy	X		
			11.3.4 | PIB - Private investment on bioeconomy			X

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6 RACER evaluation

The aim of the task 2.1 of N4C project is to propose a system of integrated multi-scale and multi-thematic UPIs for the assessment of UCs, associated USCs and NBS. In this section we propose a first attempt at selecting a reduced list of KPIs from the comprehensive indicator system presented in the previous sections. The Table 22 includes the weighted scoring scheme within the legend as well as the specific and relevant RACER criterions and sub-criterions. The following tables (

Table 23, Table 24,

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Table 26, Table 27, Table 28, Table 29, Table 30, Table 31 and Table 32) show the final result matrix of the RACER Evaluations of the UPIs and the choosen KPI for each USC, based on RACER scoring and documentated expert judgement.

Table 22: RACER Evaluation summary final matrix with weighted scoring Part I_LEGEND and CRITERIA

Legend:

2 points	criterion completely fulfilled
1 point	criterion partly fulfilled
0 points	criterion not fulfilled
KEY PERFORMANCE INDICATOR	

RELEVANT			ACCEPTED			CREDIBLE			EASY			ROBUST		
R1: Linkage to project aim	R2: Policy support for policies	R3: Comparability	A1: Policy makers	A2: Practioners	A3: Other Stakeholders	C1: Unambiguous results	C2: Transparency	C3: Documentation of assumptions	E1: Availabilty of data	E2: Technical feasibility	E3: Reproducibility	R1: Data quality	R2: Sensitiveness	R3: Scale

Table 23: RACER Evaluation summary final matrix with weighted scoring Part I_CLIMATE

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				R1	R2	R3	A1	A2	A3	C1	C2	C3	E1	E2	E3	R1	R2	R3	
CLIMATE	1 CLIMATE ISSUES	1.1 Climate mitigation	1.1.1 | CO2 - Annual carbon sequestration	2	1	2	1	2	2	2	1	1	2	2	2	2	2	2	26
			1.1.2 | GHG - Avoided GHG emissions	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	29
		1.2 Climate adaption	1.2.1 | AT - Air temperature	2	2	2	2	2	1	1	2	2	1	2	2	2	2	2	27
			1.2.2 | TLO - Thermal load of outstreaming body	2	2	2	0	1	1	2	2	2	1	1	2	2	2	2	24
			1.2.3 | AC - Adaptive Comfort (indoor)	2	2	2	2	1	2	2	2	2	1	1	2	2	2	1	26
			1.2.4 | TCS - Thermal Comfort Score (outdoor)	2	2	1	0	1	1	2	2	2	1	0	2	2	1	2	21
			1.2.5 | PET - Physiological equivalent temperature	2	2	1	0	2	2	2	2	2	1	0	2	2	1	2	23
			1.2.6 | UTCI - Universal thermal climate index	2	2	1	0	2	2	2	2	2	0	0	2	2	1	2	22
			1.2.7 | MRT - Mean radiant temperature	1	2	1	0	1	2	0	2	2	2	2	2	2	1	2	22
			1.2.8 | PT - Perceived temperature	2	2	1	0	1	1	2	2	2	0	0	2	2	1	2	20
			1.2.9 | PMV - Predicted mean vote	2	2	1	1	1	1	2	2	2	0	0	2	2	1	2	21
			1.2.10 | β - Bowen ratio	2	2	2	0	1	2	1	2	2	1	1	2	2	2	2	24
	2 WATER MANAGEMENT	2.1 Urban water management and quality	2.1.1 | EPTvar - Evapotranspiration variation	2	0	2	0	0	0	0	1	2	1	2	2	2	2	1	17
			2.1.2 | SWS - Soil water storage	2	1	0	0	0	0	1	1	1	1	2	1	2	2	2	16
			2.1.3 | PFvar - Peak flow variation	2	1	2	1	1	1	0	1	2	1	1	2	2	2	2	21
			2.1.4 | WQ - Stormwater quality	2	2	2	2	1	2	1	2	2	1	2	2	2	2	1	26
		2.2 Flood management	2.2.1 | TROvol - Total runoff volume	2	0	2	0	1	1	0	1	2	1	1	2	2	2	1	18
			2.2.2 | TRFvol - Total rainfall volume	2	2	2	0	2	2	2	2	1	0	1	2	2	2	1	23
			2.2.3 | RRR - Total runoff/Total rainfall ratio	2	0	2	0	1	2	1	1	0	1	1	2	2	2	1	18
			2.2.4 | FAV - Variation of flooded area	2	0	2	0	0	2	0	1	1	1	1	2	2	2	2	18
			2.2.5 | WDT - Water Detention Time	2	0	2	0	0	2	2	2	2	1	1	2	2	1	2	21

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Table 24: Rationale KPI decision_CLIMATE

CHOSEN KPI	RATIONALE
1.1.1 | CO2 - Annual carbon sequestration	We dediced to chose this indicator because it has the second best score and allows to cover an additional dimension and important issue of the USC.
1.1.2 | GHG - Avoided GHG emissions	based on highest RACER score within the USC
1.2.1 | AT - Air temperature	based on highest RACER score within the USC
1.2.3 | AC - Adaptive Comfort (indoor)	We dediced to chose this indicator because it has the second best score and allows to cover an additional dimension of the USC.
1.2.4 | TCS - Thermal Comfort Score (outdoor)	We decided to chose this innovative indicator, because of the easy understanding and expressiveness regarding the very complex bio-human indicies issue, although this have less points then the other selected.
1.2.5 | PET - Physiological equivalent temperature	We decided to chose this innovative indicator too, again although this one have less points then the other selected, but because it's the base for the previous mentioned TCS indicator and thus a basic indicator for bio-human indicies.
2.1.3 | PFvar - Peak flow variation	We dediced to chose this indicator because it has the second best score and allows to cover an additional dimension of the USC.
2.1.4 | WQ - Stormwater quality	based on highest RACER score within the USC
2.2.2 | TRFvol - Total rainfall volume	based on highest RACER score within the USC
2.2.5 | WDT - Water Detention Time	We dediced to chose this indicator because it has the second best score and allows to cover an additional dimension of the USC.

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Table 25: RACER Evaluation summary final matrix with weighted scoring Part II_ENVIRONMENT

				R1	R2	R3	A1	A2	A3	C1	C2	C3	E1	E2	E3	R1	R2	R3	
ENVIRONMENT	3 AIR QUALITY	3.1 Air quality at district/city scale	3.1.1 | CAQI - Common Air Quality Index	2	2	2	0	1	2	2	2	2	1	2	2	2	2	1	25
			3.1.2 | EAQLVcity - Exceedance of air quality limit value – City scale	2	2	2	2	0	2	2	2	2	1	0	2	2	2	0	23
			3.1.3 | AAPCV - Annual amount of pollutants captured by vegetation	2	2	2	2	0	2	2	2	2	1	0	2	2	2	0	23
		3.2 Air quality locally	3.2.1 | EAQLVlocal - Exceedance of air quality limit value – Local scale	2	2	2	0	1	1	2	1	1	0	0	1	2	2	0	17
	4 GREEN SPACE AND BIODIVERSITY	4.1 Biodiversity	4.1.1 | UGSP - Urban Green Space Proportion	2	2	2	2	2	2	2	2	1	1	2	2	0	2	2	26
			4.1.2 | SDIH – Shannon Diversity Index of Habitats	2	2	2	1	2	2	2	2	2	1	2	2	2	2	0	26
			4.1.3 | IAS - Number of invasive alien species	1	2	2	2	2	1	2	2	2	1	2	2	2	2	0	25
			4.1.4 | PALHB - Potential of areas likely to host biodiversity	2	2	2	0	1	2	2	1	1	1	2	1	2	1	2	22
			4.1.5 | RNPS - Ratio of Native Plant Species	2	2	2	1	2	2	2	2	2	1	1	2	2	1	0	24
			4.1.6 | PSL - Land Use and associated impacts on biodiversity	2	2	1	0	1	1	1	2	2	2	2	2	2	2	2	24
		4.2 Urban space development and regeneration	4.2.1 | BAF - Biotope Area Factor	2	2	1	2	2	1	1	2	2	1	2	2	2	1	1	24
			4.2.2 | CGS - Connectivity of green spaces	2	2	2	0	1	2	2	2	2	2	2	2	2	1	2	26
			4.2.3 | LUsom – Land use related to Soil organic matter changes	2	2	1	0	1	1	0	2	2	2	2	2	2	2	2	23
			4.2.4 | NDVI - Normalized Difference Vegetation Index	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	29
		4.3 Urban space management	4.3.1 | SPI – Sustainable practices indicator	2	1	1	2	1	1	1	2	1	1	2	2	2	0	1	20
	5 URBAN REGENARATION AND SOIL	5.1 Soil management and quality	5.1.1 | Cfer - Chemical fertility of soil	2	1	1	2	2	2	2	2	2	1	1	2	2	2	0	24
			5.1.2 | EcoF - Ecotoxicology factor	2	1	1	2	2	2	2	2	2	1	1	2	2	2	0	24
			5.1.3 | SWI - Soil water infiltration	2	1	2	0	2	2	2	2	2	2	2	2	2	2	0	25
			5.1.4 | SBA - Soil biological activity	2	1	2	0	2	2	2	2	2	1	2	2	2	2	2	26
			5.1.5 | ScF - Soil classification Factor	2	1	2	2	2	2	2	2	2	1	1	2	2	2	1	26
			5.1.6 | SCr - Soil Crusting	2	1	2	0	2	2	2	2	2	1	2	2	2	2	0	24
			5.1.7 | Sct - Soil contamination	2	1	1	2	2	2	2	2	2	1	1	2	2	2	0	24
			5.1.8 | SMP - Soil macro porosity	2	1	2	0	2	2	2	2	2	1	2	2	2	2	0	24
			5.1.9 | SOM - Soil Organic Matter	2	1	2	0	2	2	2	2	2	1	2	2	2	2	0	24
			5.1.10 | SR - Soil respiration	2	1	2	0	2	2	2	2	2	1	0	2	2	2	0	22
			5.1.11 | SWR - Soil water reservoir for plants	1	1	2	2	2	2	2	2	2	1	2	2	2	2	0	25

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Table 26: Rationale KPI decision_ENVIRONMENT

CHOSEN KPI	RATIONALE
3.1.1 | CAQI - Common Air Quality Index	based on highest RACER score within the USC
3.2.1 | EAQLVlocal - Exceedance of air quality limit value – Local scale	based on highest RACER score within the USC
4.1.1 | UGSP - Urban Green Space Proportion	based on highest RACER score within the USC (draw)
4.1.2 | SDIH – Shannon Diversity Index of Habitats	based on highest RACER score within the USC (draw)
4.2.1 | BAF - Biotope Area Factor	We dediced to chose this indicator because it has the third best score, is an easy understandable indicator and allows to cover an additional dimension of the USC.
4.2.2 | CGS - Connectivity of green spaces	We dediced to chose this indicator because it has the second best score and allows to cover an additional dimension of the USC.
4.2.4 | NDVI - Normalized Difference Vegetation Index	based on highest RACER score within the USC
4.3.1 | SPI – Sustainable Practices Indicator	based on highest RACER score within the USC
5.1.4 | SBA - Soil biological activity	based on highest RACER score within the USC (draw)
5.1.5 | ScF - Soil classification Factor	based on highest RACER score within the USC (draw)

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Table 27: RACER Evaluation summary final matrix with weighted scoring Part III_RESOURCE

			Indicator	R1	R2	R3	A1	A2	A3	C1	C2	C3	E1	E2	E3	R1	R2	R3	
RESOURCE	6 RESOURCE EFFICIENCY	6.1 Food, energy and water	6.1.1 | EE - Energy Efficiency	2	2	1	2	1	2	1	1	1	1	2	2	2	2	2	24
			6.1.2 | ES - Energy Security	2	2	2	1	1	2	2	2	2	1	2	2	2	2	1	26
			6.1.3 | EIWS - Energy Intensity of Water Supply	2	2	2	1	2	2	1	2	2	1	2	2	2	0	2	25
			6.1.4 | EUA - Energy use in Agriculture	1	1	1	1	1	2	1	2	2	1	2	2	2	0	1	20
			6.1.5 | PCFPV - Per Capita Food Production Variability	1	2	2	1	1	2	1	2	2	1	2	2	2	2	1	24
			6.1.6 | PCFSV - Per Capita Food Supply Variability	1	2	2	1	1	2	1	2	2	1	2	2	2	2	1	24
			6.1.7 | WS - Water Security	2	2	2	1	1	2	1	2	2	1	2	2	2	0	1	23
			6.1.8 | AWW - Agricultural water withdrawal	1	2	2	1	1	2	1	2	2	1	2	2	2	0	1	22
			6.1.9 | BEN - Buildings Energy needs	2	2	2	2	2	2	2	2	2	1	1	2	2	2	1	27
			6.1.10 | CED - Cumulative Energy Demand	2	2	2	2	2	2	1	2	2	1	2	2	2	2	1	27
			6.1.11 | WSc - Water scarcity	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	29
			6.1.12 | AWC - Absolute Water Consumption	1	1	1	1	2	1	1	2	2	1	1	2	2	2	2	22
			6.1.13 | WE - Water Efficiency	1	1	1	1	2	1	1	2	2	1	1	2	2	2	2	22
			6.1.14 | WI - Water Intensity	1	1	1	1	2	1	1	2	2	1	1	2	2	2	2	22
		6.2 Raw Material	**6.2.1 | RME - Raw Material Efficiency**	2	2	2	2	1	2	2	2	2	2	2	2	2	1	2	28
			6.2.2 | ARDfuels - Abiotic resource depletion – Fossil fuels	1	2	2	1	2	2	1	2	2	1	2	2	2	2	1	25
			6.2.3 | ARDmetalmineral - Abiotic resource depletion – Metal and Mineral	1	2	2	1	2	2	1	2	2	1	2	2	2	2	1	25
		6.3 Waste	**6.3.1 | SWG - Specific waste generation**	2	2	1	2	1	2	1	1	2	2	2	1	1	0	1	21
		6.4 Recycling	**6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes**	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	29
			6.4.2 | ROL - Rate of landfilling	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	29
			6.4.3 | ROR - Rate of recycling	2	2	2	2	2	2	1	2	2	2	2	2	2	2	2	29

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Table 28: Rationale KPI decision_RESOURCE

CHOSEN KPI	RATIONALE
6.1.2 | ES - Energy Security	We dediced to chose this indicator because it has the second best score for the sub-topic Energy and allows to cover an additional dimension of the USC.
6.1.5 | PCFPV - Per Capita Food Production Variability	based on highest RACER score for the sub-topic Food within the USC
6.1.9 | BEN - Buildings Energy needs	based on highest RACER score for the sub-topic Energy within the USC (draw)
6.1.10 | CED - Cumulative Energy Demand	based on highest RACER score for the sub-topic Energy within the USC (draw)
6.1.11 | WSc - Water scarcity	based on highest RACER score for the sub-topic Water within the USC
6.2.1 | RME - Raw Material Efficiency	based on highest RACER score within the USC
6.3.1 | SWG - Specific waste generation	based on highest RACER score within the USC
6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes	based on highest RACER score within the USC. We prefered the ERP compared to the equal scored ROL or ROR because of the overall evaluation approach.

Table 29: *RACER Evaluation summary final matrix with weighted scoring Part IV_SOCIAL*

				R1	R2	R3	A1	A2	A3	C1	C2	C3	E1	E2	E3	R1	R2	R3	
SOCIAL	7 PUBLIC HEALTH AND WELL-BEING	7.1 Acoustics	7.1.1 | Lden - Day-evening-night noise level	2	2	2	2	2	1	1	2	2	1	1	1	1	0	2	22
			7.1.2 | Lnight - Night noise level	2	2	2	2	2	1	1	2	2	1	1	1	1	0	2	22
			7.1.3 | ENNH - Effects of night noise on health	2	2	2	2	1	1	2	2	2	1	1	2	1	1	2	24
			7.1.4 | PAI – Population Annoyance Index	2	2	2	1	1	1	2	2	2	1	1	2	1	1	2	23
		7.2 Quality of Life	7.2.1 | QOL - Quality of life	2	2	2	2	2	2	2	2	2	1	2	2	1	0	2	26
		7.3 Health	7.3.1 | PH - Perceived health	2	2	2	2	2	2	2	2	2	1	2	2	1	0	2	26
			7.3.2 | HIM - Heat induced mortality	2	2	2	0	2	2	2	2	2	1	2	2	1	1	2	25
			7.3.3 | AQEshort – Air quality indicators: short term health effects	2	2	2	1	2	2	2	2	2	1	2	2	1	1	2	26
			7.3.4 | AQElong – Air quality indicators: long term health effects	2	2	2	1	2	2	2	2	2	1	2	2	1	1	2	26
	8 SOCIAL JUSTICE AND COHESION	8.1 Environmental justice	8.1.1 | REC - Recognition	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.1.1 | PA - Place attachment	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.1.2 | BI - Bodily integrity	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.1.3 | AES - Availability ES	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.2 | PJ - Procedural justice	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.3 | DJ - Distributional justice	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.3.1 | GEN - Gentrification	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.4 | CAP - Capabilities	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
			8.1.5 | RES - Responsibility	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
		8.2 Social cohesion	8.2.1 | SC - Social capital	2	2	2	0	1	2	2	2	2	1	1	2	2	2	2	25
	9 URBAN PLANNING AND GOVERNANCE	9.1 Urban planning and form	9.1.1 | AS – Areal Sprawl	2	0	2	0	1	0	2	2	2	2	1	2	2	0	2	20
			9.1.2 | BN - Betweenness	2	0	1	0	1	2	1	2	2	2	1	2	2	0	2	20
			9.1.3 | ACC - Accessibility	2	0	1	0	1	2	1	2	2	2	1	2	2	0	2	20
		9.2 Governance in planning	9.2.1 | ABNA – Annual Budget of Natural Assets	2	2	2	0	2	0	2	2	2	2	2	2	2	2	2	26
			9.2.2 | SI – Segregation Index	2	2	2	2	1	2	1	2	2	2	2	2	2	1	1	26
	10 PEOPLE SECURITY	10.1 Control of crime	10.1.1 | CC - Crime counts	1	1	1	1	1	1	1	1	2	1	1	2	1	1	2	18
			10.1.2 | PC - Perceived crime	1	1	1	1	1	1	1	1	2	1	1	2	1	1	2	18
			10.1.3 | PCFS - Percentage of citizens feeling safe	1	1	1	1	2	1	2	2	2	2	2	2	2	2	0	23
			10.1.4 | PGV - Percentage of gender violence	1	1	1	2	2	2	2	2	2	2	2	2	2	2	0	25
			10.1.5 | PV - Percentage of victimization	1	1	1	2	2	2	2	2	2	2	2	2	2	2	0	25
		10.2 Control of extraordinary events	10.2.1 | DPIC - Domestic Property Insurance Claims	2	2	2	2	1	2	2	0	1	1	2	2	2	0	2	23
			10.2.2 | NDMP - Number of deaths and missing people	2	2	2	2	1	2	1	2	2	1	2	2	2	0	2	25
			10.2.3 | NPIRE - Number of people injured, relocated and evacuated	2	2	2	2	1	2	1	2	2	1	2	2	2	0	2	25

Table 30: Rationale KPI decision_SOCIAL

CHOSEN KPI	RATIONALE
7.1.1 | Lden - Day-evening-night noise level	We dediced to chose this indicator because it has the second best score for the USC and allows to cover an additional dimension of the USC.
7.1.3 | ENNH - Effects of night noise on health	based on highest RACER score within the USC
7.2.1 | QOL - Quality of life	based on highest RACER score within the USC
7.3.1 | PH - Perceived health	based on highest RACER score within the USC (draw)
7.3.2 | HIM - Heat induced mortality	We dediced to chose this indicator because it has the second best score for the USC and allows to cover an additional dimension of the USC.
7.3.3 | AQEshort – Air quality indicators: short term health effects	based on highest RACER score within the USC (draw)
7.3.4 | AQElong – Air quality indicators: long term health effects	based on highest RACER score within the USC (draw)
8.1.1 | REC - Recognition	based on highest RACER score within the USC (draw)
8.1.2 | PJ - Procedural justice	based on highest RACER score within the USC (draw)
8.1.3 | DJ - Distributional justice	based on highest RACER score within the USC (draw)
8.1.4 | CAP - Capabilities	based on highest RACER score within the USC (draw)

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8.1.5 | RES - Responsibility	based on highest RACER score within the USC (draw)
8.2.1 | SC - Social capital	based on highest RACER score within the USC (draw)
9.1.3 | ACC - Accessibility	based on highest RACER score within the USC (draw)
9.2.2 | SI – Segregation Index	based on highest RACER score within the USC (draw)
10.1.4 | PGV - Percentage of gender violence	based on highest RACER score within the USC (draw)
10.1.5 | PV - Percentage of victimization	based on highest RACER score within the USC (draw)
10.2.1 | DPIC - Domestic Property Insurance Claims	We dediced to chose this indicator because it has also a good score and allows to cover an additional dimension of the USC.
10.2.2 | NDMP - Number of deaths and missing people	based on highest RACER score within the USC

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Table 31: RACER Evaluation summary final matrix with weighted scoring Part V_ECONOMY

				R1	R2	R3	A1	A2	A3	C1	C2	C3	E1	E2	E3	R1	R2	R3	
ECONOMY	11 GREEN ECONOMY	11.1 Circular economy	**11.1.1 | C&DW - Construction and demolition waste**	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2	**28**
			11.1.2 | MCI - Material Circulatory Indicator	2	2	2	0	2	2	2	2	2	2	2	2	2	0	2	**26**
			11.1.3 | RRMW - Recycling rate of municipal waste	2	2	2	2	1	1	1	1	1	0	2	0	0	1	2	**18**
		11.2 Bioeconomy activities	**11.2.2 | GVAEGS - Gross Value Added in the local Environmental Good & Services sector**	2	2	1	1	2	1	1	2	2	1	2	2	2	0	2	**23**
			11.2.3 | LPB - Labour productivity of bioeconomy	1	0	2	0	1	0	2	2	2	2	2	2	2	0	0	**18**
			11.2.4 | NVATRBB - N° of VAT registered bioeconomy business	2	0	2	0	2	0	2	2	2	2	2	2	2	0	0	**20**
		11.3 Direct economic value of NBS	**11.3.1 | ANS - Adjusted Net Saving**	2	0	1	1	2	1	1	2	2	1	2	2	2	0	0	**19**
			11.3.2 | HPI - House Pricing Index	2	2	2	1	2	2	2	2	2	1	2	2	2	0	2	**26**
			11.3.3 | DIPSB - Direct and indirect public spending on bioeconomy	1	1	2	0	1	0	2	2	1	1	2	2	2	0	0	**17**
			11.3.4 | PIB - Private investment on bioeconomy	1	1	2	0	1	0	2	2	1	1	2	2	2	0	0	**17**

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Table 32: Rationale KPI decision_ECONOMY

CHOSEN KPI	RATIONALE
11.1.1 | C&DW - Construction and demolition waste	based on highest RACER score within the USC
11.1.2 | MCI - Material Circulatory Indicator	We dediced to chose this indicator because it has the second best score for the USC and allows to cover an additional dimension of the USC.
11.2.2 | GVAEGS – Gross Value Added in the local Environmental Good & Services sector	based on highest RACER score within the USC
11.3.1 | ANS - Adjusted Net Saving	We dediced to chose this indicator because it has the second best score for the USC and allows to cover an additional dimension of the USC.
11.3.2 | HPI - House Pricing Index	based on highest RACER score within the USC

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7 Key Performance Indicators (KPIs)

Finally, the following Table 33, Table 34, Table 35, Table 36, Table 37 show the deductive and comprehensive summarized set of N4C T 2.1 KPI's for each UC and USC, which is composed out of 50 defined relevant KPI's.

7.1 KPI - CLIMATE

Table 33: Nature4Cities T 2.1 set of KPI's_Part I_CLIMATE

TOPIC	URBAN CHALLENGES	SUB-CHALLENGES	INDICATORS
CLIMATE	1 CLIMATE ISSUES	1.1 Climate mitigation	1.1.1 | CO_2 - Annual carbon sequestration
			1.1.2 | GHG - Avoided GHG emissions
		1.2 Climate adaption	1.2.1 | AT - Air temperature
			1.2.3 | AC - Adaptive Comfort (indoor)
			1.2.4 | TCS - Thermal Comfort Score (outdoor)
			1.2.5 | PET - Physiological equiv. temperature
	2 WATER MANAGEMENT AND QUALITY	2.1 Urban water management and quality	2.1.3 | PFvar - Peak flow variation
			2.1.4 | WQ - Stormwater quality
		2.2 Flood management	2.2.2 | TRFvol - Total rainfall volume
			2.2.5 | WDT - Water Detention Time

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7.2 KPI - ENVIRONMENT

Table 34: Nature4Cities T 2.1 set of KPI's_Part II_ENVIRONMENT

ENVIENVIRONMENTRONMENT	**3 AIR QUALITY**	**3.1 Air quality at district/city scale**	3.1.1 | CAQI - Common Air Quality Index
	4 BIODIVERSITY AND URBAN SPACE	**3.2 Air quality locally**	3.2.1 | EAQLVlocal - Exceedance of air quality limit value – Local scale
		4.1 Biodiversity	4.1.1 | UGSP - Urban Green Space Proportion
			4.1.2 | SDIH – Shannon Diversity Index of Hhabitats
		4.2 Urban space development and regeneration	4.2.1 | BAF - Biotope Area Factor
			4.2.2 | CGS - Connectivity of green spaces
			4.2.4 | NDVI - Normalized Difference Vegetation Index
		4.3 Urban Space Management	4.3.1 | SPI – Sustainable Practices Index
	5 SOIL MANAGEMENT	**5.1 Soil management**	5.1.4 | SBA - Soil biological activity
			5.1.5 | ScF - Soil classification Factor

7.3 KPI - RESOURCE

Table 35: Nature4Cities T 2.1 set of KPI's_Part III_RESOURCE

RESOURCE	**6 RESOURCE EFFICIENCY**	**6.1 Food, energy and water**	6.1.2 | ES - Energy Security
			6.1.5 | PCFPV - Per Capita Food Production Variability
			6.1.9 | BEN - Buildings Energy needs
			6.1.10 | CED - Cumulative Energy Demand
			6.1.11 | WSc - Water scarcity
		6.2 Raw Material	6.2.1 | RME - Raw Material Efficiency
		6.3 Waste	6.3.1 | SWG - Specific waste generation
		6.4 Recycling	6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes

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7.4 KPI - SOCIAL

Table 36: Nature4Cities T 2.1 set of KPI's_Part IV_SOCIAL

SOCIAL	7 PUBLIC HEALTH AND WELL-BEING	7.1 Acoustics	7.1.1 | Lden - Day-evening-night noise level
			7.1.3 | ENNH - Effects of night noise on health
		7.2 Quality of Life	7.2.1 | QOL - Quality of life
		7.3 Health	7.3.1 | PH - Perceived health
			7.3.2 | HIM - Heat induced mortality
			7.3.3 | AQEshort – Air quality indicators: short term health effects
			7.3.4 | AQElong – Air quality indicators: long term health effects
	8 SOCIAL JUSTICE AND COHESION	8.1 Environmental justice	8.1.1 | REC - Recognition
			8.1.2 | PJ - Procedural justice
			8.1.3 | DJ - Distributional justice
			8.1.4 | CAP - Capabilities
			8.1.5 | RES - Responsibility
		8.2 Social cohesion	8.2.1 | SC - Social capital
	9 URBAN PLANNING AND GOVERNANCE	9.1 Urban planning and form	9.1.3 | ACC - Accessibility
		9.2 Goverance in planning	9.2.2 | SI – Segregation Index
	10 PEOPLE SECURITY	10.1 Control of crime	10.1.4 | PGV - Percentage of gender violence
			10.1.5 | PV - Percentage of victimization
		10.2 Control of extraordinary events	10.2.1 | DPIC - Domestic Property Insurance Claims
			10.2.2 | NDMP - Number of deaths and missing people

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7.5 KPI - ECONOMY

Table 37: Nature4Cities T 2.1 set of KPI's_Part V_ECONOMY

ECONOMY	**11 GREEN ECONOMY**	**11.1 Circular economy**	11.1.1 | C&DW - Construction and demolition waste
			11.1.2 | MCI - Material Circulatory Indicator
		11.2 Bioeconomy activities	11.2.2 | GVAEGS – Gross Value Added in the local Environmental Good & Services sector
		11.3 Direct economic value of NBS	11.3.1 | ANS - Adjusted Net Saving
			11.3.2 | HPI - House Pricing Index

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8 Conclusions

This document finally constitutes a state-of-the-art reference book for multi-scale and multi-thematic urban performance indicators (UPI's) as a base for the assessment of urban challenges (UC's) and NBS, not least because of the literature-based collection of potential UPI's and detailed compiled information's which comprises 110 meaningful collected UPI's within five main Topics, divided into 11 UC's and further 26 urban sub-challenges (USC's).

Out of this comprehensive indicator system, we've proposed a first selection of Key Performance Indicators (KPI's) adapted to the urban planning praxis and based on the RACER criteria: Relevant, Accepted, Credible, Easy, Robust. The result is a set of 50 highly expressive Urban Performance Indicators (UPI) covering the Urban Challenge (UC) and sub-challenges (USC) comprehensively. The overall indicator system and the selected KPIs wil serve as a starting point for further discussion and work in WP2, WP3 and WP4. The RACER evaluation concept was mobilized in an attempt to identify the most relevant and operational indicators to support the uptake of NBS in urban planning. However, it has to be noticed that it is a subjective evaluation with the threat for strictness differences between the consultees (expert groups and partners). To lessen these differences, a very detailed formulation of the evaluation criteria was proposed and done within the RACER Evaluation Factsheet.

The KPI's selected based on the RACER evaluation results will be following contrasted in the light of the work of Task 2.2, which is going to identify expert tools and best possible indicators to describe the impact of NBS on specific USC's.

Often it's not easy, to separate and evaluate a specific NBS impact to only one single UC as well as to a single level of scale. The cross-scale impacts at the level of object have to be examined more in detail. There is also a need for deeper future research regarding the relation of the impact of NBS design with all the impacts, they produce and thus contributing specificly to certain UC. Last but not least, the field of NBS-related actions is a very wide and multidisciplinary one, why it's not easy to cover all urban challenges at the same level and expertise.

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APPENDIX I

UC Literature review

Babi Almenar, 2020

A - EU-Projects and Documents

- Insight Project (Alonso et al, 2017)
- Cities of Tomorrow (EU, 2011)
- Cities in Europe (EU's cohesion policy 2014-2020)
- ICLEI Action Plan 2015 -2021: Seoul Plan (2015) – Priorities/Challenges extracted from the Urban Agendas and their main points
- Council of European Municipalities and regions
- Urban Agenda 2016 (12 priority themes)
- IUCN 2016 report (Societal Challenges)
- Challenges identified by EKLIPSE expert group 2017

B - City Urban Planning Reports: Sustainable Plans, Resilient Strategies, Urban Development Concepts, Agenda 21, etc.

- Amman (Jordan). Resilience Strategy (2017) - Priorities/Challenges extracted from goals
- Amsterdam. Sustainable Agenda (2015)
- Randstad Urban Region (NL). Structural Vision 2040 (2008)
- Athens. Resilient Strategy (2017?) - Priorities/Challenges extracted from goals
- Bangkok. Resilient Strategy (2017?) - Priorities/Challenges extracted from goals
- Barcelona Metropolitan Area (2014). Sustainability Plan Priorities/Challenges extracted from Key Actions
- Berlin. Urban Development Concept (2015) - Priorities/Challenges extracted from Strategies
- Boston. Climate Action Plan (2014) – Priorities/Challenges extracted from priorities
- Bristol. Resilient Strategy. – Priorities/Challenges extracted from Stresses Relevant to Bristol
- Budapest. Budapest 2030 Long Term Urban Development Concept - Priorities/Challenges extracted from the subdivision of goals
- Byblos (Lybia). Resilience Strategy (2017?)– Priorities/Challenges extracted from the goals
- Calgary (Canada). 2020 Sustainability Direction (2013) – Priorities/Challenges extracted from the Goals and their objectives. Goal without objectives indicate non-relevant objectives.
- Copenhagen. Municipal Plan (2015) – Priorities/Challenges extracted from Vision
- Lisboa. LX –Europa 2020 – Priorities/Challenges extracted from Objetivos 1.1.
- Madrid. Plan Estratégico 2015-2019 (2015)– Priorities/Challenges extracted from Summary
- Da Nang (Vietnam). Resilient Strategy (2017?). Priorities/Challenges extracted from resilience values

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- Dakar (Senegal). Resilient Strategy (2016). Priorities/Challenges extracted from key themes
- Glasgow. Resilience Strategy (2016). Challenges/Priorities extracted from Goals
- Gothenburg. Urban Challenges, Policy and Action in Gothenburg (2014) - Priorities/Challenges extracted from “Challenges for sustainable urban development”
- London City. Climate change adaptation strategy (2010)
- Luxembourg (Country). Sustainable National Plan (2010)– Challenges/Priorities extracted from tendencies against sustainability
- Metropolitan Melbourne. Plan Melbourne 2017-2050 (2017) – Priorities/Challenges extracted from principles and directions (mentioned only if relevant).
- Mexico City. Resilience Strategy (2017?) – Priorities/Challenges extracted from goals
- New York. The Plan for a Strong and Just City (2013) – Priorities/Challenges extracted from visions and goals
- Rotterdam- Programme on Sustainability and Climate Change 2015-2018 (2015)- Priorities/Challenges extracted from aims and goals.
- Stockholm. Environment programme 2016-2019 (2016)- Priorities/challenges extracted from targets and sub-targets (if relevant)
- Sydney. Sustainable Sydney 2030. Priorities/challenges extracted from directions and objectives (the latter if relevant)
- Thessaloniki. Resilient Strategy (2017). Priorities/Challenges extracted from objectives (only relevant ones included)
- Vejle. Resilience Strategy (2016) - Priorities/Challenges extracted from goals
- Vitoria. Agenda 21, Plan de Accion Local 2010-2014 (2010) – Priorities/Challenges extracted from 11 strategic lines
- Wellington. Resilience Strategy (2017) – Priorities/Challenges extracted from goals

C- Scientific Publications

- Xing et al (2017) - Characterisation of Nature Based Solutions for the Built Environment
- Pisano et al (2014) - Framing Urban Sust. Development; Kievani 2010 - a review of main challenges to urban sustainability)
- U. Svedn (2015) In Filho et al (2015) - Sustainable development Knowledge Society
- Martinez-Fernandez et al (2012)
- Alberti (2017) – Grand Challenges in Urban Science
- Cheng & Tong (2017) – Challenges in Asia
- Fawzi et al (2017) – Urban Challenges identified in the National Development Plan of Irak 2013-2017
- Khan Jatoo et al (2016) – Urban Challenges Pakistan
- Nandi & Gamkhar (2013) – India Urban Challenges
- Nijkamp & Kourtit (2013) – The New Urban Europe Global Challenges
- Geneletti et al (2017) – A review of approaches and challenges for sust. Planning in urban peripheries

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APPENDIX II

UPI FACTSHEETS and UPI RACER evaluation

Contributor FACTSHEETS

Table 38: *UPI Factsheet 1st contributor and 2nd contributer/reviewer_CLIMATE*

1st Contributor	2nd Contributor / Reviewer	TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS
SZTE (Kiss)	G4C (Kraus)	CLIMATE	1 CLIMATE ISSUES	1.1 Climate mitigation	1.1.1 | CO2 - Annual carbon sequestration
EKO (Yilmaz)	G4C (Kraus)				1.1.2 | GHG - Avoided GHG emissions
AO (Chantoiseau)	SZTE (Kántor)			1.2 Climate adaption	1.2.1 | AT - Air temperature
G4C (Kraus)	SZTE (Kántor)				1.2.2 | TLO - Thermal load of outstreaming body
CER (Musy)	G4C (Kraus)				1.2.3 | AC - Adaptive Comfort (indoor)
G4C (Kraus)	SZTE (Kántor)				1.2.4 | TCS - Thermal Comfort Score (outdoor)
G4C (Kraus)	SZTE (Kántor)				1.2.5 | PET - Physiological equivalent temperature
CER (Musy)	SZTE (Kántor)				1.2.6 | UTCI - Universal thermal climate index
SZTE (Kántor)	G4C (Kraus)				1.2.7 | MRT - Mean radiant temperature
SZTE (Kántor)	G4C (Kraus)				1.2.8 | PT - Perceived temperature
SZTE (Kántor)	G4C (Kraus)				1.2.9 | PMV - Predicted mean vote
AO (Bouzoudija)	G4C (Kraus)				1.2.10 | β - Bowen ratio
IFSTTAR (Chancibault)	IFSTTAR (Rodriguez)		2 WATER MANAGEMENT	2.1 Urban water management and quality	2.1.1 | EPTvar - Evapotranspiration variation
IFSTTAR (Chancibault)	IFSTTAR (Rodriguez)				2.1.2 | SWS - Soil water storage
IFSTTAR (Rodriguez)	IFSTTAR (Chancibault)				2.1.3 | PFvar - Peak flow variation
EKO (Yilmaz)	IFSTTAR (Béatrice)				2.1.4 | WQ - Stormwater quality
IFSTTAR (Rodriguez)	IFSTTAR (Chancibault)			2.2 Flood management	2.2.1 | TROvol - Total runoff volume
CAR (González)	AO (Bournet)				2.2.2 | TRFvol - Total rainfall volume
ARG (Kürkçü)	IFSTTAR (Rodriguez)				2.2.3 | RRR - Total runoff/Total rainfall ratio
ARG (Kürkçü)	IFSTTAR (Rodriguez)				2.2.4 | FAV - Variation of flooded area
ARG (Kürkçü)	IFSTTAR (Rodriguez)				2.2.5 | WDT - Water Detention Time

Table 39: *UPI Factsheet 1st contributor and 2nd contributer/reviewer_ENVIRONMENT*

1st contributor	2nd contributor/reviewer	TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS
CARTIF (Fermoso Domínguez)	NBK (Lotteau)	ENVIRONMENT	3 AIR QUALITY	3.1 Air quality at district/city scale	3.1.1 | CAQI - Common Air Quality Index
NBK (Lotteau)	CARTIF (Fermoso Domínguez)				3.1.2 | EAQLVcity - Exceedance of air quality limit value – City scale
EKO (Şenyurt)	CARTIF (Fermoso Domínguez)				3.1.3 | AAPCV - Annual amount of pollutants captured by vegetation
NBK (Lotteau)	CARTIF (Fermoso Domínguez)			3.2 Air quality locally	3.2.1 | EAQLVlocal - Exceedance of air quality limit value – Local scale
AO (Beaujouan)	AO (Bouzouidja)		4 BIODIVERSITY AND URBAN SPACE	4.1 Biodiversity	4.1.1 | UGSP - Urban Green Space Proportion
AO (Daniel)	AO (Bulot)				4.1.2 | EHD - Ecological Habitat Diversity
AO (Daniel)	AO (Bulot)				4.1.3 | AIS - Number of alien invasive species
TRS (Muller)	AO (Bouzouidja)				4.1.4 | PALHB - Potential of areas likely to host biodiversity
AO (Daniel)	AO (Bulot)				4.1.5 | RNPS - Ratio of Native Plant Species
EKO (Şenyurt)	EKO (Yilmaz)				4.1.6 | PSL - Land Use and associated impacts on biodiversity
P&C (Laîlle)	AO (Bouzouidja)			4.2 Urban space development and regeneration	4.2.1 | BAF - Biotope Area Factor
AO (Beaujouan)	TRS (Muller)				4.2.2 | CGS - Connectivity of green spaces
EKO (Şenyurt)	EKO (Yilmaz)				4.2.3 | LUsom – Land use related to Soil organic matter changes
MUTK (Szkordilisz)					4.2.4 | NDVI - Normalized Difference Vegetation Index
UN (Lebeau)	AO (Bouzouidja)		5 SOIL MANAGEMENT	5.1 Soil management and quality	5.1.1 | Cfer - Chemical fertility of soil
UN (Lebeau)	IFSTTAR (Bèchet)				5.1.2 | EcoF - Ecotoxicology factor
AO (Cannavo)	AO (Bouzouidja)				5.1.3 | SWI - Soil water infiltration
AO (Guenon)	AO (Bouzouidja)				5.1.4 | SBA - Soil biological activity
IFSTTAR (Bèchet)	AO (Bouzouidja)				5.1.5 | ScF - Soil classification Factor
IFSTTAR (Bèchet)	AO (Bouzouidja)				5.1.6 | SCr - Soil Crusting
UN (Lebeau)	IFSTTAR (Bèchet)				5.1.7 | Sct - Soil contamination
AO (Cannavo)	AO (Bouzouidja)				5.1.8 | SMP - Soil macro porosity
AO (Cannavo)	AO (Bouzouidja)				5.1.9 | SOM - Soil Organic Matter
AO (Guenon)	AO (Bouzouidja)				5.1.10 | SR - Soil respiration
AO (Cannavo)	AO (Bouzouidja)				5.1.11 | SWR - Soil water reservoir for plants
EKO (Yilmaz)					5.1.12 | SQ - Soil quality

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Table 40: *UPI Factsheet 1st contributor and 2nd contributer/reviewer_RESOURCE*

1st contributor	2nd contributor/reviewer	TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS
EKO (Yilmaz)	EKO (Yilmaz)	RESOURCE	6 RESOURCE EFFICIENCY	6.1 Food, energy and water	6.1.1 | EE - Energy Efficiency
EKO (Şenyurt)	EKO (Naneci)				6.1.2 | ES - Energy Security
EKO (Şenyurt)	EKO (Yilmaz)				6.1.3 | EIWS - Energy Intensity of Water Supply
EKO (Şenyurt)	EKO (Yilmaz)				6.1.4 | EUA - Energy use in Agriculture
EKO (Şenyurt)	EKO (Yilmaz)				6.1.5 | PCFPV - Per Capita Food Production Variability
EKO (Şenyurt)	EKO (Yilmaz)				6.1.6 | PCFSV - Per Capita Food Supply Variability
EKO (Şenyurt)	EKO (Naneci)				6.1.7 | WS - Water Security
EKO (Şenyurt)	EKO (Yilmaz)				6.1.8 | AWW - Agricultural water withdrawal
CER (Musy)	G4C (Kraus)				6.1.9 | BEN - Buildings Energy needs
EKO (Şenyurt)	EKO (Naneci)				6.1.10 | CED - Cumulative Energy Demand
EKO (Şenyurt)	EKO (Yilmaz)				6.1.11 | WSc - Water scarcity
ACC (Montané)	EKO (Yilmaz)				6.1.12 | AWC - Absolute Water Consumption
ACC (Montané)	EKO (Yilmaz)				6.1.13 | WE - Water Efficiency
ACC (Montané)	EKO (Yilmaz)				6.1.14 | WI - Water Intensity
EKO (Şenyurt)	EKO (Yilmaz)			6.2 Raw Material	6.2.1 | RME - Raw Material Efficiency
EKO (Şenyurt)	EKO (Yilmaz)				6.2.2 | ARDfuels - Abiotic resource depletion - Fossil fuels
EKO (Şenyurt)	EKO (Yilmaz)				6.2.3 | ARDmetalmineral - Abiotic resource depletion - Metal and Mineral
EKO (Şenyurt)	EKO (Yilmaz)			6.3 Waste	6.3.1 | SWG - Specific waste generation
ACC (Montané)	EKO (Yilmaz)			6.4 Recycling	6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes
ACC (Montané)	EKO (Yilmaz)				6.4.2 | ROL - Rate of landfilling
ACC (Montané)	EKO (Yilmaz)				6.4.3 | ROR - Rate of recycling

Table 41: *UPI Factsheet 1st contributor and 2nd contributer/reviewer_SOCIAL*

1st contributor	2nd contributor/reviewer	TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS
IFSTTAR (Gauvreau)	G4C (Kraus)	SOCIAL	7 PUBLIC HEALTH AND WELL-BEING	7.1 Acoustics	7.1.1 | Lden - Day-evening-night noise level
IFSTTAR (Gauvreau)	G4C (Kraus)				7.1.2 | Lnight - Night noise level
G4C (Kraus)	IFSTTAR (Gauvreau)				7.1.3 | ENNH - Effects of night noise on health
G4C (Kraus)	IFSTTAR (Gauvreau)				7.1.4 | PAI - Population Annoyance Index
UN (Fleury)	G4C (Kraus)			7.2 Quality of Life	7.2.1 | QOL - Quality of life
UN (Fleury)	G4C (Kraus)			7.3 Health	7.3.1 | PH - Perceived health
G4C (Kraus)	UN (Fleury)				7.3.2 | HIM - Heat induced mortality
G4C (Kraus)					7.3.3 | AQEshort - Air quality indicators: short term health effects
G4C (Kraus)					7.3.4 | AQElong - Air quality indicators: long term health effects
DW (Breukers)	G4C (Kraus)		8 ENVIRONMENTAL JUSTICE AND SOCIAL COHESION	8.1 Environmental justice	8.1.1 | REC - Recognition
DW (Breukers)	G4C (Kraus)				8.1.1.1 | PA - Place attachment
DW (Breukers)	G4C (Kraus)				8.1.1.2 | BI - Bodily integrity
DW (Breukers)	G4C (Kraus)				8.1.1.3 | AES - Availability ES
DW (Breukers)	G4C (Kraus)				8.1.2 | PJ - Procedural justice
DW (Breukers)	G4C (Kraus)				8.1.3 | DJ - Distributional justice
DW (Breukers)	G4C (Kraus)				8.1.3.1 | GEN - Gentrification
DW (Breukers)	G4C (Kraus)				8.1.4 | CAP - Capabilities
DW (Breukers)	G4C (Kraus)				8.1.5 | RES - Responsibility
METU (Karababa)	DW (Breukers)			8.2 Social cohesion	8.2.1 | SC - Social capital
MUTK (Csaba)	MUTK (Szkordilisz)		9 URBAN PLANNING AND GOVERNANCE	9.1 Urban form	9.1.1 | BBGM - Annual budget of blue and green infrastructure management
COL (Pisani)	MUTK (Szkordilisz)				9.1.2 | AS - Areal Sprawl
COL (Federico)	MUTK (Szkordilisz)				9.1.3 | BN - Betweenness
MUTK (Szkordilisz)					9.1.4 | SI - Segregation index
ACC (Montané)	METU (Karababa)		10 PEOPLE SECURITY	10.1 Control of crime	10.1.1 | CC - Crime counts
METU (Karababa)	METU (Karababa)				10.1.2 | PC - Perceived crime
ACC (Montané)	METU (Karababa)				10.1.3 | PCFS - Percentage of citizens feeling safe
ACC (Montané)	METU (Karababa)				10.1.4 | PGV - Percentage of gender violence
ACC (Montané)	METU (Karababa)				10.1.5 | PV - Percentage of victimization
LIST (Babi Almenar)	METU (Karababa)			10.2 Control of extraordinary events	10.2.1 | DPIC - Domestic Property Insurance Claims
LIST (Babi Almenar)	METU (Karababa)				10.2.2 | NDMP - Number of deaths and missing people
LIST (Babi Almenar)	METU (Karababa)				10.2.3 | NPIRE - Number of people injured, relocated and evacuated

Table 42: *UPI Factsheet 1st contributor and 2nd contributer/reviewer_ECONOMY*

1st contributor	2nd contributor/reviewer	TOPIC	CHALLENGES	SUB-CHALLENGES	INDICATORS
TEC (Egusquiza Ortega)	EKO (Yilmaz)	ECONOMY	11 GREEN ECONOMY	11.1 Circular economy	11.1.1 | C&DW - Construction and demolition waste
EKO (Şenyurt)	TEC (Egusquiza Ortega)				11.1.2 | MCI - Material Circulatory Indicator
TEC (Egusquiza Ortega)	EKO (Yilmaz)				11.1.3 | RRMW - Recycling rate of municipal waste
LIST (Babi Almenar)	EKO (Yilmaz)			11.2 Bioeconomy activities	11.2.1 | GVAEGS - Gross Value Added in the local Environmental Good & Services sector
EKO (Yilmaz)	LIST (Babi Almenar)				11.2.2 | LPB - Labour productivity of bioeconomy
LIST (Babi Almenar)	EKO (Yilmaz)				11.2.3 | NVATRBB - N° of VAT registered bioeconomy business
LIST (Babi Almenar)	EKO (Yilmaz)			11.3 Direct economic value of NBS	11.3.1 | ANS - Adjusted Net Saving
LIST (Babi Almenar)	EKO (Yilmaz)				11.3.2 | HPI - House Pricing Index
EKO (Yilmaz)	LIST (Babi Almenar)				11.3.3 | DIPSB - Direct and indirect public spending on bioeconomy
EKO (Yilmaz)	LIST (Babi Almenar)				11.3.4 | PIB - Private investment on bioeconomy

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UC 1 | CLIMATE ISSUES

1.1.1 | CO_2

1 | CLIMATE ISSUES

Short description of UC: The quality of life in European cities and in most of the world is threatened by a number of factors including increasing pollution levels, urban heat islands, flooding and extreme events related to climate change, as well as decreased biodiversity (Grimm et al., 2008). These can have detrimental effects for human health and well-being. At the same time, cities are a large source of carbon emissions. The importance of action on carbon mitigation and greenhouse gas control at the urban level was addressed at the COP21 in Paris, highlighting that as the world becomes more urbanized, local action is becoming increasingly important (UNFCCC, 2016).

1.1 | CLIMATE MITIGATION

Short description of USC: Climate mitigation is any action taken to permanently eliminate or reduce the long-term risk and hazard of climate change to human life, property. The International Panel on Climate Change (IPCC) defines mitigation as: *"An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001a)."*

1.1.1 | CO_2 – ANNUAL CARBON SEQUESTRATION

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.1 | Climate mitigation

INDICATOR	
NAME	**1.1.1 | CO_2 - Annual carbon sequestration**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	The annual carbon sequestration is a commonly used indicator of the global climate regulation ecosystem service of different vegetation types. The storing and sequestration of carbon (dioxide) can be quantified and monitored relatively easily, and enable spatial and temporal comparisons of the capacities of different nature-based solutions. The amount of sequestered carbon is directly proportional to biomass growth, for which a sort of biomass functions and equations are available in the fields of forestry and agricultural sciences (McPherson et al. 2016, USDA 2015). The carbon content is around 50% of the amount of biomass. This kind of knowledge is available mainly for trees which can be considered as good indicators of the whole ecosystem's capacity in areas with lack of data (as they have an outstanding role in carbon sequestration and storage). Natural and management-related mortality of biomass (and life of products if relevant) should be considered to get a total carbon balance of the investigated NBS.
FOCUS/OBJECTIVES	• contribution to climate change mitigation objectives • serve decarbonisation and green economy goals in urban planning • evaluation of green spaces efficiency

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lots of data OR High calculation and requires few data
5	High calculation difficulty and requires lots of data

DATA AND MEASUREMENT	
REQUIRED DATA	• measured data of biomass size (e.g. diameter at breast height (DBH), full height, trunk height, crown diameter of trees) • basic climatic data (average temperatures and sum of precipitation, length of vegetation period)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• measurement/monitoring • remote sensing in some cases
FREQUENCY	• occasional measurement (and long-period monitoring) of biomass size • continuous measurement of climatic data
MEASUREMENT UNIT	• tC/ha/year
REQUIRED TOOL	• clinometer for tree height, and tape measure for crown diameter and DBH measurement • precipitation and temperature sensors for climatic data • modelling tool (i-Tree Eco, CUFR Tree Carbon Calculator)
CALCULATION METHOD	• Self-developed equations, e.g. in the case of trees: $Cb_{t+1} = Cb_t + Kc[Gb_t – Ms_t – T_t – H_t]$ where: Cb_t: carbon stored in living biomass at time ‘t’ (tC/ha) Gb_t: biomass growth at time ‘t’ T_t: biomass turnover at time ‘t’ Ms_t: tree mortality due to senescence at time ‘t’ H_t: harvest at time t’ Gb = Kv * Ys where: Kv: constant to convert volume yields into dry biomass (basic wood density, in tons of dry biomass per m^3 of fresh stemwood volume Ys: the volume yield of stem wood ($m^3ha^{-1}yr^{-1}$) • ecosystem-specific proxies
OUTPUT TYPE	• numerical value • graphic map
EXAMPLES	• DAVIES, Z.G, et al. (2011): Mapping an urban ecosystem service: quantifying above-ground carbon storage at a city-wide scale. Journal of Applied Ecology 48, 1125–1134. doi:10.1111/j.1365-2664.2011.02021.x • KISS, M., et al. (2015): The role of ecosystem services in climate and air quality in urban areas: Evaluating carbon sequestration and air pollution removal by street and park trees in Szeged (Hungary). Moravian Geographical Reports 23, 36-46. doi:10.1515/mgr-2015-0016 • SCHRÖDER, C., et al. (2013): Methodology proposal for estimation of carbon storage in urban green areas. EEA Research report of Task 262-5-6 "Carbon sequestration in urban green infrastructure"

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LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • GLOBAL CLIMATE • CARBON SEQUESTRATION • CARBON STORAGE • BIOMASS GROWTH • BIOMASS EQUATIONS • CO_2
LINKS AND REFERENCES	• McPherson., G.E., van Doorn, N.S:, Peper, P.J., 2016. Urban Tree Database and Allometric Equations. General Technical Report PSW-GTR-253. USDA Forest Service, USA • Russo, A., Escobedo, F.J., Timilsina, N., Schmitt, A.O., Varela, S., Zerbe, S., 2014. Assessing urban tree carbon storage and sequestration in Bolzano, Italy, International Journal of Biodiversity Science, Ecosystem Services & Management 10:1, 54-70, doi:10.1080/21513732.2013.873822 • USDA (2015). I-Tree Eco Manual. Northern Research Station, USDA Forest Service, Website. [online] URL: http://www.itreetools.org/resources/manuals/Eco_Manual_v5.pdf

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.1 | Climate mitigation

INDICATOR	
NAME	1.1.1 CO_2 - Annual carbon sequestration

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see pp. 35-37.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable to describe initial planning problems, the annual carbon sequestration can be linked to land use or land cover categories, or any other spatial information, that is directly affected by the planning process.
R2: Policy support for policies:	The indicator itself is not frequently used, but the carbon sequestration of vegetation is a commonly used measure of the potential of nature-based solutions in climate change mitigation: • European projects : ○ Climate and Energy policy planning – Opinion of the Committee of the Regions: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014IR2691&from=EN ○ Climate change mitigation in LIFE+ Programme: • http://ec.europa.eu/environment/life/publications/lifepublications/lifefocus/documents/climate_change_mitigation.pdf
R3: Comparability:	Yes, if a common spatial anchor is fixed (e.g. urban LULC or NBS categories), the proxies of carbon sequestration potential can be measured/calculated and used in planning & development processes.

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ACCEPTED	
A1: Policy makers:	Directly not, but it has been used in policy-oriented R&D projects in the EU.
A2: Practitioners:	Yes, it is a relatively simple indicator, usable in different phases of the planning process.
A3: Other stakeholders:	Yes, as the carbon sequestration potential of the vegetation is a quite widely acknowledged process (service of ecosystems), it is present in policies in different scales and in environmental education as well.

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message (role of ecosystems in claimte change mitigation).
C2: Transparency:	It does not have a commonly accepted methodology (several approaches co-exist), but there is the possibility to define one (e.g. usable in specific NBS projects).
C3: Documentation of assumptions and limitations:	Same as above.

EASY	
E1: Availability of data to calculate the indicator:	The most exact calculations need some site- (or climatic zone-) specific input data, but reliable calculations can be carried out with widely available datasets.
E2: Technical feasibility:	Yes, the easier methods can be used with simple GIS software, on spreadsheet-based calculations.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different spatial cases). The indicator has been used in different circumstances, but most of the applications focus on capacities of urban trees (based on tree inventories)

ROBUST	
R1: Data quality:	Input data for simulation model are actual biomass (and simple climatic) data.
R2: Sensitiveness:	Yes, there are some papers dealing with validation and sensititvity anaalysis of some methods for the calculation of the indicator.
R3: Scale:	Yes, there is no limitation to use the indicator on different scales.

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1 | CLIMATE ISSUES

1.1 | CLIMATE MITIGATION

1.1.2 | GHG – GREENHOUSE GAS EMISSIONS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.1 | Climate mitigation

INDICATOR	
NAME	**1.1.2 | GHG – Avoided Greenhouse gas emissions**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Climate change causes a number of environmental mechanisms that affect both the endpoint human health and ecosystem health. Climate change models are in general developed to assess the future environmental impact of different policy scenarios. Greenhouse gases emission indicators encompass a variety of measurements on the emission and concentration of Greenhouse gases. Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. This indicator measures the emissions of the six main GHGs which have a direct impact on climate change.
FOCUS/OBJECTIVES	This indicator aim to quantify the amount of greenhouse gases (GHG) avoided as a result of implementation of NBS. GHG emissions through NBS can be avoided through reduced consumption of heating and cooling energy demands at building scale for instance. The extend of GHG emissions is one of the most widely used life cycle impact assessment indicators and the amount avoided is usually employed during scenario comparisons.
NOTES	According to the type of the NBS implemented, the priority of this indicator may change.

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lots of data OR High calculation and requires few data
5	High calculation difficulty and requires lots of data

DATA AND MEASUREMENT	
REQUIRED DATA	• The IPCC recommends monitoring of anthropogenic emissions and removals involving emissions of: carbon dioxide (CO_2) methane (CH_2) nitrous oxide (N_2O) hydrofluorocarbons (HFCs) perfluorocarbons (PFCs) sulphur hexafluoride (SF_2) nitrogen trifluoride (NF_3) trifluoromethyl sulphur pentafluoride (SF_5CF_3) halogenated ethers and other halocarbons not covered by the Montreal Protocol. • Furthermore, GHG characterization factors are required for conversion of all GHG emissions to CO_2 equivalents.
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• Commercial life cycle databases • Direct measurements from sources • Energy consumption data to obtain life cycle GHG emissions • National GHG inventories • Country-by-country estimates of CO2 emissions from fossil fuel combustion by the International Energy Agency • Data on global, regional and national fossil fuel CO2 emissions from the Carbon Dioxide Information Analysis Center at Oak Ridge National Laboratory
FREQUENCY	• anually
MEASUREMENT UNIT	• CO_2-equivalent emission is the amount of CO_2 emission that would cause the same time-integrated radiative forcing, over a given time horizon, as an emitted amount of a long-lived GHG or a mixture of GHGs. The equivalent CO_2 emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon. For a mix of GHGs, it is obtained by combining the equivalent CO_2 emissions of each gas. Equivalent CO_2 emission is a standard and useful metric for comparing emissions of different GHGs but does not imply the same climate change responses
REQUIRED TOOL	• No specific tool required for midpoint assessment.
CALCULATION METHOD	• The indicator related to GHG emissions can be quantified at two different levels; midpoint level (accounting of equivalent CO_2 emissions) and endpoint level (human and ecosystem health impacts). Within the scope of N4C, midpoint indicator will be utilized.
OUTPUT TYPE	• quantitative

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EXAMPLES	• Levasseur, A., Cavalett, O., Fuglestvedt, J.S., Gasser, T., Johanssonf, D.J.A, Jørgenseng, S.V., Raugei, M., Reisinger, A., Schivley, G., Strømman, A., Tanaka, K., Cherubini, F., 2016. Enhancing life cycle impact assessment from climate science: Review of recent findings and recommendations for application to LCA. Ecological Indicators, 71, 163 – 174 • Devkota, J., Schlachter, H., Anand, C., Phillips, R., Apul, D., 2013. Development and application of EEAST: A life cycle based model for use of harvested rainwater and composting toilets in buildings. Journal of Environmental Management, 130, 397 – 404. • Hohne, N., Harnisch, J., (Ed. VanHam, J., Baede, A.P.M., Guicherit, R., Williams Jacobse, J.G.F.), 2002. Evaluating indicators for the relative responsibility for climate change - alternatives to the Brazilian proposal and global warming potentials in Non-C02 Greenhouse Gases: Scientific Understanding, Control Options and Policy Aspects, 371 – 376. • Carabaño, R., Bedoya, C., Ruiz, D. (2014). Análisis de ciclo de vida de una nueva solución arquitectónica que mejora el rendimiento térmico de la envolvente del edificio: Fachada Natural Aljibe. Informes de la Construcción, 66(535): e034 • Pan, L., Chu, L.M., 2016. Energy saving potential and life cycle environmental impacts of a vertical greenery system in Hong Kong: A case study. Building and Environment, 96, 293 - 300

LINKS AND REFERENCES	
KEYWORDS	• Climate • Climate change • Carbon • Greenhouse gas
LINKS AND REFERENCES	• Goedkoop, M., Heijungs, R., Huijbergts, M., Schryver, A.D., Struijs, J., van Zelm, R., 2009. ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level First edition Report I: Characterisation. URL: https://www.leidenuniv.nl/cml/ssp/publications/recipe_characterisation.pdf Date of access: November 2017. • Gerdes, H., Bassi, S., Portale, E., Mazza, L., Srebotnjak, T., Porch, L., 2011. In Stream, D2.2 Final Report: Evaluation of Indicators for EU Policy Objectives. URL: https://www.ecologic.eu/sites/files/publication/2016/1901-final-report-d2-2-evaluation-of-indicators-for-eu-policy-objectives.pdf Date of access: November 2017.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.1 | Climate mitigation

INDICATOR	
NAME	**1.1.2 GHG – Avoided Greenhouse gas emissions**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	This indicator has very high relevance to the Project as climate change is one of the pressing issues for urban ecosystems. Furthermore, many NBS either reduces the baseline greenhouse gas (GHG) emissions or take up CO_2 through sequestration. These effects can occur as primary or secondary results of NBS.
R2: Policy support for policies:	There is a wide scientific consensus that emissions of greenhouse gases are responsible for global warming, with potentially dramatic economic, social and environmental consequences at the global level. The greenhouse gas emissions indicator is used to track progress in countries' efforts to lower emissions and reach environmental performance objectives. On the largest scale of assessment, GHG emissions measurement and forecasts provide a fundamental instrument in setting, improving and evaluating environmental policies.
R3: Comparability:	Some sources (Eurostat) do not include emissions and removals related to land use, land-use change and forestry (LULUCF); nor does it include emissions from international aviation and international maritime transport.

ACCEPTED	
A1: Policy makers:	The GHG emission indicator is accepted as the most important structural indicator of climate change.
A2: Practitioners:	This indicator has very high potential to be used by urban planners as it is an indispensable part of climate mitigation and adaptation strategy development.
A3: Other stakeholders:	The GHG emission indicator is accepted as the most important structural indicator of climate change.

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CREDIBLE	
C1: Unambiguous results:	There is some ambiguity as to which GHG are considered according to different sources, but all institutions consider the main pollutant to be CO_2, CH_4 and CFCs. The GHG emission indicator does not measure explicitly how much the climate will be affected by the increased accumulation of GHGs or the consequent effect of climate change on countries.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes

EASY	
E1: Availability of data to calculate the indicator:	The main institutions involved in the compilation of the EU greenhouse gas inventory are the EU Member States, the European Commission Directorate General for Climate Action (DG CLIMA), the European Environment Agency (EEA) and its European Topic Centre on Air and Climate Change (ETC/ACC),Eurostat, and the Joint Research Centre (JRC). The Climate Change Committee, made up of all EU Member States, assists the European Commission in its tasks under Council Decision No 280/2004/EC. Within the EU inventory system, the EEA and its ETC ACC are responsible for the annual compilation of the EU inventory and for the implementation of the EU QA/QC Programme. The European Commission has overall responsibility – official submission to the UNFCCC on behalf of the EU by 15 April every year. Eurostat is responsible for the IPCC reference approach for CO_2 emissions from energy combustion. The JRC is responsible for the chapters related to agriculture and LULUCF. While using this indicator at smaller scales, theoretical emission factors, emission factors from available life cycle inventories or direct measurements can be used.
E2: Technical feasibility:	As a part of life cycle indicators, avoided GHG emissions can be obtained by using LCA software. However, quantification of this indicator at midpoint level (i.e. GHG accounting level) can be carried out without the use of LCA software. The same methodologies are used for the base and all subsequent years. Data is revised and updated for all years to ensure that the same methodology is applied for the whole time series. Differences in the methodologies, background activity data or emission factors used in the Member States are documented in the inventory reports.
E3: Reproducibility:	Yes

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ROBUST	
R1: Data quality:	Data can be compared across countries and over time The same methodologies are used for the base and all subsequent years. Data is revised and updated every year to ensure that the same methodology is applied for the whole time series However, data might not be available for some sources in some countries.
R2: Sensitiveness:	Shortcomings with regard to comparability across countries are well documented. GHG emissions are strictly correlated to the industrial setting of a country (predominance of energy intensive productions, low investment in R&D and clean energy…); this characteristic allows to capture the drawbacks of a not sustainable development.
R3: Scale:	This indicator can be used at different scales including global, national, local and even at the neighbour scale.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

Short description of USC: Climate adaptation refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damage, to take advantage of opportunities, or to cope with the consequences.

1.2.1 | AT – AIR TEMPERATURE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.1 | AT - Air Temperature**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION	**AT** is the temperature of the air as measured in a shaded and ventilated shelter. However, such value can also be predicted using microclimatic or climatic models (Redon et al 2017).
OBJECTIVES	• minimize UHI-effect and hotspot mitigation (temperature reduction) • high thermal comfort

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lots of data OR High calculation and requires few data
5	High calculation difficulty and requires lots of data

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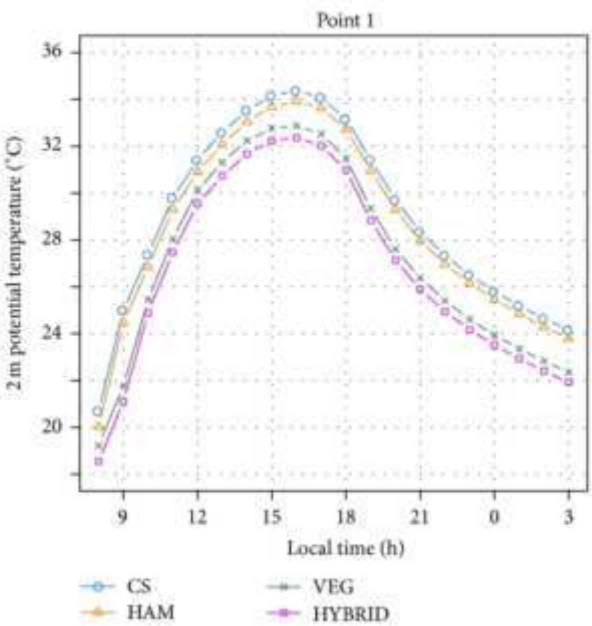
DATA AND MEASUREMENT	
REQUIRED DATA	● Measurement ○ Air temperature (Ta) ● Simulation ○ local climate ○ surrounding characterization ○ thermal (radiative, convective and conductive) and hydrological properties of each layer
INPUT TYPE	MEASUREMENT ● quantitative (Ta) SIMULATION ● quantitative (Ta, VP or RH, v, G or cloud cover) ● qualitative (3d model with surface and vegetation types incl. characteristics (e.g. albedo, emissivity,..;)
DATA SOURCE	● Microclimate simulation/modelling ● Measurement/Monitoring
FREQUENCY	● One to several times in planning process
MEASUREMENT UNIT	°C
REQUIRED TOOL	● thermometer (equipped with solar radiation shield) ● Microclimate simulation software, like: ENVI-met, SOLENE, SURFEX (Town Energy Balance)
CALCULATION METHOD	Measurement/Modelling and calculating of Tair with comparison to different scenarios
OUTPUT TYPE	● numerical value (low, mean, peak or difference scenarios) ● graphic map ● temporal evolution  Fig 1: 2m potential temperature time series at point 1.(Sodoudi (2014))

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	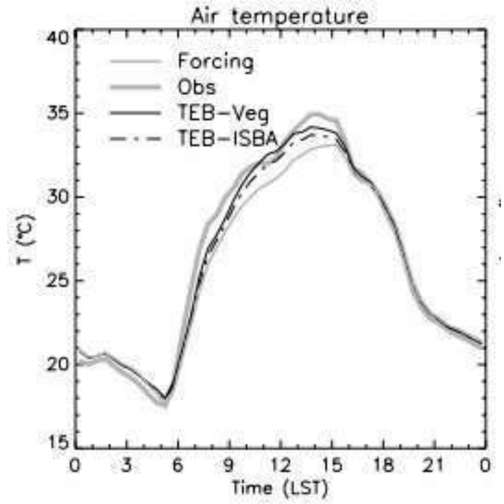 Fig 2: Lemonsu et al., 2002
EXAMPLES	● Redon, E.C., Lemonsu, A., Masson, V., Morille, B., Musy, M., 2017. Implementation of street trees within the solar radiative exchange parameterization of TEB in SURFEX v8.0. Geoscientific Model Development 10, 385–411. doi:10.5194/gmd-10-385-2017 ● de Munck, C., Pigeon, G., Masson, V., Meunier, F., Bousquet, P., Tréméac, B., Merchat, M., Poeuf, P., Marchadier, C., 2013. How much can air conditioning increase air temperatures for a city like Paris, France? Int. J. Climatol. 33, 210–227. doi:10.1002/joc.3415 ● Rosenzweig, C., Solecki, W., Slosberg, R., 2006. Mitigating New York City's heat island with urban forestry, living roofs, and light surfaces. A report to the New York State Energy Research and Development Authority. ● Sodoudi, S., Shahmohamadi, P., Vollack, K., Cubasch, U., Che-Ani, A.I., 2014. Mitigating the Urban Heat Island Effect in Megacity Tehran. Advances in Meteorology 2014, 1–19. doi:10.1155/2014/547974

LINKS AND REFERENCES

KEYWORDS	• CLIMATE • MICROCLIMATE • UHI • UHI MITIGATION • URBAN HEAT ISLAND • AIR TEMPERATURE
LINKS AND REFERENCES	● Lemonsu, A., Masson, V., Shashua-Bar, L., Erell, E., & Pearlmutter, D. (2012). Inclusion of vegetation in the Town Energy Balance model for modelling urban green areas. *Geoscientific Model Development*, *5*(6), 1377. ● de Munck, C., Pigeon, G., Masson, V., Meunier, F., Bousquet, P., Tréméac, B., Merchat, M., Poeuf, P., Marchadier, C., 2013. How much can air conditioning increase air temperatures for a city like Paris, France? Int. J. Climatol. 33, 210–227. doi:10.1002/joc.3415 ● Redon, E.C., Lemonsu, A., Masson, V., Morille, B., Musy, M., 2017. Implementation of street trees within the solar radiative exchange parameterization of TEB in SURFEX v8.0. Geoscientific Model Development 10, 385–411. doi:10.5194/gmd-10-385-2017 ● Rosenzweig, C., Solecki, W., Slosberg, R., 2006. Mitigating New York City's heat island with urban forestry, living roofs, and light surfaces. A report to the New York State Energy Research and Development Authority.

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	• Sodoudi, S., Shahmohamadi, P., Vollack, K., Cubasch, U., Che-Ani, A.I., 2014. Mitigating the Urban Heat Island Effect in Megacity Tehran. Advances in Meteorology 2014, 1–19. doi:10.1155/2014/547974

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.1 | AT – Air Temperature

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like the effect of urban landscape and different NBS on Outdoor Thermal Comfort or heat stress, only in a limited extent. Air temperature is only one from the four thermal factors (air temperature, air humidity, wind velocity, mean radiant temperature) which influence the human heat budget, thus thermal sensation and perceived thermal comfort.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	In the case of AT, existing dataset can be compared more easily than in the case of complex indices. With reasonable effort it is possible to standardise the methodology in urban environments (measurement height, distance from solid objects OR simulation guidelines), in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Because of its simplicity, AT has the greatest chance to be applied in the development and assessment of policies. The global air temperature is already used by policy makers:

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	http://www.ipcc.ch/ipccreports/tar/wg1/index.php?idp=5 https://www.eea.europa.eu/soer-2015/europe/climate-change-impacts-and-adaptation
A2: Practitioners:	AT is a simple indicator which can be used by the practitioners. However, it lacks thermophysiological relevance (AT is less relevant from human health and thermal comfort point of view than a complex thermo-physiological assessment index)
A3: Other stakeholders:	Citizens: AT is the most well-known thermal comfort parameter (green) Researchers: Thermo-physiologists and human biometeorologists agree that AT has not enough capacity do describe the thermal conditions and suggest complex indicators instead of AT (yellow)

CREDIBLE	
C1: Unambiguous results:	AT is an easy to understand parameter, however it is important to emphasize that people has no receptors to perceive air temperature. Thermal sensation and thermal comfort depends on air humidity, wind velocity and radiation as well. Therefore, people perceive cooler than air temperature in windy conditions, and they perceive warmer than air temperature if the sun shines or the air humidity is high.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applied in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet) and general data about materials (see Indicator sheet).
E2: Technical feasibility:	Yes, indicator generating/modelling/simulating is simple to be carried out by typical capabilities of realising institutions.
E3: Reproducibility:	Yes, it’s possible to apply the indicator in numerous cases (different locations, different NBS options/scenarios …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	• Yes, the indicator uses real data • Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	There is in general an uncertainty of the produced data included.
R3: Scale:	Yes, depending actually on the used software and resolution.

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1.2.2 | TLO

1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.2 | TLO – THERMAL LOAD

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.2 | TLO - Thermal load of out-streaming body**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DEFINITION	The TLO (Thermal load of out-streaming body) describes the difference (Delta K/C°) between the hourly average In- and Out-flow Air temperature of an area on the height of 1.8 m (standardized human) over the day (typical summer day). It enables thus a statement regarding the contribution of the area to the urban climate, especially the adjacent and surrounding areas and further concerning the cooling capability of NBS on a warm day. To assess the TLO a microclimatic simulation is required. For the urban heat balance, the optimisation regarding microclimate of every single building is of very high relevance. Research projects show, that NBS can have the effect of a natural air conditioning by cooling the air temperature within an area up to 1.5 °C.
FOCUS/OBJECTIVES	• indicate the exhausting air flow of an area • indicate the cooling capability of NBS

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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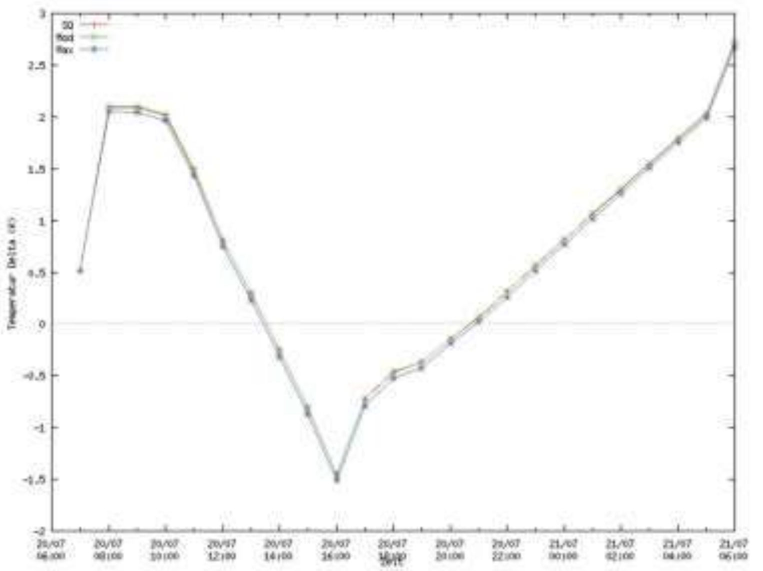
DATA AND MEASUREMENT	
REQUIRED DATA	● air temperature (T_a) ● specific humidity (q) or vapor pressure (VP) ● wind speed (v) ● wind direction
INPUT TYPE (qualitative, quantitative, …)	SIMULATION ● quantitative (Ta, VP or RH, v, G or cloud cover) ● qualitative (3d model with surface and vegetation types incl. characteristics (e.g. albedo, emissivity,..)
DATA SOURCE	● Microclimate simulation/modelling
FREQUENCY (how often to use this indicator?)	● One to several times in planning process
MEASUREMENT UNIT	● °C
REQUIRED TOOL	● GREENPASS® (ENVI-met), TEB, SOLENE-microclimat…
CALCULATION METHOD	• Measurement/Modelling and calculating of TLO, with respect to baseline values
OUTPUT TYPE	• numerical value (average hourly air temperature difference over the day) ● graphic map (diagramm)
EXAMPLES	● GREENPASS® Biotope City Vienna  Abb 6: STATUS QUO/PLANUNGS-Variante: durchschnittlicher Abluftstrom an einem Sommertag um 15 Uhr

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LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • HEAT STRESS • URBAN HEAT ISLAND • UHI • THERMAL LOAD • TLO
LINKS AND REFERENCES	• SCHARF et al., 2017: „Coole“ Städte planen - mit der GREENPASS® Methode; Zeitschrift Neue Landschaft. Patzer Verlag.) • KRAUS, F. (2017): The GREENPASS® Mehodology. Pan European Network – Government 23 publication. October 2017; • SCHARF, B.; SCHNEPF, D. (2017): H2020: Special Report: Greenpass – unleash the power of green) • ENVI-met

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.2 | TLO - Thermal load of out-streaming body**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. temperature exchange of air on human height level.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	Yes, with the methodology existing datasets can be compared with the provided data and it's possible to standardise the methodology, in order to provide fully comparable results.

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ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	TLO is a very good and potential indicator for communication purpose, because people understand it, but the data generating (simulating) and calculation requires expert knowledge because of lots of required data and a complex calculation but with GREENPASS® it will change.
A3: Other stakeholders:	Not described in a peer-reviewed paper so far, but the indicator is accepted by other stakeholders (e.g. Academia, …). GREENPASS® (SCHARF, 2018: „Coole" Städte planen - mit der GREENPASS® Methode; Zeitschrift Neue Landschaft. Patzer Verlag; KRAUS, F. (2017): The GREENPASS® Me- thodology. Pan European Network – Go- vernment 23 publication. October 2017; SCHARF, B.; SCHNEPF, D. (2017): H2020: Special Report: Greenpass – unleash the power of green)

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message.
C2: Transparency:	Yes, it has. Based on climate data, data like wind direction and speed the value is calculated.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet) and general data about the project (like 3d model see Indicator sheet). For a data update you need new calculation/simulation.
E2: Technical feasibility:	Yes, indicator generating/modelling/simulating is so far simple enough. Requires special software (as well as hardware/processing power), partially with costs. But have a clear input and methodology to avoid ambiguity and implementation errors.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Reliability:	Climate data can be sourced from meteorological statistics, research and development as well as practice projects. Model data can come out from architecture and urban planning as well as consists on assumptions.
R3: Scale:	Yes, depending actually on the used software and resolution.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.3 | AC – ADAPTIVE COMFORT

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.3 | Adaptive Comfort (indoor)**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DEFINITION	NBS can have thermal impacts on the summer buildings' thermal behaviour. One can distinguish direct and indirect impacts. Direct impacts are obtained if NBS are applied to the building (ex. green roof), indirect impacts are caused by NBS applied at the district scale when it modifies the local climate and thus comfort in buildings (ex.). These impacts are measured from the difference (building not using cooling systems) in indoor comfort. Adaptive thermal comfort approach takes into account the ways that people's perceptions of their environment change based on seasonal expectations of temperature and humidity as well as their capacity to control the conditions in a space (Nichol 2002, 2012). A calculation method is presented in NF-EN 15251 (AFNOR). Four comfort classes are defined on PPD-PMV index that takes into account clothes, activity, mean radiant temperature, air temperature, velocity and humidity. In the norm, comfort categories are expressed by: I – High level of expectation only used for spaces occupied by very sensitive and fragile persons;– II – Normal expectation, used for new building and renovations III – Moderate expectation, used for existing buildings IV – Level for the buildings that fail to be in the upper levels. It is suggested that this category should be accepted only for a short part of the year. With a relative humidity at 50% and a low air velocity, these classes are defined only from mean radiant

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temperature thresholds. These thresholds temperatures are calculated taking into account the evolution of outdoor temperature during the previous days: the outdoor moving mean temperature $\theta m,i$. It is formulated depending on its value on the previous day ($\theta m,i\text{-}1$), the mean daily value of outdoor temperature on the previous day ($\theta e,i\text{-}1$) and a coefficient α, the recommended value is equal to 0.8:

$$\theta_{m,i} = (1 - \alpha) * \theta_{e,i\text{-}1} + \alpha * (\theta_{m,i\text{-}1}) \qquad (1)$$

The limits of the comfort classes that are recommended for a residential building are expressed in the following and presented in the following figure in function of outdoor moving mean temperature:

$$\theta_{I,max} = 0.33\ \theta_m + 18{,}8 + 2 \qquad (2)$$

$$\theta_{I,min} = 0.33\ \theta_m + 18{,}8 - 2 \qquad (3)$$

$$\theta_{II,max} = 0.33\ \theta_m + 18{,}8 + 3 \qquad (4)$$

$$\theta_{II,min} = 0.33\ \theta_m + 18{,}8 - 3 \qquad (5)$$

$$\theta_{III,max} = 0.33\ \theta_m + 18{,}8 + 4 \qquad (6)$$

$$\theta_{III,min} = 0.33\ \theta_m + 18{,}8 - 4 \qquad (7)$$

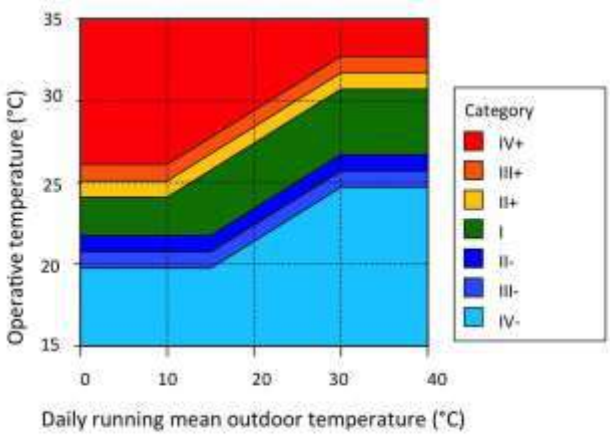

Figure23.

Calculation method for different climate and kind of buildings types in Europe are given by McCartney (2002)

FOCUS/OBJECTIVES	● minimize effect of climate on energy needs/consumption ● improve indoor comfort

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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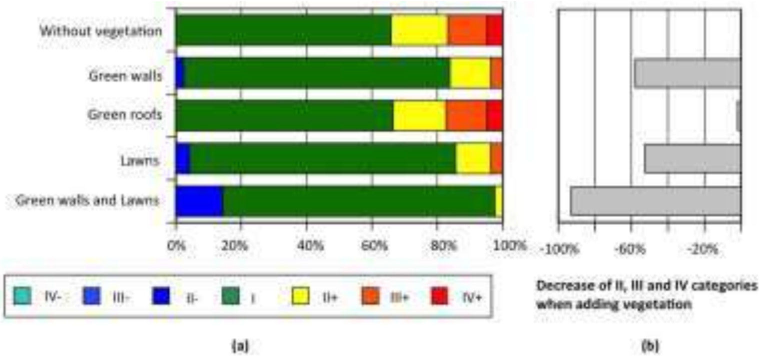
DATA AND MEASUREMENT

REQUIRED DATA	Direct impacts ● weather data ● building model (geometry +materials) ● occupancy model Indirect impacts ● weather data ● building model (geometry +materials) ● occupancy model ● district model (buildings, streets, trees, ground…)
INPUT TYPE (qualitative, quantitative, …)	● quantitative
DATA SOURCE	● Building simulation/modelling + District thermal modelling ● Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	● One to several times in a planning process.
MEASUREMENT UNIT	● time in each comfort class
REQUIRED TOOL	● Building simulation(+urban climate), like: EnergyPlus, SOLENE-microclimat, EnviBatE, Envi-met
CALCULATION METHOD	● Modelling and calculating indoor temperatures (air, surfaces), humidity and solar fluxes ● Measurement, but difficult to extract effect of NBS
OUTPUT TYPE	● numerical value (time of the day in each class)
EXAMPLES	● MALYS, L., et al. (2016): « Direct and Indirect Impacts of Vegetation on Building Comfort: A Comparative Study of Lawns, Green Walls and Green Roofs ». *Energies* 9, nº 1: 32. doi:10.3390/en9010032.



Legend: Effect of different greening strategies on the comfort at the second stage of a 4 floor non insulated building - % of time in each comfort class. + warm / - cold

I – High level of expectation only used for spaces occupied by very sensitive and fragile persons;

II – Normal expectation, used for new building and renovations

III – Moderate expectation, used for existing buildings

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	IV – Level for the buildings that fail to be in the upper levels. It is suggested that this category should be accepted only for a short part of the year.

LINKS AND REFERENCES	
KEYWORDS	• Indoor Comfort • Adaptive comfort • Buildings
LINKS AND REFERENCES	• MALYS, L., et al. (2016): « Direct and Indirect Impacts of Vegetation on Building Comfort: A Comparative Study of Lawns, Green Walls and Green Roofs ». *Energies* 9, nº 1: 32. doi:10.3390/en9010032. • MCCARTNEY et al. (2002): « Developing an adaptive control algorithm for Europe ». *Energy and Buildings* 34, nº 6: 623‑35. doi:https://doi.org/10.1016/S0378-7788(02)00013-0. • NICOL J. et al. (2012): Adaptive thermal comfort: principles and practice. London; New York: Routledge; 2012. • NICOL J., HUMPHREYS M. (2002): Adaptive thermal comfort and sustainable thermal standards for buildings. Energy Build. 2002;34(6):563‑72. • AFNOR. NF EN 15251 (2007): Critères d'ambiance intérieure pour la conception et l'évaluation de la performance énergétique des bâtiments couvrant la qualité de l'air intérieure, la thermique, l'éclairage et l'acoustique. 2007.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.3 | AC - Adaptive Comfort (indoor)

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g impact of landscape on indoor comfort.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • European projects : ○ Smart controls and thermal comfort (1997-2000 http://cordis.europa.eu/project/rcn/38904_en.html - FP4-NNE-JOULE C) ○ Thermal comfort in buildings with low-energy cooling (THERMCO, 2007-2009) • European Standard: EN15251
R3: Comparability:	Yes, it's possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Yes, it's a standard
A2: Practitioners:	Not urban planner, it's not their field.
A3: Other stakeholders:	Yes, the indicator is used in the building sector.

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message and coherences of ranges of acceptable and not acceptable temperatures
C2: Transparency:	Yes, it has. Based on climate data, and indoor surface and air temperature the value is calculated.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet) but tools are already used by all consulting firms. The real problem will be to take into account the effect of NBS that are not always included in these tools or in local climate data.
E2: Technical feasibility:	Same answer as above.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different buildings...). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	Input data for simulation model are projet and climate data
R2: Sensitiveness:	There are existing several scientific validation papers from the 20 last years
R3: Scale:	Not really and depending actually on the used software and resolution.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.4 | TCS – THERMAL COMFORT SCORE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.4 | TCS - Thermal Comfort Score**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	The TCS (Thermal Comfort Score) of an area is built on the frequency distribution of certain thermal comfort OR thermal stress categories evolving on the area at a pre-defined time (or time interval). These categories can be based on well-known thermal indices; in this case, PET (see the definition on another factsheet). Figure 1 indicates the generally adopted PET assessment scale which was developed for Western-Middle-European subjects. (It is possible to consider different thermal comfort OR stress ranges and different index evaluation scales as well.) To calculate Thermal Comfort Score of an area, PET values have to be simulated (for the appropriate human-biometeorological height of ca. 1.8 m) in a satisfying spatial resolution. Then, percentage of certain PET categories have to be calculated and weighted with an appropriate weighting factor. High weighting factors are assigned to the near-comfort PET-categories, while the extreme thermal sensation OR stress categories have to be weighted with smaller factors (Fig. 1). The overall sum of the weighted PET-category frequencies results in the Thermal Comfort Score (TCS) of the area (GREENPASS®).

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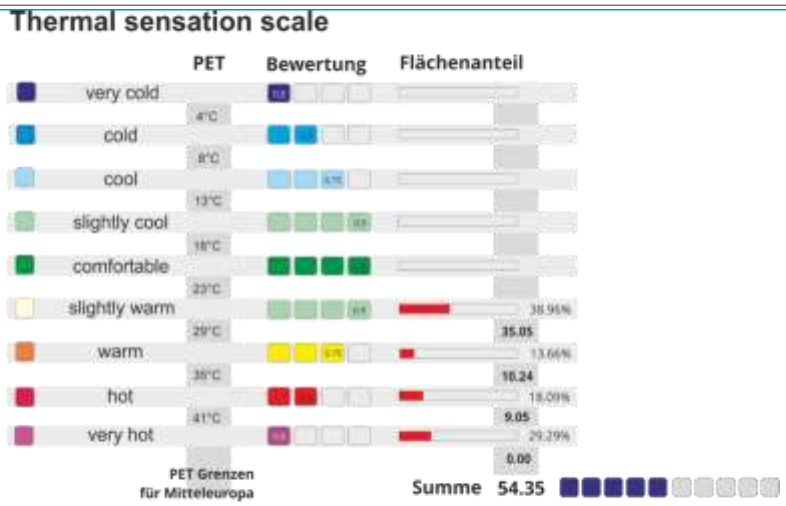

Fig 1: Thermal sensation scale (GREENPASS®)

FOCUS/OBJECTIVES	• the detailed chart on the Fig. above indicates the frequency distribution (%) of certain thermal comfort OR stress categories in the area (on a typical summer day at 3 pm)) • the final score value integrates all in one dimension-free value.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• air temperature (AT) • specific humidity (q) or vapor pressure (VP) • wind velocity (v) • Mean Radiant Temperature (MRT)
INPUT TYPE (qualitative, quantitative, …)	SIMULATION • quantitative (AT, VP or RH, v, G or cloud cover) • qualitative (3D model with surface and vegetation types incl. characteristics (e.g. albedo, emissivity,..; clothing and metabolism)
DATA SOURCE	• Microclimate simulation/modelling
FREQUENCY (how often to use this indicator?)	• One to several times in planning process
MEASUREMENT UNIT	• scoring points
REQUIRED TOOL	• GREENPASS® (ENVI-met)
CALCULATION METHOD	• Measurement/Modelling and calculating of PET Sensation Scale, (with respect to different scenarios)

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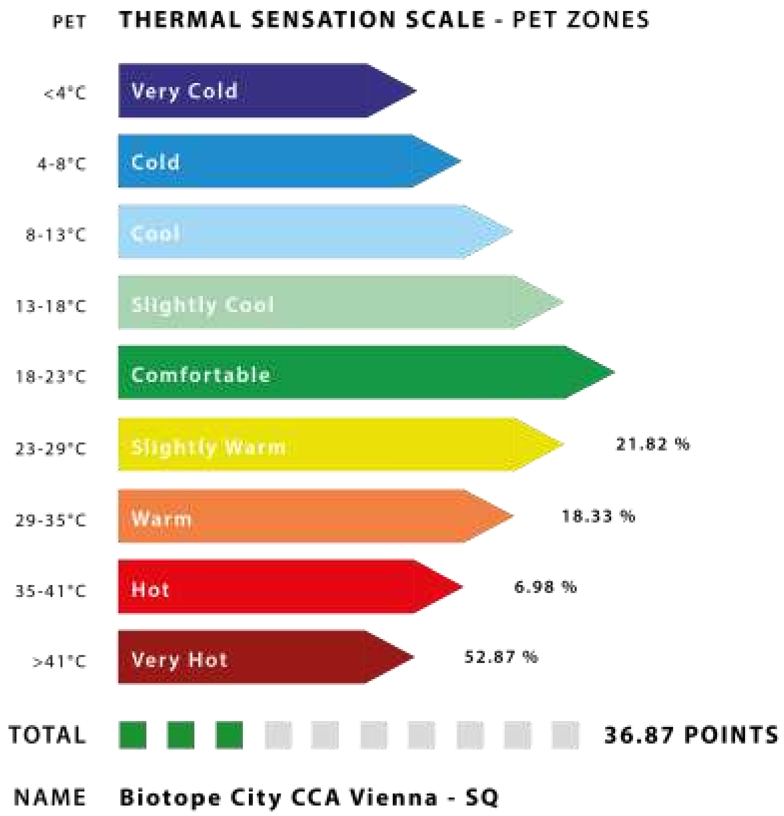
OUTPUT TYPE	● numerical value ● graphic map
EXAMPLES	● GREENPASS® Biotope City Vienna  Figure 2: PET Thermal Sensation Scale (GREENPASS®)

LINKS AND REFERENCES

KEYWORDS	● CLIMATE ● MICROCLIMATE ● HEAT STRESS ● HUMAN OUTDOOR COMFORT ● OUTDOOR THERMAL COMFORT ● PET ● PET Thermal Sensation Scale
LINKS AND REFERENCES	● GREENPASS® - www.livablecities.io ● SCHARF et al., 2017: „Coole“ Städte planen - mit der GREENPASS® Methode; Zeitschrift Neue Landschaft. Patzer Verlag.) ● KRAUS, F. (2017): The GREENPASS® Mehodology. Pan European Network – Government 23 publication. October 2017; ● SCHARF, B.; SCHNEPF, D. (2017): H2020: Special Report: Greenpass – unleash the power of green) ● MATZARAKIS, (nA): Mitigating and adapting thermal stress with urban green - Quantification with measurements and micro scale models, Albert-Ludwigs-Universität Freiburg. ● MATZARAKIS, A. et. MAYER (1996): *Another kind of environmental stress: thermal stress,* WHO Newsletter 18, 7-10.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.4 | TCS - Thermal Comfort Score

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like the effect of urban landscape and different NBS on Outdoor Thermal Comfort or heat stress, in a great extent. It is based on a complex index (PET) with thermo-physiological relevance, therefore it is more appropriate to describe human thermal comfort or heat stress than air temperature (or any other thermal factor) on its own. (Note: it is possible to develop TCS based on PT or UTCI as well) TCS combines the benefits of quantitative and qualitative facets. It is easy to compare different planning scenarios with many NBS alternatives due to the quantitative score value. On the other hand, lay persons can easily understand the result (higher scores indicate better options, while in the case of the basic index, PET, higher values not necessarily indicate better conditions).
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	TCS is built on the 2nd level indicator PET, which requires four meteorological input factors (1st level indivator MRT and simple meteorological parameters of air temperature, valopr pressure, wind speed). There are more methods to obtain the mentioned input parameters, especially the main input parameter MRT. Therefore, the resulted indicators (PET and thus TCS) values can be fully compared only in the case of the same adopted methods. Generally, a standardization of the methodology

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	would be needed in the area of outdoor thermal comfort, and it is expected in the near future.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	TCS is a promising new indicator built on PET for easy communication purpose, because people understand it. E.g. compared with PET, where values around 20°C indicate comfortable conditions and both lower and higher values indicate increasing probability of discomfort, a higher TCS score always indicate more favourable conditions. Relying on PET, data generating (measurement or simulations) requires expert knowledge. GREENPASS® is expected to increase the popularity of PET, thus TCS, in the application of urban planning.
A3: Other stakeholders:	Citizens: TCS is not well-known among citizens Researchers: TCS is not well-known among researchers because it is a brand new, but promising indicator building on PET. Thermo-physiologists and human biometeorologists apply PET several times as a measure for outdoor thermal comfort. PET (and UTCI) can be regarded the most well-known outdoor thermal indices. (It is possible to develop TCS based on UTCI values as well) (yellow)

CREDIBLE	
C1: Unambiguous results:	TCS is built on indicator PET and it conveys the more unambiguous message. In contrast to the other indicators a greater TCS means always more favourable conditions, while in the case of the other indices (PMV, PET, PT, UTCI), there is an assigned "neutral' or "comfortable" domain, and indicator values above or below this domain mean less favourable conditions.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet). But there are also some published simulation results as well as a database existing (GREENPASS® tool - which gives you a first quick assessment based on your digital model in the GREENPASS® Software). For a data update you need new model/calculation.
E2: Technical feasibility:	Indicator generating/modelling/simulating is so far not simple enough to be carried out by typical capabilities of realising institutions. It requires special equipment to measure the necessary input data OR it requires special software (as well as

	hardware/processing power), partially with costs, in order to simulate the necessary data. But GREENPASS® will simplify it and make it useable for common people soon.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, different NBS options/scenarios …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	• Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	TCS is based on PET which is sensitive regarding the input parameters, especially MRT and v (wind velocity).
R3: Scale:	Yes, depending actually on the used software and resolution, however, thermal comfort is an indicator that is related to a very local situation.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.5 | PET – PHYSIOLOGICAL EQUIVALENT TEMPERATURE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.5 | PET – Physiological equivalent temperature**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	PET (Physiological Equivalent Temperature) is an outdoor thermal index developed in the field of human biometeorology to express the combined physiological effect of the thermal environment (described by air temperature - AT, vapor pressure - VP, wind velocity - v, mean radiant temperature - MRT) using the easily interpret dimension of °C (Mayer & Höppe 1987, Höppe 1999). The basic idea behind PET (and other equivalent temperature-type indices) is that the real environment is transferred to an equivalent reference environment in which the same thermal stress, and therefore the same thermo-physiological responses of the human body can be expected (Fig. 1). More precisely, PET is defined to be equivalent to the air temperature (AT'=PET) of a standardized indoor environment that would result in the same core temperature (T_C'=T_C) and skin temperature (T_{SK}'=T_{SK}) that are observed under the real thermal conditions being assessed (Höppe 1999). For the indoor reference climate the following assumptions are made: • mean radiant temperature equals air temperature (MRT'= AT') • vapor pressure is set to a typical indoor value (VP' = 12 hPa) • wind velocity is set to a plausible indoor value (v' = 0.1 m/s) Usually, in order to facilitate general application, the personal parameters are also standardized and the reference subject is characterized by: • light clothing (e.g. light business suit with heat resistance of 0.9 clo)

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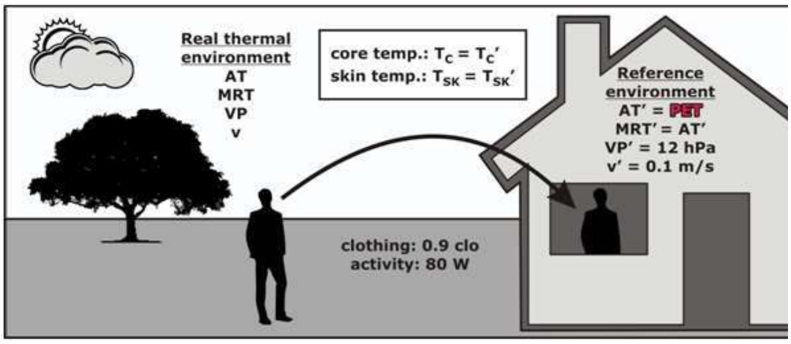
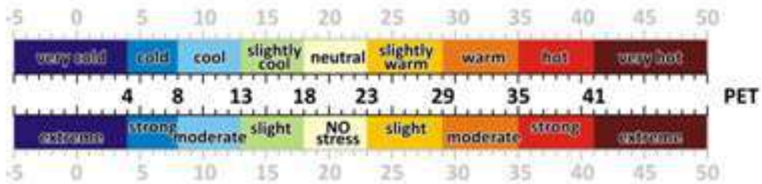
	• light activity (e.g. sedentary work with a work metabolism of 80 W) Assuming the generally adopted human-biometeorlogical reference subject (1.75 m, 75 kg, 35 year old male), the overall metabolic heat production is 164 W (the overall metabolic heat production per body surface is 86 W/m^2 = 1.5 met) However, it is possible to consider different personal parameters (age, body height, weight, gender) and adjust PET for other subjects, e.g. through the dPET-model in ENVI-met (Bruse 2000).  Figure 1: Illustration of the PET definition (edited by Kántor N according to Höppe 1999) PET values around 20°C can be characterized as neutral (Fig. 2). Higher values indicate an increasing probability of heat stress and warm thermal sensation, whereas lower values indicate cold stress and too cool conditions for comfort (Mayer & Höppe 1987).  Figure 2: PET ranges for different categories of human thermal sensation and grades of physiological stress on human beings (edited by Kántor N according to Matzarakis et al. 1999; note: the scale was derived for Central-European subjects)
FOCUS/OBJECTIVES	• indicate the level of heat stress • indicate the thermal perception of an average person among the actual thermal conditions

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• air temperature (AT) • specific humidity (q) or vapor pressure (VP) • wind velocity (v) • wind direction (if necessary, e.g. ENVI-met) • Mean Radiant Temperature (MRT)
INPUT TYPE (qualitative, quantitative, …)	MEASUREMENT • quantitative (AT, VP or RH, v, Ki-Li) SIMULATION • quantitative (AT, VP or RH, v, G or cloud cover) • qualitative (3Dmodel with surface and vegetation types incl. characteristics (e.g. albedo, emissivity,..; clothing and metabolism)
DATA SOURCE	• Microclimate simulation/modelling • Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	• One to several times in planning process
MEASUREMENT UNIT	• °C
REQUIRED TOOL	Measurement • thermometer and hygrometer (equipped with solar radiation shield) • anemometer • net radiometer(s) OR globe thermometer Simulation: Microclimate simulation software, like: • ENVI-met, • RayMan, • TEB, • SOLENE-microclimat
CALCULATION METHOD	• Measurement/Modelling and calculating of PET, with respect to baseline values
OUTPUT TYPE	• numerical value (low, mean, peak or difference scenarios) • graphic map
EXAMPLES	• HUTTNER S, et al. (2008): Using ENVI-met to simulate the impact of global warming on the microclimate in central European cities • HUTTNER S, et al. (2009): Strategies for mitigating thermal heat stress in central European cities: The project KLIMESa

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LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • HEAT STRESS • HUMAN OUTDOOR COMFORT • OUTDOOR THERMAL COMFORT • PET
LINKS AND REFERENCES	• BRUSE, M (2000): Assessing thermal comfort in urban environments using an integrated dynamic microscale biometeorological model system • HÖPPE, P (1984). Die Energiebilanz des Menschen: In: Münchener Universitätsschriften- Fachbereich Physik, Wissenschaftliche Mitteilungen Nr. 49. Meteorologisches Institut, Universität München, München. • HÖPPE, P (1999): The physiological equivalent temperature - a universal index for the biometeorological assessment of the thermal environment. Int. J. Biometeorol. 43:71-75 • HÖPPE P, MAYER H (1987): Planungsrelevante Bewertung der thermischen Komponente des Stadtklimas. Landschaft + Stadt Vol. 19, 22-30. • MATZARAKIS, A et al. (1999): Application of a universal thermal index: physiological equivalent temperature. Int J Biometeorol 43, 76–84 • MAYER, H; HÖPPE, P (1987): Thermal comfort of man in different urban environments. Theor Appl Climatol 38, 43–49 Höppe P (1999): The physiological equivalent temperature – an universal index for the biometeorological assessment of the thermal environment. Int J Biometeorol 43, 71–75 • VDI (2008): VDI-Guideline VDI 3787 Part 2, Environmental meteorology – Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning at regional level, Part I: Climate. Beuth Verlag, Berlin, 32 p

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.5 | PET – Physiological equivalent temperature

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like the effect of urban landscape and different NBS on Outdoor Thermal Comfort or heat stress, in a great extent. Being a complex index with thermo-physiological relevance, PET is more appropriate to describe human thermal comfort or heat stress than air temperature (or any other thermal factor) on its own. PET is based on a human heat budget model (MEMI) which takes into account the most important thermoregulation mechanisms. PET was developed for outdoor application.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	The methodology is described in forms of guidelines. e.g.: - VDI (2008): VDI-Guideline VDI 3787 Part 2, Environmental meteorology – Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning at regional level, Part I: Climate. Beuth Verlag, Berlin, 32 p. There are more methods to obtain the input parameters, especially the main input parameter MRT. Therefore the resulted indicator (PET) values can be fully compared only in the case of the same adopted methods. A standardization of the methodology would needed in the area of outdoor thermal comfort, and it is expected in the near future. Generally, a standardization of the methodology would needed in the area of outdoor thermal comfort, and it is expected in the near future.

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ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	PET is significant indicator for thermal comfort and because of its 'equivalant temperature-type' character urban planners (and any stakeholders) can easily understand it. However, data generating (measurement or simulation) and calculation requires time and expert knowledge. GREENPASS® is expected to increase the popularity of PET in the application of urban planning in the near future. There are already some examples, especially from Germany, when PET was adapted in the planning practice. E.g.: - Mayer H, Lee H, Oertel A, Schulzer Dieckhoff R, Schmid M, Steinerstauch B, Lampen T, Kapp R, Reuter U, Oediger H (2015): KlippS - Climate Planning Passport Stuttgart. Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg, U83-W03-N17
A3: Other stakeholders:	Citizens: PET is not well-known among citizens (red) Researchers: Thermo-physiologists and human biometeorologists apply PET several times as a measure for outdoor thermal comfort. PET (and UTCI) can be regarded the most well-known outdoor thermal indices. (green)

CREDIBLE	
C1: Unambiguous results:	Any stakeholder (urban planners, decision makers and general public) can understand the described message of PET: the temperature that our body 'perceive'. Compared to air temperature, PET has greater relevance in description of the thermal stress or thermal comfort, because it combines the effect of all relevant meteorological parameters. Because of the °C-dimension, it is easy to interpret PET and compare it with own experiences. Supplementing the numerical PET values with the assessment scale, anybody can easily understand the meaning of PET as thermal sensation or thermal stress.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applied in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data, which has to be generated (see Indicator sheet) by simulation or measured. But approximations can be obtained from an existing database (GREENPASS® tool - which gives you a first quick assessment based on your digital model in the GREENPASS® Software). For a very local assessment calculation the complete description of the scene (vegetation, water, materials…) and climate is needed.

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E2: Technical feasibility:	Indicator generating/modelling/simulating is so far not simple enough to be carried out by typical capabilities of realising institutions. It requires special equipment to measure the necessary input data OR it requires special software (as well as hardware/processing power), partially with costs, in order to simulate the necessary data.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, different NBS options/scenarios …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	• Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	The indicator is sensitive regarding the input parameters, especially MRT and v (wind velocity) which are not so easy to calculate or measure.
R3: Scale:	Yes, depending actually on the used software and resolution, however, thermal comfort is an indicator that is related to a very local situation.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.6 | UTCI – UNIVERSAL THERMAL CLIMATE INDEX

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.6 | UTCI – Universal thermal climate index**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	The UTCI (Universal Thermal Climate Index) allows assessing the thermophysiological effects of the atmospheric environment. The development of UTCI has been funded by European Union within the COST Action 730. The term “universal” must be understood in terms of appropriate for all assessments of the outdoor thermal conditions in the major fields of human biometeorology such as public weather service, public health system, precautionary planning, and climate impact research in the health sector. UTCI should become an international standard based on recent scientific progress in human response related thermo-physiological modelling. After accessible models of human thermoregulation had been evaluated, the advanced multi-node ‘Fiala’ thermoregulation model was selected, extensively validated, and extended for purposes of the project. In the next step a state-of-the-art adaptive clothing model was developed and integrated. This model considers (i) the behavioural adaptation of clothing insulation observed for the general urban population in relation to the actual environmental temperature, (ii) the distribution of the clothing over different body parts providing local insulation values for the different model segments, and (iii) the reduction of thermal and evaporative clothing resistances caused by wind and the movement of the wearer, who was assumed walking 4 km/h on the level. UTCI was then developed following the concept of an equivalent temperature. This involved the definition of a reference environment with 50% relative humidity

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(but not exceeding 20 hPa), with still air and radiant temperature equalling air temperature, to which all other climatic conditions are compared. Equal physiological conditions are based on the equivalence of the dynamic physiological response predicted by the model for the actual and the reference environment. As this dynamic response is multidimensional (body core temperature, sweat rate, skin wettedness etc at different exposure times), a single dimensional strain index was calculated by principal component analysis. The UTCI equivalent temperature for a given combination of wind, radiation, humidity and air temperature is then defined as the air temperature of the reference environment which produces the same strain index value. The associated assessment scale was derived from the simulated physiological responses and comprises ten thermal stress categories ranging from extreme cold stress to extreme heat stress.

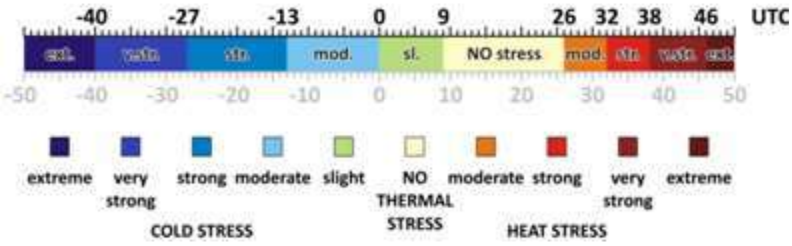

Figure 1: UTCI ranges for different grades of physiological stress on human beings (edited by Kántor N according to Bröde et al. 2012)

As calculating the UTCI equivalent temperatures by running the thermoregulation model repeatedly could be too time-consuming for climate simulations and numerical weather forecasts, several options to speed up this calculation were considered. In the first instance polynomial regression equations predicting the UTCI equivalent temperature values are available as an operational procedure which is accessible both as software source code and executable program at the project's website (www.utci.org). Comparisons to existing thermal stress/strain assessment procedures showed good conformity. However, in contrast to these procedures, UTCI is based on contemporary science. The difficulties of different meteorological data levels (observations, numerical simulations, etc.), particularly with respect to the calculation of mean radiant temperature, were also assessed. Potential applications were identified in the fields of public weather services, public health systems, urban planning, tourism & recreation and climate impact research. It is recommended to run the UTCI model for the fundamental application in Numerical Weather Predictions and climate assessments operationally in Regional Specialised Meteorological Centres or Regional Climate Centres, respectively.

FOCUS/OBJECTIVES	• indicate the level of heat stress • indicate the thermal perception of an average person among the actual thermal conditions

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data

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3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• air temperature (AT) • specific humidity (q) or vapor pressure (VP) • wind speed (v) • wind direction (if necessary, e.g. ENVI-met) • Mean Radiant Temperature (MRT)
INPUT TYPE (qualitative, quantitative, …)	MEASUREMENT • quantitative (AT, VP or RH, v, Ki-Li) SIMULATION • quantitative (AT, VP or RH, v, G or cloud cover) • qualitative (3D model with surface and vegetation types incl. characteristics (e.g. albedo, emissivity,..; clothing and metabolism)
DATA SOURCE	• Microclimate simulation/modelling • Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	• One to several times in planning process
MEASUREMENT UNIT	• °C
REQUIRED TOOL	• Microclimate simulation software, like: ENVI-met, RayMan, TEB, SOLENE-microclimat
CALCULATION METHOD	• Measurement/Modelling and calculating of UTCI, with respect to baseline values
OUTPUT TYPE	• numerical value (low, mean, peak or difference scenarios) • graphic map
EXAMPLES	• SCHRIJVERS, P.J.C., et al. (2016): The effect of using a high-albedo material on the Universal Temperature Climate Index within a street canyon. *Urban Climate* 17 (septembre 2016): 284‑303. doi:10.1016/j.uclim.2016.02.005. • KETTERER, C. et MATZARAKIS, A..(2014): Human-biometeorological assessment of the urban heat island in a city with complex topography – The case of Stuttgart, Germany. *Urban Climate* 10, Part 3 (2014): 573‑84. doi:http://dx.doi.org/10.1016/j.uclim.2014.01.003.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • HEAT STRESS • COLD STRESS • HUMAN OUTDOOR COMFORT • OUTDOOR THERMAL COMFORT • UTCI
LINKS AND REFERENCES	• BLAZEJCZYK, K. et al. (2013): An introduction to the universal thermal climate index (UTCI). • WEIHS, P., et al. (2012): The Uncertainty of UTCI Due to Uncertainties in the Determination of Radiation Fluxes Derived from Measured and Observed Meteorological Data. *International Journal of Biometeorology* 56, nº 3 (2012): 537‑55. doi:10.1007/s00484-011-0416-7. • Jendritzky G, de Dear R, Havenith G (2012): UTCI – Why another thermal index? Int J Biometeorol 56, 421-428 • Błażejczyk K, Epstein Y, Jendritzky G, Staiger H, Tinz B (2012): Comparison of UTCI to selected thermal indices. Int J Biometeorol 56, 515–535 • Bröde P, Fiala D, Błażejczyk K, Holmér I, Jendritzky G, Kampmann B, Tinz B, Havenith G (2012): Deriving the operational procedure for the Universal Thermal Climate Index (UTCI). Int J Biometeorol 56, 481–494 • Bröde P, Błazejczyk K, Fiala D, Havenith G, Holmér I, Jendritzky G, Kuklane K, Kampmann B (2013): The Universal Thermal Climate Index UTCI compared to ergonomics standards for assessing the thermal environment. Ind Health 51, 16-24 • Fiala D, Havenith G, Bröde P, Kampmann B, Jendritzky G (2012): UTCI-Fiala multi-node model of human heat transfer and temperature regulation. Int J Biometeorol 56, 429-441 • Havenith G, Fiala D, Błazejczyk K, Richards M, Bröde P, Holmér I, Rintamaki H, Benshabat Y, Jendritzky G (2012): The UTCI-clothing model. Int J Biometeorol 56, 461-470

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.6 | UTCI - Outdoor Thermal Comfort Index

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like the effect of urban landscape and different NBS on Outdoor Thermal Comfort or heat stress, in a great extent. Being a complex index with thermo-physiological relevance, UTCI is more appropriate to describe human thermal comfort or heat stress than air temperature (or any other thermal factor) on its own. UTCI is based on the most sophisticated multi-node human heat budget model (supplemented with an adaptive clothing model) which takes into account the most important thermoregulation mechanisms and several body parameters. UTCI was developed for outdoor application.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	There are more methods to obtain the input parameters, especially the main input parameter MRT. Therefore, the resulted indicator (UTCI) values can be fully compared only in the case of the same adopted methods. Generally, a standardization of the methodology would be needed in the area of outdoor thermal comfort, and it is expected in the near future.

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ACCEPTED	
A1: Policy makers:	No, not so far.
A2: Practitioners:	UTCI is significant indicator for thermal comfort and because of its 'equivalant temperature-type' character urban planners (and any stakeholders) can easily understand it. However, data generating (measurement or simulation) and calculation requires time and expert knowledge. UTCI has been used to assess Paris greening scenario. It has also been used to communicate on Nice station project.
A3: Other stakeholders:	Citizens: UTCI is not well-known among citizens (red) Researchers: Thermo-physiologists and human biometeorologists apply UTCI several times as a measure for outdoor thermal conditions (heat stress or cold stress). UTCI (and PET) can be regarded the most well-known outdoor thermal indices. (green)

CREDIBLE	
C1: Unambiguous results:	Any stakeholder (urban planners, decision makers and general public) can understand the described message of UTCI: the temperature that our body 'perceive'. Compared to air temperature, UTCI has greater relevance in description of the thermal stress, because it combines the effect of all relevant meteorological parameters. Because of the °C-dimension, it is easy to interpret UTCI and compare it with own experiences. Supplementing the numerical UTCI values with the assessment scale, anybody can easily understand the meaning of UTCI as thermal stress. (The UTCI assessment scale, ranging from extreme cold stress to extreme heat stress, has however a little shortcoming compared to the assessment scales of PET and PET; the UTCI scale doesn't contain the slight heat stress category, although it incorporates slight cold stress category, making the assessment a little bit unbalanced)
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applied in all EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet).
E2: Technical feasibility:	Indicator generating/modelling/simulating is so far not simple enough to be carried out by typical capabilities of realising institutions. It requires special equipment to measure the necessary input data OR it requires special software (as well as hardware/processing power), partially with costs, in order to simulate the necessary data.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, different NBS options/scenarios …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	• Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	The indicator is sensitive regarding the input parameters, especially MRT and v (wind velocity).
R3: Scale:	Yes, depending actually on the used software and resolution, however, thermal comfort is an indicator that is related to a very local situation.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.7 | MRT – MEAN RADIANT TEMPERATURE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.7 | MRT – Mean radiant temperature**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	MRT (Mean Radiant Temperature) is an index used in the field of human biometeorology to quantify the thermal effect of the radiation conditions – that is, all short- and long-wave radiation flux densities reaching the human body – using the easily interpret dimension of °C (Fanger 1972, VDI 1998). MRT is defined as the uniform temperature of an imaginary black-radiant enclosure in which the body would exchange the same energy via radiation as in the real non-uniform environment (ASHRAE 2001). In indoor conditions, without greater radiation asymmetry, the MRT is close to the air temperature (VDI 1998). In outdoors, however, the radiation environment around the body may be complex, and the value of MRT may be much higher than the air temperature, even up to 30 °C. In urban areas, very different radiation conditions, and therefore, very different MRT values may be developed in the vicinity of each other due to the complex surface morphology, various shading conditions and different materials (Mayer and Höppe 1987; Gulyás et al. 2006; Lee et al. 2013). Several researchers have already pointed out that daytime, in clear sky conditions, the MRT is the primary factor that governs the course of human-biometeorological indices like PET, and this is the main parameter that results in heat stress on sunny summer days (Mayer and Höppe 1987; Mayer 1993; Gulyás et al. 2006; Ali-Toudert and Mayer 2006, 2007a, 2007b; Mayer et al. 2008; Holst and Mayer 2010; Shashua-Bar et al. 2012; Lee et al. 2013). To calculate MRT accurately, one needs to determine all the radiation flux densities reaching the body and also the angular factors of the surrounding radiation surfaces (Fanger 1972). This task would require too much time and energy in such complex environments like urban areas (Höppe 1992; VDI 1998). Therefore, the

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	researchers either simulate the radiation conditions by numerical models, like ENVI-met (Bruse and Fleer 1998), RayMan (Matzarakis et al. 2007, 2010), and SOLWEIG (Lindberg et al. 2008; Lindberg and Grimmond 2011), or conduct exhaustive field-measurements. The most popular measurement methods are the accurate but very expensive six-directional technique (Höppe 1992) suggested by the VDI 3787 (VDI 1998) and the cheap but less accurate globe thermometer technique described in the ISO 7726 (ISO 1985, 1998).
FOCUS/OBJECTIVES	• indicate the radiation heat load in °C dimension

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT

REQUIRED DATA	Accurate method (measurements with net radiometers OR numerical simulations): • short-wave radiation flux densities from the surroundings (K_i) • long-wave radiation flux densities from the surroundings (L_i) Less accurate method (measurements with globe thermometer, thermometer and anemometer): • globe temperature (GT) • air temperature (AT) • wind velocity (v)
INPUT TYPE (qualitative, quantitative, …)	Accurate measurement method: • quantitative: ○ K_i, L_i measured at ca. 1.1–1.2 m agl ○ absorption coefficients of the clothed human body for the short- and long-wave radiation domain (a_k, a_l) ○ area projection factors of the body to the individual radiation flux densities (depend on the assumed body shape and position; W_i) Less accurate measurement method: • quantitative: ○ GT, AT, v measured at ca. 1.1–1.2 m agl ○ diameter of the globe (D_g) ○ emission coefficient of the globe (Ɛ (depends on its material and colour) In the case of simulations: • quantitative: meteorological parameters from the nearest weather station or assumptions (e.g. full-forcing method). ○ global radiation (G) or at least cloud cover ○ air temperature (AT) ○ air humidity (VP or RH) • qualitative: 3D model of the surroundings, surface materials
DATA SOURCE	• Microclimate simulation/modelling • Measurement/Monitoring

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	The measurement of this parameter is hardly feasible in high spatial and temporal resolution, therefore radiation simulations are of high importance in determining MRT and thus any outdoor thermal comfort indices.
FREQUENCY (how often to use this indicator?)	● One to several times in planning process
MEASUREMENT UNIT	● °C
REQUIRED TOOL	Accurate measurement technique: ● net radiometers (three set or one set on a rotatable arm) or ● at least one pyranometer-pyrgeometer pair (on a rotatable arm) Less accurate measurement technique: ● globe thermometer and ● thermometer with sun protection and ● anemometer Simulation: Microclimate simulation software, like: ● ENVI-met (Bruse & Fleer 1998, Bruse 2004), ● RayMan (Matzarakis et al. 2007, 2010), ● SOLWEIG (Lindberg et al. 2008, Lindberg & Grimmond 2011), ● SOLENE-microclimat (Musy et al. 2015)
CALCULATION METHOD	● Measurement/Modelling and calculating MRT, with respect to baseline values/comparison to different scenarios
OUTPUT TYPE	● numerical value (low, median, mean, peak or difference between scenarios) ● graphic map
EXAMPLES	● Gulyás Á, Unger J, Matzarakis A (2006): Assessment of the microclimatic and thermal comfort conditions in a complex urban environment: modelling and measurements. Build Environ 41, 1713–1722 ● Ali-Toudert F (2005): Dependence of outdoor thermal comfort on street design in hot and dry climate. Dissertation. Universität Freiburg, Freiburg, Germany, Ber Meteor Inst Univ Freiburg 15, 224p ● Ali-Toudert F, Mayer H (2006): Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. Build Environ 41, 94–108 ● Ali-Toudert F, Mayer H (2007a): Effects of asymmetry, galleries, overhanging façades and vegetation on thermal comfort in urban street canyons. Solar Energy 81, 742–754 ● Ali-Toudert F, Mayer H (2007b): Thermal comfort in an east–west oriented street canyon in Freiburg (Germany) under hot summer conditions. Theor Appl Climatol 87, 223–237 ● Mayer H, Holst J, Dostal P, Imbery F, Schindler D (2008): Human thermal comfort in summer within an urban street canyon in Central Europe. Meteorol Z 17, 241–250 ● Holst J, Mayer H (2010) Urban human-biometeorology: investigations in Freiburg (Germany) on human thermal comfort. Urban Climate News 38, 5–10 ● Lindberg F, Grimmond CSB (2011): The influence of vegetation and building morphology on shadow patterns and mean radiant temperatures in urban areas: model development and evaluation. Theor Appl Climatol 105, 311–323

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	• Huttner S (2012): Further development and application of the 3D micro-climate simulation ENVI-met. Dissertation. Johannes Gutenberg-Universität Mainz, Mainz, Germany, 137p • Shashua-Bar L, Tsiros, IX, Hoffman M (2012): Passive cooling design options to ameliorate thermal comfort in urban streets of a Mediterranean climate (Athens) under hot summer conditions. Build Environ 57, 110–119 • Lee H, Holst J, Mayer H (2013): Modification of human-biometeorologically significant radiant flux densities by shading as local method to mitigate heat stress in summer within urban street canyons. Adv Meteorol, 06/2013:1-13, Article ID 312572 • Kántor N, Kovács A, Takács Á (2016): Small-scale human-biometeorological impacts of shading by a large tree. Open Geosciences 8, 231–245 • Lindberg F, Onomura S, Grimmond CSB (2016): Influence of ground surface characteristics on the mean radiant temperature in urban areas. International Journal of Biometeorology, 60, 9, 1439–1452

LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • RADIATION • HEAT STRESS • HUMAN OUTDOOR COMFORT • OUTDOOR THERMAL COMFORT • MRT
LINKS AND REFERENCES	• Fanger PO (1972): Thermal Comfort. McGraw Hill Book Co, New York, USA, 244 p • ISO (1985) ISO Standard 7726. Thermal environments – Instruments and methods for measuring physical quantities. • ISO (1998) ISO Standard 7726. Ergonomics of the thermal environments – Instruments for measuring physical quantities. • Mayer H, Höppe P (1987): Thermal comfort of man in different urban environments. Theor Appl Climatol 38, 43–49 • Höppe P (1992): Ein neues Verfahren zur Bestimmung der mittleren Strahlungstemperatur in Freien. Wetter und Leben 44, 147–151 • Mayer H (1993): Urban bioclimatology. Experientia 49, 957–963 • VDI (1998): Methods for the human-biometeorological assessment of climate and air hygiene for urban and regional planning. Part I: Climate. VDI 3787, Part 2. Beuth, Berlin, 29 p • VDI (2008): VDI-Guideline VDI 3787 Part 2, Environmental meteorology – Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning at regional level, Part I: Climate. Beuth Verlag, Berlin, 32 p • ASHRAE (2001): Chapter 14 – Measurements and instruments. In: ASHRAE Fundamentals Handbook. American Society for heating Refrigerating and Air Conditioning, Atlanta: 14.28 –14.29

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.7 | MRT – Mean radiant temperature

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like the effect of urban landscape and different NBS on Outdoor Thermal Comfort or heat stress, in a major, but not full extent. MRT is only one from the four thermal factors (air temperature, air humidity, wind velocity, mean radiant temperature) which influence the human heat budget, thus thermal sensation and perceived thermal comfort. However, in summertime, MRT is regarded to be the most important from the mentioned four factors from the viewpoint of outdoor thermal comfort and heat stress.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	There are several methods to obtain MRT outdoors, which are described partly in the German VDI Guideline (for urban and regional planning) and partly in standards dedicated for indoor climates (ISO standards). - VDI (2008): VDI-Guideline VDI 3787 Part 2, Environmental meteorology – Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning at regional level, Part I: Climate. Beuth Verlag, Berlin, 32 p. MRT can be obtained through different measurement techniques and different model simulation techniques (different equations and assumptions when modelling radiation components and calculating MRT). The outdoor MRT-technique is not standardized, therefore the fully comparability of

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	the existing datasets cannot be guaranteed. Generally, a standardization of the methodology would be needed in the area of outdoor thermal comfort, and it is expected in the near future.

ACCEPTED	
A1: Policy makers:	No, not so far.
A2: Practitioners:	MRT is a sifnificant indicator regarding outdoor thermal comfort, and it is usually the main source of heat stress in summer. Moreover, from the four main meteorlological factors which influence outdoor thermal comfort, MRT is easy to alter via urban planning and landscape design measures (e.g. tree planting). However, data generating (measurement or simulation) and calculation requires time and expert knowledge. There are already some examples, especially from Germany, when MRT was adapted in the planning practice. E.g.: - Mayer H, Lee H, Oertel A, Schulzer Dieckhoff R, Schmid M, Steinerstauch B, Lampen T, Kapp R, Reuter U, Oediger H (2015): KlippS - Climate Planning Passport Stuttgart. Landesanstalt für Umwelt, Messungen und Naturschutz Baden-Württemberg, U83-W03-N17
A3: Other stakeholders:	Citizens: MRT is not well-known among citizens (red) Researchers: Thermo-physiologists and human biometeorologists agree that in summer MRT is the most important factor regarding outdoor thermal comfort. There are several research papers published in the last decades about MRT and its modification by small-scale planning interventions in urban public areas (shading structures, surface materials or colours). (green)

CREDIBLE	
C1: Unambiguous results:	Yes, convey a clear message, but it's harder to understand as PET or UTCI, because of the complexity.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet).
E2: Technical feasibility:	Indicator generating/modelling/simulating is so far not simple enough to be carried out by typical capabilities of realising institutions. It requires special equipment to measure the necessary input data OR it requires special software (as well as hardware/processing power), partially with costs, in order to simulate the necessary data.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, different NBS options/scenarios …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

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ROBUST	
R1: Data quality:	Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	MRT is sensitive to the utilized measurement or simulation technique. Although there are several research papers which compare different MRT-techniques, the issue needs more research focus and much more validation studies among different environmental circumstances
R3: Scale:	Yes, depending actually on the used software and resolution, however, thermal comfort is an indicator that is related to a very local situation.

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1.2.8 | PT

1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.8 | PT – PERCEIVED TEMPERATURE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.8 | PT – Perceived temperature**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	PT (Perceived Temperature) is an outdoor thermal index developed in the field of human biometeorology to express the combined effect of the thermal environment (described by AT, VP, v, MRT) using the easily interpret dimension of °C (Jendritzky et al. 2000, Staiger et al. 2012). The basic idea behind PT (and other equivalent temperature-type indices) is that the real environment is transferred to an equivalent reference environment in which the same thermal stress, and therefore the same thermal perception can be expected (Fig. 1). More precisely, PT is defined to be equivalent to the air temperature (AT'=PT) of a standardized outdoor environment that would result in the same thermal perception (same Predicted Mean Vote, PMV'=PMV) as the actual thermal conditions being assessed. Perceived cold or heat (that is, PMV) is computed by means of the Klima-Michel-Model (Jendritzky et al. 1979), which is a complete heat budget model of the human body based on the comfort equation by Fanger (1972) and adjusted to outdoor application (Jendritzky et al. 2000, Staiger et al. 2012). For the outdoor reference climate the following assumptions are made: · mean radiant temperature equals air temperature (MRT'= AT') which means that the subject is in shade · vapor pressure equals the actual value (VP' = VP) as far as it is not reduced by condensation · wind velocity is reduced to light air. The most important personal parameters of the reference subject are defined corresponding to the outdoor reference environment: · adjustable clothing to maintain thermal comfort as long as possible: heat resistance of clothing can be changed between 0.5 clo (summertime garment) and 1.75 clo (wintertime garment)

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· walking on a flat ground with 4 km/h (1.1 m/s) with a work metabolism of 172.5 W.

· Assuming the generally adopted human-biometeorlogical reference subject, 'Klima-Michel' (1.75 m, 75 kg, 35 year old male), the overall metabolic heat production is 256.5 W (the overall metabolic heat production per body surface is 135 W/m^2 = 2.3 met)

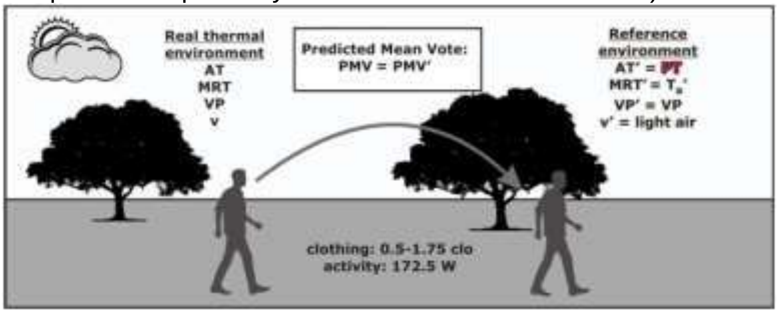

Figure 1: Illustration of the PT definition (edited by Kántor N according to Jendritzky et al. 2000 and Staiger et al. 2012)

The heat health warning system of the German Meteorological Service (Deutscher Wetterdienst, DWD) is built on the assessment scale of the PT index where 32°C is the lower threshold of strong heat stress, and 38°C is the benchmark of extreme heat stress (Fig. 2).

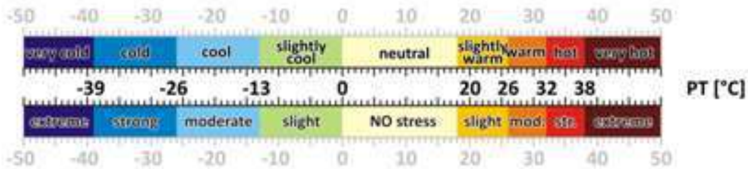

Figure 2: PT ranges for different categories of human thermal perception and grades of physiological stress on human beings (edited by Kántor N according to Staiger et al. 2012; note: the scale was derived for 'typical' Central-European subjects)

Since elder persons are more sensitive against heat events because their thermoregulation is less effective, DWD introduced in 2017 'Klima Michel Senior' (1.75 m, 70 kg, 75 year old male walking 1 km/h) as new reference subject for heat health warning system. Corresponding to the modified thermoregulation and metabolic rate, the threshold of extreme heat stress for the elder population is lower: 36°C (DWD).

FOCUS/ OBJECTIVES

- indicate the level of heat stress
- indicate the thermal perception of an average person among the actual thermal conditions

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT

REQUIRED DATA

- air temperature (AT)
- specific humidity (q) or vapor pressure (VP)

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	• wind velocity (v) • Mean Radiant Temperature (MRT)
INPUT TYPE (qualitative, quantitative, …)	MEASUREMENT • quantitative (AT, VP or RH, v, Ki-Li) SIMULATION • quantitative (AT, VP or RH, v, G or cloud cover) • qualitative (3Dmodel with surface and vegetation types incl. characteristics (e.g. albedo, emissivity,..; clothing and metabolism)
DATA SOURCE	• Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	• One to several times in planning process
MEASUREMENT UNIT	• °C
REQUIRED TOOL	Measurement • thermometer and hygrometer (equipped with solar radiation shield) • anemometer • net radiometer(s) OR globe thermometer Simulation: • Microclimate simulation software RayMan Pro
CALCULATION METHOD	• Measurement/Modelling and calculating of PT, with respect to baseline values/comparison to different scenarios
OUTPUT TYPE	• numerical value (low, mean, peak or difference scenarios) • graphic map
EXAMPLES	DWD – Deutscher Wetterdienst: • http://www.dwd.de/DE/leistungen/gefahrenindizesthermisch/gefuehltetemp.html • https://www.youtube.com/watch?v=chjj5v_hNI8 • https://www.youtube.com/watch?v=ObxMGMKSRs0

LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • HEAT STRESS • HEAT HEALTH WARNING SYSTEM • HUMAN OUTDOOR COMFORT • OUTDOOR THERMAL COMFORT • PT
LINKS AND REFERENCES	• Jendritzky G, Sönning W, Swantes HJ (1979): Ein objektives Bewertungsverfahren zur Beschreibung des thermischen Milieus in der Stadt- und Landschaftsplanung ("Klima-Michel-Modell"). Beiträge d. Akad. f. Raumforschung und Landesplanung Bd. 28, Hannover. • Jendritzky G, Staiger H, Bucher K, Graetz A, Laschewski G (2000): The Perceived Temperature – The Method of the Deutscher Wetterdienst for the Assessment of Cold Stress and Heat Load for the Human Body. Internet Workshop on Windchill, hosted by Environment Canada, April 3–7, 2000 • http://www.utci.org/isb/documents/perceived_temperature.pdf • Staiger H, Laschewski G, Grätz A (2012): The perceived temperature – a versatile index for the assessment of the human thermal environment. Part A: scientific basics. Int J Biometeorol 56, 165–176 • DWD – Deutscher Wetterdienst:

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	○ http://www.dwd.de/DE/leistungen/gefahrenindizesthermisch/gefuehltetemp.html ○ https://www.youtube.com/watch?v=chjj5v_hNI8 ○ https://www.youtube.com/watch?v=ObxMGMKSRs0

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.8 | PT – Perceived temperature

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems,like the effect of urban landscape and different NBS on Outdoor Thermal Comfort or heat stress, in a great extent. Being a complex index with thermo-physiological relevance, PT is more appropriate to describe human thermal comfort or heat stress than air temperature (or any other thermal factor) on its own. PT is based on the so-called KlimaMichel-Model (KMM) (which is a further developed version of Fanger's comfort equation and it is supplemented with an outdoor radiation model). PT was developed for outdoor application.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	The methodology is described in forms of guidelines. e.g.: - VDI (2008): VDI-Guideline VDI 3787 Part 2, Environmental meteorology – Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning at regional level, Part I: Climate. Beuth Verlag, Berlin, 32 p. There are more methods to obtain the input parameters, especially the main input parameter MRT. Therefore, the

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	resulted indicator (PT) values can be fully compared only in the case of the same adopted methods. Generally, a standardization of the methodology would be needed in the area of outdoor thermal comfort, and it is expected in the near future.

ACCEPTED	
A1: Policy makers:	No, not so far.
A2: Practitioners:	PT is significant indicator for thermal comfort and because of its 'equivalant temperature-type' character urban planners (and any stakeholders) can easily understand it. However, data generating (measurement or simulation) and calculation requires time and expert knowledge.
A3: Other stakeholders:	Citizens: PT is generally not well-known among citizens. However, in Germany, PT is used by the German Meteorological Service as a basis for the Heat Health Warning system (yellow) Researchers: Only few research papers were published in the last decades that utilized PT as measure of outdoor thermal comfort (PET and UTCI are more popular) (yellow)

CREDIBLE	
C1: Unambiguous results:	Any stakeholder (urban planners, decision makers and general public) can understand the described message of PT: the temperature that our body 'perceive'. Compared to air temperature, PT has greater relevance in description of the thermal stress or thermal comfort, because it combines the effect of all relevant meteorological parameters. Because of the °C-dimension, it is easy to interpret PT and compare it with own experiences. Supplementing the numerical PT values with the assessment scale, anybody can easily understand the meaning of PT as thermal sensation or thermal stress.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet).
E2: Technical feasibility:	Indicator generating/modelling/simulating is so far not simple enough to be carried out by typical capabilities of realising institutions. It requires special equipment to measure the necessary input data OR it requires special software (as well as hardware/processing power), partially with costs, in order to simulate the necessary data.
R3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, different NBS options/scenarios …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

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ROBUST	
R1: Data quality:	Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	The indicator is sensitive regarding the input parameters, especially MRT and v (wind velocity).
R3: Scale:	Yes, depending actually on the used software and resolution.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.9 | PMV – PREDICTED MEAN VOTE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.9 | PMV – Predicted mean vote**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DEFINITION	**PMV (Predicted Mean Vote)** is probably the most well-known thermal comfort index which was developed by P. Ole Fanger (1972) and later adopted as an ISO and ASHRAE standard to describe indoor thermal comfort. **Thermal comfort** is a subjective perception which can be defined as that condition of mind which expresses satisfaction with the surrounding thermal environment (ASHRAE 2004). Because thermal comfort influences human health, well-being, and working efficiency it would be essential to evaluate thermal conditions every time when designing spaces that will be occupied by people (especially indoor spaces, but semi-outdoor and outdoor environments as well). Thermal comfort depends on six main physical factors – four environmental and two personal factors. The environmental factors comprise the meteorological parameters of air temperature, air humidity, mean radiant temperature, and air velocity; while the personal factors include metabolic rate (heat produced by human body), and clothing (thermal insulation of the garment). Even if these six factors are the same, thermal comfort is highly subjective and it is difficult to measure because each person experiences the thermal environment differently due to physiological and psychological differences. The **PMV** index predicts the mean thermal perception vote of a larger group of people according the 7-point thermal sensation scale (Fig. 1).  Figure 1: PMV values corresponding to the 7-point ASHRAE scale

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	PMV can be obtained from Fanger's 'comfort-equation' developed using climate chamber experiments when thousands of subjects were exposed to different thermal conditions and they were asked to indicate their thermal sensation votes on the above mentioned scale. The PMV can be calculated by as: PMV = $(0.303\ e^{-0.036M} + 0.028)\ L$ where · PMV = Predicted Mean Vote · M = metabolic rate · L = thermal load L is defined as the difference between the internal heat production of the body and the heat loss to the actual environment – for a person at comfort skin temperature and evaporative heat loss by sweating at the actual activity level. Because it was derived from climate chamber experiments and assumes steady state energy balance, the PMV comfort-equation only applies to humans exposed for a long period to constant climatic conditions at a constant metabolic rate and clothing. PMV was used several times to assess outdoor thermal conditions as well e.g. to characterize the bioclimates at different locations within a city (Mayer and Höppe 1987). However, its scientific basics, i.e. Fanger's comfort-equation refers to conditions close to thermal comfort and assumes the mean skin temperature and the sweat rate to always have the comfort values. This is hardly reached in outdoors where thermal conditions may be extreme stressful and they change rapidly over time and space as well. Therefore PMV cannot be used to model actual physiological parameters and heat fluxes of the human body far away from thermal comfort conditions. Indices developed for outdoor application are e.g. PET and UTCI.
FOCUS/OBJECTIVES	● indicate the general thermal perception among the actual thermal conditions using the ASHRAE-scale

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	● air temperature (AT) ● specific humidity (q) or vapor pressure (VP) ● wind velocity (v) ● Mean Radiant Temperature (MRT) ● metabolic rate (M) ● thermal insulation value of clothing (I_{cl})
INPUT TYPE (qualitative, quantitative, …)	● quantitative: ○ AT, ○ VP or RH, ○ v,

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	○ GT (globe temperature) or Ki-Li (short- and long-wave radiation flux densities) in order to calculate MRT • qualitative: • basic personal parameters (age, height, weight, gender) and activity level (may be observed or assumed) in order to assess M • garment worn (may be observed or assumed) in order to assess I_{cl}
DATA SOURCE	• Measurement/Monitoring (indoor thermal comfort and outdoor thermal comfort as well) • Microclimate simulation/modelling (outdoor thermal comfort)
FREQUENCY (how often to use this indicator?)	• One to several times in planning process
MEASUREMENT UNIT	• [-]
REQUIRED TOOL	Measurement • thermometer and hygrometer (equipped with solar radiation shield) • anemometer • net radiometer(s) OR globe thermometer Simulation: Microclimate simulation software, like: • ENVI-met, • RayMan
CALCULATION METHOD	• Measurement/Modelling and calculation of PMV, with respect to baseline values/comparison to different scenarios
OUTPUT TYPE	• numerical value (low, mean, peak or difference scenarios) • graphic map
EXAMPLES	• ...

LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • HUMAN COMFORT • INDOOR THERMAL COMFORT • OUTDOOR THERMAL COMFORT • THERMAL SENSATION • THERMAL PERCEPTION • PMV
LINKS AND REFERENCES	• Fanger PO (1972): Thermal Comfort. McGraw Hill Book Co, New York, USA, 244 p • ASHRAE (2004): ANSI/ASHRAE Standard 55-2004. Thermal Environmental Conditions for Human Occupancy. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.9 | PMV – Predicted mean vote

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like the effect of urban landscape and different NBS on Human Thermal Comfort, in a great extent. PMV is a complex index which combines the effect all necessary thermal factors (air temperature, air humidity, wind velocity, mean radiant temperature) and therefore it is more appropriate to describe human thermal comfort than air temperature (or any other thermal factor) on its own. However, it was developed for indoors and therefore it is more appropriate for indoor application than for outdoor usage.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	Indoor thermal comfort: The methodology is standardized.e.g.: - ASHRAE (2004): ANSI/ASHRAE Standard 55-2004. Thermal Environmental Conditions for Human Occupancy. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. Outdoor thermal comfort: The methodology is described in forms of guidelines. e.g.:

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	- VDI (2008): VDI-Guideline VDI 3787 Part 2, Environmental meteorology – Methods for the human biometeorological evaluation of climate and air quality for urban and regional planning at regional level, Part I: Climate. Beuth Verlag, Berlin, 32 p There are more methods to obtain the input parameters, especially the main input parameter MRT. Therefore the resulted indicator (PMV) values can be fully compared only in the case of the same adopted methods. A standardization of the methodology would needed in the area of outdoor thermal comfort, and it is expected in the near future. Generally, a standardization of the methodology would needed in the area of outdoor thermal comfort, and it is expected in the near future.

ACCEPTED	
A1: Policy makers:	No, not for open space so far, but in building regulations.
A2: Practitioners:	Indoor thermal comfort: Maintaining indoor thermal comfort in buildings or other enclosures is one of the most important goals of HVAC (heating, ventilating and air conditioning) design engineers. PMV is probably the most well-known thermal comfort index which is adopted as an ISO and ASHRAE standard to describe indoor thermal comfort. Outdoor thermal comfort: PMV is suggested as an assessment index for outdoor thermal comfort (VDI 2008), however, data generating (measurement or simulation) requires time and expert knowledge. Because of its dimension-less character, it may be harder to understand its message than in the case of the other thermo-physiological assessment indices with °C-dimension (equivalent temperature-type indices: PET, PT, UTCI).
A3: Other stakeholders:	Citizens: PMV is not well-known among citizens (red) Researchers: Thermo-physiologists and human biometeorologists used to apply PMV several times as a measure for indoor and outdoor thermal comfort. However, recent research papers propose other complex indices instead of PMV (equivalent temperature-type assessment indices like PET and UTCI become more popular for outdoor usage) (yellow)

CREDIBLE	
C1: Unambiguous results:	PMV is directly associated with a thermal sensation scale (from very cold to very warm), and therefore people can understand it.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet).
E2: Technical feasibility:	Indicator generating/modelling/simulating is so far not simple enough to be carried out by typical capabilities of realising institutions. It requires special equipment to measure the necessary input data OR it requires special software (as well as hardware/processing power), partially with costs, in order to simulate the necessary data.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, different NBS options/scenarios …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	The indicator is sensitive regarding the input parameters, especially MRT and v (wind velocity).
R3: Scale:	Yes, depending actually on the used software and resolution.

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1 | CLIMATE ISSUES

1.2 | CLIMATE ADAPTION

1.2.10 | β – BOWEN RATIO

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	**1.2.10 | β– Bowen ratio**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DEFINITION	The Bowen ratio is the ratio between the part of the energy exchanged between the surfaces that warm (or cool) the surrounding air (sensible heat), and the one that is dissipated by evapotranspiration (latent heat). Positive values indicate heat transfer to the air, and negative values from the air to the surface. The higher the absolute value is, the more the heat transfer involves temperature change. The ratio is calculated by correlating fluctuations of vertical wind speed with fluctuations of temperature and vapour concentration at different heights. Due to turbulence, these values must be recorded at high frequency during a long time in order to perform a statistical treatment. Also, the convective and latent fluxes can be estimated by lysimeters, water balance, gas exchange with small and large chambers, micro-meteorological data, and remote sensing
FOCUS/OBJECTIVES	• minimize UHI-effect and hotspot mitigation (temperature reduction) • high thermal comfort • evaluation of green spaces efficiency

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data

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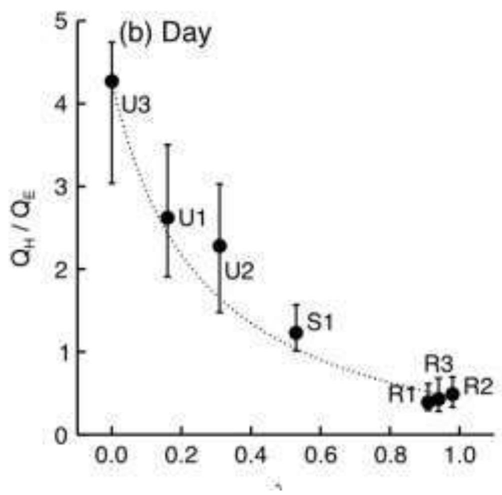
4	Medium calculation difficulty but requires lots of data OR High calculation and requires few data
5	High calculation difficulty and requires lots of data

DATA AND MEASUREMENT	
REQUIRED DATA	• air temperature (T_a) • specific humidity (q) or vapor pressure (VP)
INPUT TYPE (qualitative, quantitative, …)	• MEASUREMENT • quantitative (Ta, VP or RH)
DATA SOURCE	• measurement/Monitoring • empirical relationship
FREQUENCY	• Continuous measurement during several days to assess a situation • One to several times in the planning process
MEASUREMENT UNIT	• without unit [0 to 1]
REQUIRED TOOL	• Sonic 3-D anemometers • Hygrometer / temperature sensors
CALCULATION METHOD	2 Eddy covariance / statistical treatment $\beta = \frac{H}{\lambda E} = \frac{C_p \times \underline{w'T'_s}}{q_{v_{H_2O}} \times \underline{w'q'}} = \gamma \frac{\Delta T_a}{\Delta e}$ with: H is convective flux [W m^{-2}]. λE is the latent heat of evaporation [W m^{-2}]. C_p is the heat capacity [J kg^{-1} K^{-1}], q' is the vapor density [g m^{-3}], T'_s is the air temperature [°C], w' is the vertical component of wind speed [mm day^{-1}], q_{vH2O} is the saturated vapor density [g m^{-3}]. γ is the psychrometric constant [Pa.K^{-1}] and e is the vapor partial pressure [Pa]. • modelling tool (ENVI-met, SURFEX (Town Energy Balance), SOLENE)
OUTPUT TYPE	• numerical value • graphic map  Fig 1: CHRISTEN et al. (2004)

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EXAMPLES	• Christen, A., Vogt, R., 2004. Energy and radiation balance of a central European city. International Journal of Climatology 24, 1395–1421. doi:10.1002/joc.1074 • Coutts, A.M., Daly, E., Beringer, J., Tapper, N.J., 2013. Assessing practical measures to reduce urban heat: Green and cool roofs. Building and Environment 70, 266–276. doi:10.1016/j.buildenv.2013.08.021 • Goldbach, A., Kuttler, W., 2013. Quantification of turbulent heat fluxes for adaptation strategies within urban planning. International Journal of Climatology 33, 143–159. doi:10.1002/joc.3437 • Kotthaus, S., Grimmond, C.S.B., 2014. Energy exchange in a dense urban environment – Part I: Temporal variability of long-term observations in central London. Urban Climate 10, 261–280. doi:10.1016/j.uclim.2013.10.002

LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • UHI • URBAN HEAT ISLAND • EVAPOTRANSPIRATION • GREEN SPACES • BOWEN RATIO
LINKS AND REFERENCES	• Bowen, I.S., 1926: The ratio of heat losses by conduction and by evaporation from any water surface. Physics Review, 27, pp 779—787. • Goldbach, A., Kuttler, W., 2013. Quantification of turbulent heat fluxes for adaptation strategies within urban planning. International Journal of Climatology 33, 143–159. doi:10.1002/joc.3437 • Christen, A., Vogt, R., 2004. Energy and radiation balance of a central European city. International Journal of Climatology 24, 1395–1421. doi:10.1002/joc.1074 • Payero, J.O., Neale, C.M.U., Wright, J.L., Allen, R.G., 2003. Guideline for validating bowen ratio data. Transactions of the ASAE 46. doi:10.13031/2013.13967

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	1 | Climate Issues	1.2 | Climate adaption

INDICATOR	
NAME	1.2.10 | BRA – Bowen ratio

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. thermal exchange and thus UHI-Effect.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	Yes, it's possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, the indicator hasn't been applied in the development and assessment of policies.
A2: Practitioners:	No. The Bowen ratio isn´t easy for communication purpose, because it is to complex and the data generating (simulating) and calculation requires expert knowledge so far.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results:	No, it's hard to understand the complexity of the indicator for political decision makers as well as the general public.
C2: Transparency:	Yes, it has. Based on air temperature, specific humidity and vapor pressure the value is calculated.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	The indicator needs data that has already been collected but the indicator can be updated with just including new data in the calculation.
E2: Technical feasibility:	No, indicator generating/modelling/simulating is so far not simple enough to be carried out by typical capabilities of realising institutions. It requires special software (as well as hardware/processing power), partially with costs. But has a clear input and methodology to avoid ambiguity and implementation errors.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	Input data for simulation model are real data. Climate data input can be based on real data.
R2: Sensitiveness:	There are existing several scientific validation papers from the last years as well as comparisons of different models and state-of-the art software's.
R3: Scale:	Yes, depending actually on the used software and resolution.

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UC 2 | WATER MANAGEMENT AND QUALITY

2.1.1 | EPTvar

2 | WATER MANAGEMENT AND QUALITY

Short description of UC: Urban areas are characterized by impervious surfaces that strongly modify the water cycle, compared to natural surfaces (Fletcher et al, 2013): decreased groundwater, increased surface runoff, higher stormwater pollution fluxes and lower evapotranspiration. If urban water management was mainly first focused on conveyance of water away from cities (Burian & Edwards, 2002), in the last decades it adopted an approach driven by multiple objectives (Fratini et al, 2012). If flood protection and public health stay crucial objectives, more recently environment protection and urban sustainability are also taken into account.

2.1 | URBAN WATER MANAGEMENT AND QUALITY

Short description of USC: Since the last decades, urban water management has been more engaged in environment protection and urban sustainability. European legislation with the EU water framework Directive adopted in 2000 participated to the awareness of stakeholders. Water pollution and water resources are now at the heart of topics of urban water management. Imperviousness of urban surfaces and human activities lead to decreased groundwater recharge impacting water resource, increased surface runoff leading to more frequent and more intense floods, higher stormwater pollution fluxes potentially impacting groundwater quality or urban river quality, lower evapotranspiration favouring the urban heat island phenomenon.

2.1.1 | EPTvar – EVAPOTRANSPIRATION VARIATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	**2.1.1 | EPTvar – Evapotranspiration variation**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The evapotranspiration variation is the difference of the total amount of evapotranspiration cumulated during a prescribed period (a year, a season, a month, a day etc.) between two situations using or not NBS, in a same context (with a same meteorological forcing and a same soil texture). It helps to understand how NBS can change the water balance. And it can allow to anticipate potential effects on thermal comfort as higher latent heat fluxes contribute to lower air temperature. This indicator can then be used in both subchallenges “sustainable urban water management” and “potential thermal control”.
FOCUS/OBJECTIVES	• To better understand the effect of NBS on water balance • To evaluate the potential impact of NBS on outside thermal comfort

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Observed data of evapotranspiration (rarely available, only possible at object scale) measured with a scintillometer, a lysimeter or an eddy covariance technique • Calculated from observed radiation data, air humidity temperature, etc. (depending on the formula)
INPUT TYPE (qualitative, quantitative, …)	• quantitative : net radiation, air-air vapor pressure deficit, leaf area index...
DATA SOURCE	• measurement/monitoring • modelling
FREQUENCY (how often to use this indicator?)	• Year scale • season scale • heat wave event scale (few days)
MEASUREMENT UNIT	• mm (= 1L of water/m2)
REQUIRED TOOL	• hydrological model
CALCULATION METHOD	• Penman-Monteith model with cultural coefficients (Penman, 1948)
OUTPUT TYPE	• numerical value (min, max, mean, standard deviation)
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Evapotranspiration • Latent heat flux • Cover resistance
LINKS AND REFERENCES	• Penman, H.L., 1948. Natural Evaporation from Open Water, Bare Soil and Grass. Proc. R. Soc. Lond. Math. Phys. Eng. Sci. 193, 120–145. doi:10.1098/rspa.1948.0037 • Stanghellini, C., 1987. Transpiration of greenhouse crops; an aid to climate management, University of Wageningen

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	2.1.1 | EPTvar – Evapotranspiration variation

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	• No
R3: Comparability:	Yes, the methodology is able to provide data comparable to datasets. Yes, it is possible to standardise the methodology, to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	Probably not, as observed data are not so common. And these data can be difficult to calculate, in order to evaluate NBS impact.
A3: Other stakeholders:	Probably not.

CREDIBLE	
C1: Unambiguous results:	No. This indicator only indicate a potential indirect effect of potential NBS impact on local conditions. Both decision makers and citizen are probably not used to hear about this indicator.
C2: Transparency:	It has to be defined, when used, as there are many methods to calculate data used for this indicator.
C3: Documentation of assumptions and limitations:	Yes, data needed for the calculation of this indicator are fully disclosed, as the methods available for the calculation of data are plentiful. Once well identified, the method will be widely known by experts.

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EASY	
E1: Availability of data to calculate the indicator:	Data required for the calculation of the indicator have to be calculated from data provided by national meteorological services. And cultural coefficients have to be known for specific vegetation. It then has to be generated. Update is not so easy.
E2: Technical feasibility:	Once meteorological data available, calculation can be done by standard software.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	The scale on which the indicator can be applied will depend on the heterogeneity of land use. It is better to use it on a quite homogeneous surface.

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2 | WATER MANAGEMENT AND QUALITY

2.1 | URBAN WATER MANAGEMENT AND QUALITY

2.1.2 | SWS – SOIL WATER STORAGE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	**2.1.2 | SWS – Soil water storage**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood/catchment ☒ Object
DEFINITION	The soil water storage is an indicator allowing to assess water resource. By comparing this indicator calculated by using or not NBS it will highlight water needs for NBS especially the green ones. This indicator is the difference of the cumulative soil water content over the root development depth between the the beginning and the end of a studied period. This period is usually the hydrological year. According to the studied site, the soil water storage will be calculated from the soil water volume and from the water table variation if present.
FOCUS/OBJECTIVES	• assess one NBS type benefit (for UHI mitigation for example) against its water need and water availability. • assess mixed NBS at large scales to allow enough water availability for irrigation of green solutions, for example.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• soil water content detailed enough (horizontally and vertically) according to the studied scale at 2 dates (typically beginning and end of one hydrological year) • water table
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• hydrological modelling • measurement/monitoring
FREQUENCY (how often to use this indicator?)	• It can be calculated before an urban development project, or regularly each year to anticipate a potential risk of lack of water. • Different time scales may be examined (year, month, day)
MEASUREMENT UNIT	• mm or %
REQUIRED TOOL	• hydrological/soil model for NBS scenario evaluation or measures for a reference study case.
CALCULATION METHOD	• measurement and modelling for evaluation of greening scenarios over a defined period
OUTPUT TYPE	• numerical value (min, max, mean, standard deviation)
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Water conservation • Efficiency • Evapotranspiration • Water productivity
LINKS AND REFERENCES	•

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	2.1.2 | SWS – Soil water storage

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	No
R3: Comparability:	The difficulty of the methodology is to define the depth for the calculation. The root zone is not fully documented. Observation of soil moisture on a vertical profile is not very common. But when it exists, it is easy to compare with.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	No
A3: Other stakeholders:	No

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CREDIBLE	
C1: Unambiguous results:	People is not used to hear about this indicator, but the concept is maybe quite understandable.
C2: Transparency:	No, due to the definition of the soil depth to make the calculation. Root zone is not well known parameter.
C3: Documentation of assumptions and limitations:	No, due to the definition of the soil depth to make the calculation. Root zone is not well known parameter.

EASY	
E1: Availability of data to calculate the indicator:	Averaged observed soil moisture is not an available data. It is usually only available on studied experimental sites or by hydrological modelling means. Simulated averaged soil moisture is not made available by national services for urban areas. This can be simulated by hydrological models adapted to urban context.
E2: Technical feasibility:	Yes
E3: Reproducibility:	By the use of hydrological model dedicated to urban areas, it takes some time to adapt the simulation for each case. Then numerous cases may be optimistic. But some cases is possible. It has been used over an instrumented catchment in northwestern France and gave reasonable results compared to observed data.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	Yes

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2.1.3 | PFvar

2 | WATER MANAGEMENT AND QUALITY

2.1 | URBAN WATER MANAGEMENT AND QUALITY

2.1.3 | PFvar – PEAKFLOW VARIATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	**2.1.3 | PFvar – Peakflow variation**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood/catchment ☒ Object
DEFINITION	The peakflow is the maximum value of the flowrate due to a given rain event. Peakflow variation is defined by the relative error in peakflow between the peakflow of the catchment with NBS and the peakflow of a catchment without NBS. This indicator can be calculated as the average value of a sample of peakflows deduced from a rain/runoff time series (typically one year) and may be obtained with observed runoff (if pre- and post- NBS setting is available) or simulated runoff. This indicator will directly assess the impact of NBS in the reduction of the flowrate, which peakflow is a characteristic value.
FOCUS/OBJECTIVES	• assess one NBS type benefit • assess the impact of a combination of NBS set on one large catchment

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Flowrate data (in case of observed coefficient estimation) in pre- and post-NBS setting • Simulated flowrates (in case of simulated coefficient estimation)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• Hydrological modelling • Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	• It can be calculated before an urban planning option in order to evaluate its impact
MEASUREMENT UNIT	• % (but flowrates are in l/s or l/s/ha (in case of different catchments comparison))
REQUIRED TOOL	• hydrological model for NBS scenario evaluation • observations (with and without NBS)
CALCULATION METHOD	• measurement and modelling for evaluation of greening scenarios over a defined period
OUTPUT TYPE	• numerical value (min, max, mean, standard deviation) • distribution of the values (histogram)
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• WATER MANAGEMENT • PEAKFLOW • FLOWRATE
LINKS AND REFERENCES	•

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	2.1.3 | PFvar – Peakflow variation

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	Yes, it could be: this indicator may help estimate peakflow limitation induced by NBS so it may fulfill specific policies
R3: Comparability:	Yes, the methodology is able to provide data comparable to datasets. Yes, it is possible to standardise the methodology.

ACCEPTED	
A1: Policy makers:	Yes, it could have been to avoid flooding in specified zones
A2: Practitioners:	Yes, it could be
A3: Other stakeholders:	Yes, it could be

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CREDIBLE	
C1: Unambiguous results:	No, this indicator reveals a potential indirect effect. Both decision makers and citizens are probably not familiar with this indicator
C2: Transparency:	Probably not because it may be estimated by two means (simulation and observation). It may be easily computed by using a model. In case of observed estimation, it makes it necessary to collect flowrate data.
C3: Documentation of assumptions and limitations:	Yes, data needed for the estimation of this indicator are fully disclosed, interpretable and reproducible.

EASY	
E1: Availability of data to calculate the indicator:	Data required for the estimation of the indicator have to be calculated either from a model, or from monitoring. In case of model estimation, it requires input data provided by national meteorological services (typically rainfall and potential evapotranspiration)
E2: Technical feasibility:	In case of model estimation, once meteorological data is available, calculation makes it necessary to run the appropriate hydrological model. Then the indicator can be estimated from the model results by standard software.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	Yes, it could be

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2 | WATER MANAGEMENT AND QUALITY

2.1 | URBAN WATER MANAGEMENT AND QUALITY

2.1.4 | WQ – STORMWATER QUALITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	**2.1.4 | WQ – Stormwater quality**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood/catchment ☒ Object
DEFINITION	The stormwater quality parameters are the values of physico-chemical parameters and the values of micropollutant concentrations (organic and inorganic) that are regulated.
FOCUS/OBJECTIVES	• A 'core' group of indicators is constituted with the regulated parameters. The parameters are measured and compared to the surface quality standards defined within the EU water framework. The performance of the NBS regarding the stormwater quality will be appropriate if the pollutant concentrations in the treated water are below the thresholds and the total parameters remain in certain range of values.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• concentrations of pollutant (total/dissolved concentrations), physico-chemical parameters (pH, conductivity, oxygen chemical demand, redox….)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• literature • measurement/monitoring
FREQUENCY (how often to use this indicator?)	• initial diagnostic • throughout the service life of the system
MEASUREMENT UNIT	• [M.L-1] (for pollutant) and various units for parameters
REQUIRED TOOL	• samplers • filters • chemical analyses • physico-chemical measurements
CALCULATION METHOD	• no calculation or simple calculation (substraction) by considering a reference
OUTPUT TYPE	• set of indicators
EXAMPLES	• measurement of pH of water leaving an infiltration basin • concentration of total lead in runoff waters leaving a swale

LINKS AND REFERENCES	
KEYWORDS	• concentration, • pollutant, • total/dissolved concentration, • physico-chemical parameter
LINKS AND REFERENCES	• US EPA (2002). National Recommended Water Quality Criteria: 2002.Water quality standards • European Water Framework Directive • Surface water quality standards

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.1 | Urban water management and quality

INDICATOR	
NAME	**2.1.4 | WQ – Stormwater quality**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like high total suspended solids.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Water Framework Directive
R3: Comparability:	Yes, the methodology used to provide data is already standardised.

ACCEPTED	
A1: Policy makers:	Yes, they are basic indicators used by water policies.
A2: Practitioners:	Yes, if urban planner has some fundamental skills about water quality. The indicator has the potential to be used.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results:	Yes, the results will be clear but the general public may not really understand what the indicators are.
C2: Transparency:	Yes, it has. Based on international measurements methods and standards
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicated in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Some of the informations/data could be already available. Data could be updated easily if the practitioners have a miminum of knowledge about the water quality.
E2: Technical feasibility:	No calculation or very simple calculations will be required.
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations and systems). The indicator has been used in different circumstances (different SUDS) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is provided with the measurement method and the uncertainty of the measurement or analyses
R3: Scale:	No, it is appropriate at the entity. Require a number of samples.

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2.2.1| TROvol

2 | WATER MANAGEMENT AND QUALITY

2.2 | FLOOD MANAGEMENT

Short description of USC: Urban areas are characterized by impervious surfaces that strongly modify the water cycle, compared to natural surfaces (Fletcher et al, 2013). The increased surface runoff and the higher speed transfer of water at the surface and into the pipes, lead to more intense and more frequent flow peaks.

2.2.1 | TROvol – TOTAL RUNOFF VOLUME

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	**2.2.1 | TROvol – Total runoff volume**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood/catchment ☒ Object
DEFINITION	The total runoff volume is deduced from the flowrate at the outlet of a considered catchment/neighbourhood. It's the sum of the runoff volume on the whole chosen period. This indicator may be calculated on a rain/runoff time series (typically one year) and may be obtained with observed runoff (if pre- and post- NBS setting is available) or simulated runoff. The comparison of this indicator for a catchment with or without NBS will characterize the impact of NBS in the hydrological balance, and especially the potential of NBS for recovering a natural hydrological response according to the catchment overall behaviour. The total runoff volume may be potentially separated into the during-event runoff volume and the dry-weather runoff volume.
FOCUS/OBJECTIVES	• assess one NBS type benefit • assess the impact of a combination of NBS set on one large catchment

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Rainfall data (typically one hydrological year) • Flowrate data (in case of observed coefficient estimation) in pre- and post-NBS setting • Simulated flowrates (in case of simulated coefficient estimation)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• Hydrological modelling • Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	• It can be calculated before an urban planning option in order to evaluate its impact
MEASUREMENT UNIT	• m3 (may be converted in water depth in mm for convenience)
REQUIRED TOOL	• hydrological model for NBS scenario evaluation • observations (with and without NBS)
CALCULATION METHOD	• measurement and modelling for evaluation of greening scenarios over a defined period
OUTPUT TYPE	• Simple value (total defined period) • Sample of event runoff volumes =>distribution of the values
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• RUNOFF • VOLUME • FLOWRATE
LINKS AND REFERENCES	•

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	2.2.1 | TROvol – Total runoff volume

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	No
R3: Comparability:	Yes, the methodology is able to provide data comparable to datasets. Yes, it's possible to standardise the methodology.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	Probably not
A3: Other stakeholders:	Probably not

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CREDIBLE	
C1: Unambiguous results:	No this indicator reveals a potential indirect effect. Both decision makers and citizens are probably not familiar with this indicator
C2: Transparency:	Probably not because it may be estimated by two means (simulation and observation). It may be easily computed by using a model. In case of observed estimation, it makes it necessary to collect flowrate data.
C3: Documentation of assumptions and limitations:	Yes, data needed for the estimation of this indicator are fully disclosed, interpretable and reproductible.

EASY	
E1: Availability of data to calculate the indicator:	Data required for the estimation of the indicator have to be calculated either from a model, or from monitoring. In case of model estimation, it requires input data provided by national meteorological services (typically rainfall and potential evapotranspiration)
E2: Technical feasibility:	In case of model estimation, once meteorological data is available, calculation makes it necessary to run the appropriate hydrological model. Then the indicator can be estimated from the model results by standard software.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	Yes, it could be

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2.2.2| TRFvol

2 | WATER MANAGEMENT AND QUALITY

2.2 | FLOOD MANAGEMENT

2.2.2 | TRFvol – TOTAL RAINFALL VOLUME

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	**2.2.2 | TRFvol – Total rainfall volume**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Grass, urban trees and pit grass has the ability to cope with rainfall events. The total runoff volumes absorption is the interception value of a rainfall event.
FOCUS/OBJECTIVES	• To know total runoff volume absorption of NBS or green canopy areas. • Increase the level of drainage for an urban area, using permeable hard surfaces and increasing the use of vegetation to reduce runoff and floods. • The combination of NBS can reduce runoff as well as take advantage of the rainfall.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Rainfall captured • Meteorological data
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Measurement/ modelling
FREQUENCY (how often to use this indicator?)	• The number of tips should be manually recorded daily. This will allow the total runoff for each 24-hour period to be calculated. • Year scale • Season scale • Rainfall event scale
MEASUREMENT UNIT	• ml or mm • %
REQUIRED TOOL	• Meteorological data
CALCULATION METHOD	• Regression analysis, ANOVA • Measurement
OUTPUT TYPE	• Numerical value (%, standard deviation...)
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Interception • Runoff • Urban trees • Tree pit • Rainfall • Flooding
LINKS AND REFERENCES	• Armson, D., et al., The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. Urban Forestry & Urban Greening (2013), http://dx.doi.org/10.1016/j.ufug.2013.04.001

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	2.2.2 | TRFvol – Total rainfall volume

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	Yes, Directive 2000/60/EC – framework for Community action in the field of water policy
R3: Comparability:	Yes, it is possible to standardise the methodology.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	Yes. It is possible.
A3: Other stakeholders:	Yes, especially in some NBS

CREDIBLE	
C1: Unambiguous results:	Yes
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	The method can be only replicated in some new actions

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EASY	
E1: Availability of data to calculate the indicator:	Yes, It cannot exist measurement in cities
E2: Technical feasibility:	-
R3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	The scale on which the indicator can be applied will depend on the heterogeneity of land use. It is better to use it on a quite homogeneous surface.

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2 | WATER MANAGEMENT

2.2 | FLOOD MANAGEMENT

2.2.3 | RRR – TOT. RUNOFF/RAINFALL RATIO

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	**2.2.3 | RRR – Total runoff/rainfall ratio**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	Runoff in this context is the total amount of water discharged from a watershed via a river or stream and rainfall data indicates the amount of rainfall in a unit area. Runoff / rainfall ratio gives us the percentage and the amount of the water discharged into river or stream. As a result of the calculation we obtain the increment over the water body.
FOCUS/OBJECTIVES	• Evaluate NBS ability to reduce possible flood event • To determine the amount of water increment

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Total runoff • Total rainfall
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Total rainfall data from the General Directorate of Meteorology • Topological data (3D Buildings, Map) is going to obtain via LIDAR scans by the customer/third parties • Observed or simulated discharge or water height measurement at the outlet of the river
FREQUENCY (how often to use this indicator?)	• Event based • Year scale
MEASUREMENT UNIT	• no unit or %
REQUIRED TOOL	• Tool will be required (e.g. simple flood management visualization tool out of N4C Project)
CALCULATION METHOD	• Total runoff / Total rainfall
OUTPUT TYPE	• Simple quantitative ratio
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Rainfall • Runoff • Permeability
LINKS AND REFERENCES	•

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	2.2.3 | RRR – Total runoff/rainfall ratio

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	No
R3: Comparability:	Yes, as the outcome of the method, common usable ratio will be obtained. Yes, it is possible to standardise the methodology.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	It may be usable during water and flood management plans.
A3: Other stakeholders:	Yes, e.g.: Blume, T.; Zehe, E.; Bronstert, A., 2007. Rainfall–runoff response, event-based runoff coefficients and hydrograph separation. Hydrological Sciences–Journal–des Sciences Hydrologiques, 52: 843–862.

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CREDIBLE	
C1: Unambiguous results:	The general public does not familiar with the concept; therefore, this indicator can be considered as technical for general public.
C2: Transparency:	No, methodology can differentiate due to the usage purposes.
C3: Documentation of assumptions and limitations:	No, they are not.

EASY	
E1: Availability of data to calculate the indicator:	No. The required input data for the calculation have to be collected before the estimation.
E2: Technical feasibility:	Once total runoff and total rainfall data are available, it is easy to make calculations via simple procedure.
R3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	Yes, most likely

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2.2.4| FAV

2 | WATER MANAGEMENT AND QUALITY

2.2 | FLOOD MANAGEMENT

2.2.4 | FAV – VARIATION OF FLOODED AREA

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	**2.2.4 | FAV – Variation of flooded area**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	This indicator allows us to determine the direction of the water during any kind of flood event and where water will accumulate in the flood area. With the help of burst pipe analyses, we can identify risky areas and prevent possible devastating impacts of flood.
FOCUS/OBJECTIVES	• Evaluate NBS ability to prevent possible water accumulation before flood event • Determine the water flow directions and flow rates

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Surface map coverage • Digital elevation data • 3D mesh data of buildings • Burst location • Burst flowrate
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Topological data (3D Buildings, Map) is obtained via LIDAR scans by the customer/third parties • Surface morphology elevation data is obtained from topology and 3D building data is generated from scans, modelled by experts, imported from CityGML
FREQUENCY (how often to use this indicator?)	• The frequency will be dependent on the frequency of database update. Since flooding events are not that frequent and usually related to specific periods of the year, data will be used and updated event by event.
MEASUREMENT UNIT	• mm
REQUIRED TOOL	• Tool will be required
CALCULATION METHOD	• Soil sampling • Hydroperiod sampling • Statistical data analysis
OUTPUT TYPE	• Simple quantitative value
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Water accumulation • 3D mesh • Digital Elevation Model
LINKS AND REFERENCES	• Tsheboeng G, Bonyongo M, Murray-Hudson M. Flood variation and soil nutrient content in floodplain vegetation communities in the Okavango Delta. S Afr J Sci. 2014;110(3/4), Art. #2013-0168, 5 pages. http://dx.doi.org/10.1590/ sajs.2014/20130168

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	2.2.4 | FAV – Variation of flooded area

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	No
R3: Comparability:	Yes, it is possible to standardise the methodology.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	No
A3: Other stakeholders:	Yes.http://repositori.uji.es/xmlui/bitstream/handle/10234/65654/48175.pdf;sequence=1

CREDIBLE	
C1: Unambiguous results:	The general public does not familiar with the concept; therefore, this indicator may not understand fully by public.
C2: Transparency:	No, methodology can differentiate due to the usage purposes.
C3: Documentation of assumptions and limitations:	No, since each location has its own ground position parameters, data will be required.

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EASY	
E1: Availability of data to calculate the indicator:	The methodology requires input data for the calculation. Elevation data can obtain via global DEM projects; however, water direction data has to be generated. Update will be difficult.
E2: Technical feasibility:	Once elevation and coordinate data is provided, it is easy to calculate via the flood management tool. There are available softwares; however, they require purchasing. Obtaining precise data may not be possible due to the real world data acquisition.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	Currently working on the analyses product to develop such functionalities.
R3: Scale:	Yes

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2.2.5 | WDT

2 | WATER MANAGEMENT AND QUALITY

2.2 | FLOOD MANAGEMENT

2.2.5 | WDT – WATER DETENTION TIME

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	**2.2.5 | WDT – Water detention time**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ |☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ |☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	The detention time corresponds to the theoretically calculated time required for a given amount of water to flow from a given area to another area at a given flow rate.Theoretical water detention time calculations are much simpler than real life data in terms of various parameters compared to the complexity of calculations. As an indicator for flood management, water detention time gives us the elapsed time difference between start and end time of flood event. While calculating the detention time, we need to be sure the total volume of water that fills the entire and the incoming water flow rate.
FOCUS/OBJECTIVES	• Evaluate NBS ability to prevent possible flood hazards • To evaluate the potential impact of NBS on flood events over urban areas

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• The basin volume data of disaster area • Incoming water flow rate (depending on the previous flood events or observed data) • Soil permeability or soil water storage data and • Digital terrain model or • Available observed hydrograms
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• Hydrological modelling • Measurement/monitoring • Modelling
FREQUENCY (how often to use this indicator?)	• Yearly • Season • Event based
MEASUREMENT UNIT	• Hours/minutes/seconds
REQUIRED TOOL	• Hydrological model
CALCULATION METHOD	• Detention time
OUTPUT TYPE	• Time/duration (hours/minutes/seconds)
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• WATER MANAGEMENT • FLOOD MANAGEMENT • WATER DETENTION TIME • DETENTION TIME
LINKS AND REFERENCES	• Polish J. of Environ. Stud. Vol. 18, No. 2 (2009), 289-292

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
CLIMATE	2 | Water management and quality	2.2 | Flood management

INDICATOR	
NAME	2.2.5 | WDT – Water detention time

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator is capable to describe initial urban planning problems like climate issues and water management.
R2: Policy support for policies:	No
R3: Comparability:	Yes, it is a standardised methodology.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	It is not likely used by an urban planner.
A3: Other stakeholders:	Yes

CREDIBLE	
C1: Unambiguous results:	Yes
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Methodology is simple to use regarding its universality.

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EASY	
E1: Availability of data to calculate the indicator:	No. Since each required data is almost unique, obtaining and generating the data will be event based.
E2: Technical feasibility:	Once data is obtained, practicing the calculation will quite easy.
R3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	Yes

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3 | AIR QUALITY

Short description of UC: The quality of life in European cities and in most of the world is threatened by a number of factors. The drivers include increasing pollution levels, urban heat islands, flooding and extreme events related to climate change, as well as decreased biodiversity. These can have detrimental effects for human health and well-being.
Green infrastructures are beneficial but they do not represent a solution to completely remove air pollution from cities. We should keep in mind that trying to reduce the concentration of a pollutant once it is already diluted is much more inefficient than when acting directly on the source.

3.1 | AIR QUALITY AT DISTRICT/CITY SCALE

Short description of USC: Air quality is a major concern worldwide, **particularly in urban areas**, due to its direct consequences on human health, plants, animals, infrastructure and historical buildings (among others). The improvement of air quality in cities is a complex problem. It depends on a large number of factors such as amount and type of traffic, location or weather.

3.1.1 | CAQI – COMMON AIR QUALITY INDEX

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale

INDICATOR	
NAME	**3.1.1 | CAQI – Common air quality index**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ **2** ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ **2nd** ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ **Assessment** ☐ Monitoring
SCALE (☐ | ☒)	☒ **City** ☒ Neighbourhood ☒ Object
DEFINITION	In 2005 the Common Air Quality Index (CAQI) was proposed to facilitate the comparison of air quality in European cities in real-time[16]. There are many air quality indices (AQI-s) in use in the world. All are different in concept and presentation and comparing air quality in cities was virtually impossible for the lay public[1]. The CAQI and the accompanying website www.airqualitynow.eu or app were introduced as a 'lingua franca' solution to overcome this problem[17].
FOCUS/OBJECTIVES	• Improve Air Quality

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

[16] Elshout S van den, Léger K, Nussio F. Comparing urban air quality in Europe in real time, a review of existing air quality indices and the proposal of a common alternative. Environ Int 2008; 34(5):720–6.

[17] Elshout S van den. CITEAIR II project. INTERREG IVC Programme. www.airqualitynow.eu/download/CITEAIR-Comparing_Urban_Air_Quality_across_Borders.pdf, 2012. [Accessed oct-2017].

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DATA AND MEASUREMENT	
REQUIRED DATA	• Hourly value NO_2, PM_{10} and O3 (additionally CO, SO_2, $PM_{2,5}$) • Daily average value NO_2, PM_{10} and O_3 (additionally CO, SO_2, $PM_{2,5}$) • Yearly average value (additionally CO, SO_2, $PM_{2,5}$)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	• Continuously
MEASUREMENT UNIT	• Dimensionless
REQUIRED TOOL	• Official measures from municipalities.
CALCULATION METHOD	• CAQI methodology.
OUTPUT TYPE	• numerical value (very low, low, medium, high and very high) • graphic map
EXAMPLES	• Elshout S van den, Léger K, Nussio F. Comparing urban air quality in Europe in real time, a review of existing air quality indices and the proposal of a common alternative. Environ Int 2008; 34(5):720–6. • www.airqualitynow.eu

LINKS AND REFERENCES	
KEYWORDS	• AIR QUALITY • PARTICULATE MATTER • PM10, PM2,5, NO2, O3, CO • AIR POLLUTANTS • HEALTH • PUBLIC AWARENESS
LINKS AND REFERENCES	• www.airqualitynow.eu • Elshout S van den, Léger K, Nussio F. Comparing urban air quality in Europe in real time, a review of existing air quality indices and the proposal of a common alternative. Environ Int 2008; 34(5):720–6. • Elshout S van den. CITEAIR II project. INTERREG IVC Programme. www.airqualitynow.eu/download/CITEAIR-Comparing_Urban_Air_Quality_across_Borders.pdf, 2012. [Accessed oct-2017].

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale

INDICATOR	
NAME	3.1.1 | CAQI – Common air quality index

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. better air quality.
R2: Policy support for policies:	High score for policy support Europe-wide and international: ● EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities ● EU Strategy on Green Infrastructure The Directive 2008/50/EC of the European Parliament
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	CAQI is a very good and potential indicator for easy communication and awareness purposes, because citizens understand it easily. However, it requires the municipality commitment providing air quality data.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, http://www.airqualitynow.eu…)

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and public can understand easily message and coherences of the CAQI.
C2: Transparency:	Yes, it has. Based on public air quality data the value could be calculated.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	The indicator needs data, which has to be generated (see Indicator sheet). However, there are also some public information http://www.airqualitynow.eu. For data update, it is needed data from municipalities. It is needed because instrumentation to measure properly implies high cost equipment and maintenance operations.
E2: Technical feasibility:	Yes
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations, scales,). The indicator can be used in all the cities (with the air quality data available) and delivered reasonable results.

ROBUST	
R1: Data quality:	Input data for simulation model are real data.
R2: Sensitiveness:	Two EU project developed and validated the methodology.
R3: Scale:	No. It is useful mainly at city scale (or depending on the city at neighbourhood scale.

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3 | AIR QUALITY

3.1 | AIR QUALITY AT DISTRICT/CITY SCALE

3.1.2 | EAQLVcity – AIR QUALITY LIMIT – CITY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale

INDICATOR	
NAME	**3.1.2 | EAQLVcity – Exceedance of air quality limit value – city scale**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator shows the fraction of a city population that is potentially exposed to ambient air concentrations of certain pollutants ($PM_{2.5}$, PM_{10} , O_3 , NO_2 , SO_2 and BaP) that are in excess of the EU limit or target values (EU, 2004, 2008) set for the protection of human health. This indicator is an adaptation at city scale of the indicator CSI 004 of the European Environment Agency : Exceedance of air quality limit values in urban areas.
FOCUS/OBJECTIVES	High population densities in urban areas and related economic activities result in increased emissions of air pollutants, which in turn lead to higher ambient concentrations of these pollutants and greater exposure to them. This indicator focuses on those pollutants that are more relevant in terms of their health effects and urban concentrations: PM — both PM_{10} (particles with a diameter of 10 micrometres or less) and fine PM or $PM_{2.5}$ (particles with a diameter of 2.5 micrometres or less); O_3; NO_2; sulfur dioxide (SO_2); and benzo[a]pyrene (BaP). According to different World Health Organization studies (WHO, 2000, 2006, 2013, 2014), exposure to PM can cause or aggravate cardiovascular and lung diseases, heart attacks and arrhythmias. It can also affect the central nervous system, the reproductive system and cause cancer. Exposure to high O_3 concentrations can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases. Exposure to NO_2 increases symptoms of bronchitis in asthmatic children and reduces lung function growth. SO_2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes.

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	Finally, BaP is carcinogenic, and is used as an indicator of the carcinogenic effect of the total polycyclic aromatic hydrocarbons (PAHs).

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• City population • Share of population living closer than 100 meters from major roads • The following data are needed from at least one “urban traffic” station (i.e. located closer than 100 meters from a major road) and one “urban background” station (i.e. located farer than 100 meters from a major road): ○ Daily $PM_{2.5}$ concentration ○ Daily PM_{10} concentration ○ Hourly 0_3 concentration ○ Daily NO_2 concentration ○ Daily SO_2 concentration ○ Daily BaP concentration • In case of several stations of the same type the location of the different stations as well as the spatial distribution of the population can be used to derive allocation rules in terms of population exposure.
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	For main cities throughout Europe useful data can be found in the following sources : • Information on cities is obtained from the **Urban Audit (UA)** data (Eurostat, 2014c). UA data collection, maintained by Eurostat, provides information and comparable measurements on the different aspects of the quality of urban life in selected European cities. The urban population considered is the total number of people represented by any of the urban monitoring stations. https://www.eea.europa.eu/data-and-maps/data/external/gisco-urban-audit-2004 • **City population** : https://www.eea.europa.eu/data-and-maps/data/external/city-population • **Air quality measurements** can be obtained from: ○ Air Quality e-Reporting (AQ e-Reporting), provided by European Commission : https://www.eea.europa.eu/data-and-maps/data/aqereporting-2 ○ AirBase – TheEuropean air quality database, provided by the European Environment Agency : https://www.eea.europa.eu/data-

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	and-maps/data/aqereporting-2#tab-data-by-country • National data on the population living closer than 100 metres from major roads have been taken from : ENTEC, 2006. Development of a methodology to assess population exposed to high levels of noise and air pollution close to major transport infrastructure , Final Report April 2006, Entec UK Limited
FREQUENCY (how often to use this indicator?)	• yearly
MEASUREMENT UNIT	• Micrograms (mg) of pollutant per cubic meter for $PM_{2.5}$, PM_{10}, O_3, NO_2 and SO_2. • Nanograms (ng) of pollutant per cubic metre for BaP.
REQUIRED TOOL	• Air quality measurement stations
CALCULATION METHOD	**Population exposure** Two types of monitoring stations are considered, classified as 'urban traffic', and 'urban background'. The “urban traffic” stations represent the environmental conditions of places located closer than 100 meters from major roads. The “urban background” stations represent the average environmental conditions in the city. The percentage of the city population living closer than 100 meters from major roads is used to allocate exposure of the city population to the two types of environmental conditions. In case there are several stations of the same type an allocation rule has to be established to allocate the population to the different stations of the same type. **EU limit and target values** Particulate matter ($PM_{2.5}$) The annual mean concentration is calculated for each of the selected stations. Depending on the mean concentration, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (below or equal to the target value (25 µg/m3), or above it). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each concentration class by the sum of the population assigned to each station. Particulate matter (PM_{10}) For each selected station, the 90.4 percentile (P90.4) of the daily mean concentration series is calculated. P90.4 represents, in a complete series of 365 elements, the 36th highest value. When P90.4 is below or equal to 50 µg/m3, it indicates that the daily limit value (DLV) would not have been exceeded on more than 35 days. Depending on the value of P90.4, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (P90.4 > 50 µg/m3, i.e. above the DLV and P90.4 ≤ 50 µg/m3, i.e. below the DLV). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each individual concentration class by the sum of the population assigned to each station. Ozone (O_3)

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	For each selected station, the 93.2 percentile (P93.2) of the daily maximum 8-hourly mean concentration series is calculated. P93.2 represents, in a complete series of 365 elements, the 26th highest value. When P93.2 is below or equal to 120 µg/m3, it indicates that the long term objective would have not been exceeded on more than 25 days. Depending on the value of P93.2, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (P93.2 > 120 µg/m3, i.e. exceedance of the long term objective on more than 25 days, and P93.2 ≤ 120 µg/m3, i.e. exceedance of the long term objective is less than or equal to 25 days). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each individual concentration class by the sum of the population assigned to each station. Nitrogen dioxide (NO_2) The annual mean concentration is calculated for each of the selected stations. Depending on the annual mean concentration, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (below or equal to the limit value (40 µg/m3), or above the limit value). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each concentration class by the sum of the population assigned to each station Benzo[a]pyrene (BaP) The annual mean concentration is calculated for each of the selected stations. Depending on the mean concentration, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (below or equal to the target value (1.0 ng/m3), or above the target value). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each concentration class by the sum of the population assigned to each station. Sulfur dioxide (SO_2) For each selected station, the 99.2 percentile (P99.2) of the daily mean concentration series is calculated. P99.2 represents, in a complete series of 365 elements, the 4th highest value. When P99.2 is below or equal to 125 µg/m3, it indicates that the daily limit value would have not been exceeded on more than three days. Depending on the value of P99.2, each station (and its allocated population) is then classified uniquely in one of these two concentration classes (P99.2 > 125 µg/m3, i.e. above the daily limit value and P99.2 ≤ 125 µg/m3, i.e. below the daily limit value). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each individual concentration class by the sum of the population assigned to each station Data quality For PM_{10}, $PM_{2.5}$, O_3, NO_2 and SO_2, only stations with at least 75 % of valid data per calendar year are used. That is, in the case of daily values, those having more than 274 valid daily values per calendar year (or 275 days in a leap year). And in the case

	of hourly values, having more than 6 570 valid hourly values per calendar year (or 6 588 hours in a leap year). For BaP, the minimum data time coverage accepted is 14 % (51 days), according to the data quality objectives related to indicative measurements in the Directive 2004/107/EU (EU, 2004).
OUTPUT TYPE	● Percentage of the city population exposed to annual $PM_{2.5}$ concentrations above 25 µg/m3. ● Percentage of the city population exposed to daily PM_{10} concentrations exceeding 50 µg/m3 for more than 35 days a year. ● Percentage of the city population exposed to maximum daily 8-hour mean O_3 concentrations exceeding 120 µg/m3 for more than 25 days a year. ● Percentage of the city population exposed to annual NO_2 concentrations above 40 µg/m3 ● Percentage of the city population exposed to annual BaP concentration above 1.0 ng/m3
EXAMPLES	● **No example**s, this indicator is proposed as an adaptation of EEA CSI 004 indicator (Exceedance of air quality limit values in urban areas) that is an indicator at European level.

LINKS AND REFERENCES	
KEYWORDS	● Air quality ● Air pollution ● Health ● Particulate matter ● NO2 ● SO2 ● Ozone ● Benzo[a]pyrene
LINKS AND REFERENCES	● European Environment Agency – Exceedance of air quality limit values in urban areas, indicator CSI 004 : https://www.eea.europa.eu/data-and-maps/indicators/exceedance-of-air-quality-limit-3 ● European Environment Agency – Exceedance of air quality limit values in urban areas, indicator CSI 004 : https://www.eea.europa.eu/data-and-maps/indicators/exceedance-of-air-quality-limit-3/assessment-2 ● EU, 2004 : Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32004L0107 ● EU, 2008 : Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0050

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale

INDICATOR	
NAME	**3.1.2 | EAQLVcity – Exceedance of air quality limit value – city scale**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable if describing the exceedance of air quality limit values at city scale which can be considered as an initial planning problem.
R2: Policy support for policies:	This indicator is an adaptation of the indicator CSI 004 of the European Environment Agency. The initial indicator as well as the proposed adaptation are relevant for the current European air quality legislation related to the protection of human health in the Air Quality Directives 2004/107/EC and 2008/50/EC (EU, 2004, 2008). The 7th EU Environment Action Programme (EU, 2013a) includes priority objectives that aim, among others, to protect, conserve and enhance the EU's natural capital, safeguard the EU's citizens from environment-related pressures and risks to health and wellbeing, and enhance the sustainability of the EU's cities. The EU Clean Air Policy Package, adopted by the European Commission on 18 December 2013, proposes in the Communication “A Clean Air Programme for Europe” (EU, 2013b) the short-term objective of achieving full compliance with existing legislation by 2020 at the latest.
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

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ACCEPTED	
A1: Policy makers:	The initial indicator (at the level of European cities) is used to assess existing air quality policies. The calculation of the initial indicator (at the level of European cities) already relies on calculations at city level. The adaptation proposed at city scale could be used to assess the contribution of a city to the policies.
A2: Practitioners:	No
A3: Other stakeholders:	The indicator should be interesting for municipality officers. In fact large agglomerations already use this type of indicators throughout Europe.

CREDIBLE	
C1: Unambiguous results:	Yes, both the decision makers and the general public understand the message conveyed by the indicator.
C2: Transparency:	Yes, the indicator has a clear methodology
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Depending the cities data might be available in European Air Quality Database or not. If not it requires the deployment of new air quality monitoring stations. Data in the European Air Quality Database are updated annualy.
E2: Technical feasibility:	No, very complex topic.
R3: Reproducibility:	The indicator is fully reproducible. The indicator has not been specifically used at city level, but The calculation of the initial indicator (at the level of European cities) already relies on calculations at city level. And large agglomerations throughout Europe already use this type of indicators.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	The indicator addresses the city scale only.

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3.1.3| AAPCV

3 | AIR QUALITY

3.1 | AIR QUALITY AT DISTRICT/CITY SCALE

3.1.3 | AAPCV – ANN. AMOUNT POLLUTANTS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale

INDICATOR	
NAME	**3.1.3 | APPCV – Annual amount of pollutants captured by vegetation**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ **4** ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ **2nd** ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ **No**
TYPE (☐ | ☒)	☐ Descriptive ☒ **Assessment** ☐ **Monitoring**
SCALE (☐ | ☒)	☒ **City** ☒ **Neighbourhood** ☒ Object
DEFINITION	Annual amount of pollutants captured by vegetation indicates the amount of particulate and gaseous emissions through deposition and dispersion. Trees affect air quality through the direct removal of air pollutants, altering local microclimates and building energy use, and through the emission of volatile organic compounds (VOCs), which can contribute to O3 and PM2.5 formation. However, integrative studies have revealed that trees, particularly low VOC emitting species, can be a viable strategy to help reduce urban O3 levels. Trees remove gaseous air pollution primarily by uptake via leaf stomata, though some gases are removed by the plant surface. For O3, SO2 and NO2, most of the pollution is removed via leaf stomata. Once inside the leaf, gases diffuse into intercellular spaces and may be absorbed by water films to form acids or react with inner-leaf surfaces. Trees directly affect particulate matter in the atmosphere by intercepting particles, emitting particles (e.g., pollen) and resuspension of particles captured on the plant surface. Some particles can be absorbed into the tree, though most intercepted particles are retained on the plant surface. The intercepted particles often are resuspended to the atmosphere, washed off by rain, or dropped to the ground with leaf and twig fall. During dry periods, particles are constantly intercepted and resuspended, in part, dependent upon wind speed. The accumulation of particles on the leaves can affect photosynthesis and therefore potentially affect pollution removal by trees. During precipitation, particles can be washed off and either dissolved or transferred to the soil. Consequently, vegetation is only a temporary retention site for many

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	atmospheric particles, where particles are eventually moved back to the atmosphere or moved to the soil.
FOCUS/OBJECTIVES	There are many NBS types that include formation or enhancement of vegetation. Especially for urban areas where air quality is a challenge, this indicator can be used for a criterion in selection of NBS type and species. Moreover, the potential of vegetation to capture particulate matter and gaseous emissions can be used to monitor the performance of a NBS.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Area coverage of certain vegetation types • Capture potential of vegetation types (calculated from deposition velocity, pollutant concentration and properties specific to species e.g. LAI)
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Municipalities and institutes responsible for statistics and forests (for the area covered by vegetation and the species) • Literature and other references (for the capture potential of different vegetation types)
FREQUENCY (how often to use this indicator?)	• Annual
MEASUREMENT UNIT	• t pollutant per ha/year
REQUIRED TOOL	• No specific tool needed for calculation • i-Tree Eco
CALCULATION METHOD	• **Tiwary method**: An integrated modelling approach which utilises air dispersion (ADMS-Urban) and particulate interception modelling (UFORE) to predict the PM10 concentrations both before and after greenspace establishment, using a 10x10 km area of East London Green Grid (ELGG) as a case study. • **Mapping air purification** using spatially-explicit data on ecosystem types and characteristics (particularly Leaf Area Index LAI), and pollution distribution. • **Forest Inventory Analysis (FIA):** estimation of pollutant capture via using the data from FIA lichen indicator. FIA lichen indicator shows the intensity of lichens in a forest that are tolerant to a specific pollutant. • **I-Tree Eco** method is based on creating a detailed urban forest inventory and calculating structural indicators (LA, LAI) or regulating ecosystem services (Cseq, air pollution removal, water retention). The latter need detailed meteorological and pollution datasets.
OUTPUT TYPE	• Numerical value

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EXAMPLES	● A study by USDA Forest Service showed that the abundance of N-loving lichens has a strong linear correlation with total N deposition and is not a response to any particular N pollutant ● Tiwary et. al. presented an integrated modelling approach which utilises air dispersion (ADMS-Urban) and particulate interception modelling (UFORE) to predict the PM10 concentrations both before and after greenspace establishment, using a 10x10 km area of East London Green Grid (ELGG) as a case study. ● Nowak et. al. used the pollutant removal data to estimate avoided health impacts and associated dollar benefits of air pollution removal by trees and forests in the conterminous United States in 2010. This analysis included: ○ the total tree cover and leaf area index (LAI) on a daily basis, ○ the hourly flux of pollutants to and from the leaves, ○ the effects of hourly pollution removal on pollutant concentration in the atmosphere, and ○ the health impacts and monetary value of the change in NO2, O3, PM2.5 and SO2 concentration using information from the U.S. EPA Environmental Benefits Mapping and Analysis Program (BenMAP) model.

LINKS AND REFERENCES	
KEYWORDS	● Air Quality ● Pollutant capture/removal ● Air Pollutants ● Forest Inventory Analysis
LINKS AND REFERENCES	● An impact evaluation framework to support planning and evaluation of nature-based solutions projects, An EKLIPSE Expert Working Group report, 2017, Centre for Ecology & Hydrology, UK. ● Nowak et. al., 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution 193, pg. 119-129. ● Tiwary et. al, 2009. An integrated tool to assess the role of new planting in PM10 capture and the human health benefits: A case study in London. Environmental Pollution 157, pg. 2645–2653 ● Forest Inventory and Analysis, Fiscal Year 2013 Business Report. 2014, United States Department of Agriculture Forest Service.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.1 | Air quality at district/city scale

INDICATOR	
NAME	**3.1.3 | APPCV – Annual amount of pollutants captured by vegetation**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe the annual amount of pollutants, captured by vegetation.
R2: Policy support for policies:	This indicator is an adaptation of the indicator CSI 004 of the European Environment Agency. The initial indicator as well as the proposed adaptation are relevant for the current European air quality legislation related to the protection of human health in the Air Quality Directives 2004/107/EC and 2008/50/EC (EU, 2004, 2008). The 7th EU Environment Action Programme (EU, 2013a) includes priority objectives that aim, among others, to protect, conserve and enhance the EU's natural capital, safeguard the EU's citizens from environment-related pressures and risks to health and wellbeing, and enhance the sustainability of the EU's cities. The EU Clean Air Policy Package, adopted by the European Commission on 18 December 2013, proposes in the Communication “A Clean Air Programme for Europe” (EU, 2013b) the short-term objective of achieving full compliance with existing legislation by 2020 at the latest.
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

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ACCEPTED	
A1: Policy makers:	Yes.
A2: Practitioners:	No
A3: Other stakeholders:	The indicator should be interesting for municipality officers. In fact large agglomerations already use this type of indicators throughout Europe.

CREDIBLE	
C1: Unambiguous results:	Yes, both the decision makers and the general public understand the message conveyed by the indicator.
C2: Transparency:	Yes, the indicator has a clear methodology
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Depending the cities data might be available in European Air Quality Database or not. If not it requires the deployment of new air quality monitoring stations. Data in the European Air Quality Database are updated annually.
E2: Technical feasibility:	No, very complex topic.
E3: Reproducibility:	The indicator is fully reproducible. The indicator has not been specifically used at city level, but The calculation of the initial indicator (at the level of European cities) already relies on calculations at city level. And large agglomerations throughout Europe already use this type of indicators.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	The indicator addresses the city scale only.

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3 | AIR QUALITY

3.2 | AIR QUALITY AT LOCAL SCALE

Short description of USC: At the local or street level, it is easier to locate places with worse air quality in the city for various reasons. Sometimes, in these places there are buildings such as schools or sports facilities where air quality should be especially cared.

3.2.1 | EAQLVlocal – AIR QUALITY LIMIT – LOCAL

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.2 | Air quality at local scale

INDICATOR	
NAME	**3.2.1 | EAQLVlocal – Exceedance of air quality limit value – local scale**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator shows the fraction of a given area (local) that is potentially exposed to ambient air concentrations of certain pollutants ($PM_{2.5}$, PM_{10} , O_3 , NO_2 , SO_2 and BaP) that are in excess of the EU limit or target values (EU, 2004, 2008) set for the protection of human health. This indicator is an adaptation at city scale of the indicator CSI 004 of the European Environment Agency : Exceedance of air quality limit values in urban areas.
FOCUS/OBJECTIVES	High population densities in urban areas and related economic activities result in increased emissions of air pollutants, which in turn lead to higher ambient concentrations of these pollutants and greater exposure to them. This indicator focuses on those pollutants that are more relevant in terms of their health effects and urban concentrations: PM — both PM_{10} (particles with a diameter of 10 micrometres or less) and fine PM or $PM_{2.5}$ (particles with a diameter of 2.5 micrometres or less); O_3; NO_2; sulfur dioxide (SO_2); and benzo[a]pyrene (BaP). According to different World Health Organization studies (WHO, 2000, 2006, 2013, 2014), exposure to PM can cause or aggravate cardiovascular and lung diseases, heart attacks and arrhythmias. It can also affect the central nervous system, the reproductive system and cause cancer. Exposure to high O_3 concentrations can cause breathing problems, trigger asthma, reduce lung function and cause lung diseases. Exposure to NO_2 increases symptoms of bronchitis in asthmatic children and reduces lung function growth. SO_2 can affect the respiratory system and the functions of the lungs, and causes irritation of the eyes.

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	Finally, BaP is carcinogenic, and is used as an indicator of the carcinogenic effect of the total polycyclic aromatic hydrocarbons (PAHs).

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	● Area population ● Share of population living closer than 100 meters from major roads ● The following data are needed from at least one "urban traffic" station (i.e. located closer than 100 meters from a major road) and one "urban background" station (i.e. located farer than 100 meters from a major road): ○ Daily $PM_{2.5}$ concentration ○ Daily PM_{10} concentration ○ Hourly 0_3 concentration ○ Daily NO_2 concentration ○ Daily SO_2 concentration ○ Daily BaP concentration ● In case of several stations of the same type the location of the different stations as well as the spatial distribution of the population can be used to derive allocation rules in terms of population exposure.
INPUT TYPE (qualitative, quantitative, …)	● quantitative
DATA SOURCE	For main cities throughout Europe useful data can be found in the following sources: ● Information on cities is obtained from the **Urban Audit (UA)** data (Eurostat, 2014c). UA data collection, maintained by Eurostat, provides information and comparable measurements on the different aspects of the quality of urban life in selected European cities. The urban population considered is the total number of people represented by any of the urban monitoring stations. https://www.eea.europa.eu/data-and-maps/data/external/gisco-urban-audit-2004 ● **City population**: https://www.eea.europa.eu/data-and-maps/data/external/city-population ● **Air quality measurements** can be obtained from: ○ Air Quality e-Reporting (AQ e-Reporting), provided by European Commission: https://www.eea.europa.eu/data-and-maps/data/aqereporting-2 ○ AirBase – TheEuropean air quality database, provided by the European Environment Agency: https://www.eea.europa.eu/data-and-maps/data/aqereporting-2#tab-data-by-country

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	• National data on the population living closer than 100 metres from major roads have been taken from: ENTEC, 2006. Development of a methodology to assess population exposed to high levels of noise and air pollution close to major transport infrastructure , Final Report April 2006, Entec UK Limited
FREQUENCY (how often to use this indicator?)	• yearly
MEASUREMENT UNIT	• Micrograms (mg) of pollutant per cubic meter for $PM_{2.5}$, PM_{10}, O_3, NO_2 and SO_2. • Nanograms (ng) of pollutant per cubic metre for BaP.
REQUIRED TOOL	• Air quality measurement stations
CALCULATION METHOD	**Population exposure** Two types of monitoring stations are considered, classified as 'urban traffic', and 'urban background'. The “urban traffic” stations represent the environmental conditions of places located closer than 100 meters from major roads. The “urban background” stations represent the average environmental conditions in the city. The percentage of the city population living closer than 100 meters from major roads is used to allocate exposure of the city population to the two types of environmental conditions. In case there are several stations of the same type an allocation rule has to be established to allocate the population to the different stations of the same type. This indicator is usually used at city scale where averaging effects come to play. These averaging effects won’t be effective ate a smaller scale. Thus the allocation of populations to the different monitoring stations becomes a key issue. A proper methodology with this regard has to be developed; number of monitoring stations, locations of the monitoring stations, allocation of population to the different station, … **EU limit and target values** <u>Particulate matter ($PM_{2.5}$)</u> The annual mean concentration is calculated for each of the selected stations. Depending on the mean concentration, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (below or equal to the target value (25 µg/m3), or above it). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each concentration class by the sum of the population assigned to each station. <u>Particulate matter (PM_{10})</u> For each selected station, the 90.4 percentile (P90.4) of the daily mean concentration series is calculated. P90.4 represents, in a complete series of 365 elements, the 36th highest value. When P90.4 is below or equal to 50 µg/m3, it indicates that the daily limit value (DLV) would not have been exceeded on more than 35 days. Depending on the value of P90.4, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (P90.4 > 50 µg/m3, i.e. above the DLV and P90.4 ≤ 50 µg/m3, i.e. below the DLV). The percentage of the urban population allocated to these two concentration classes is calculated by dividing

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	the population represented by the stations assigned to each individual concentration class by the sum of the population assigned to each station. <u>Ozone (O_3)</u> For each selected station, the 93.2 percentile (P93.2) of the daily maximum 8-hourly mean concentration series is calculated. P93.2 represents, in a complete series of 365 elements, the 26th highest value. When P93.2 is below or equal to 120 µg/m3, it indicates that the long term objective would have not been exceeded on more than 25 days. Depending on the value of P93.2, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (P93.2 > 120 µg/m3, i.e. exceedance of the long term objective on more than 25 days, and P93.2 ≤ 120 µg/m3, i.e. exceedance of the long term objective is less than or equal to 25 days). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each individual concentration class by the sum of the population assigned to each station. <u>Nitrogen dioxide (NO_2)</u> The annual mean concentration is calculated for each of the selected stations. Depending on the annual mean concentration, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (below or equal to the limit value (40 µg/m3), or above the limit value). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each concentration class by the sum of the population assigned to each station <u>Benzo[a]pyrene (BaP)</u> The annual mean concentration is calculated for each of the selected stations. Depending on the mean concentration, each station (and its allocated population) is then classified uniquely in one of the two concentration classes (below or equal to the target value (1.0 ng/m3), or above the target value). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each concentration class by the sum of the population assigned to each station. <u>Sulfur dioxide (SO_2)</u> For each selected station, the 99.2 percentile (P99.2) of the daily mean concentration series is calculated. P99.2 represents, in a complete series of 365 elements, the 4th highest value. When P99.2 is below or equal to 125 µg/m3, it indicates that the daily limit value would have not been exceeded on more than three days. Depending on the value of P99.2, each station (and its allocated population) is then classified uniquely in one of these two concentration classes (P99.2 > 125 µg/m3, i.e. above the daily limit value and P99.2 ≤ 125 µg/m3, i.e. below the daily limit value). The percentage of the urban population allocated to these two concentration classes is calculated by dividing the population represented by the stations assigned to each individual concentration class by the sum of the population assigned to each station

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	Data quality For PM_{10}, $PM_{2.5}$, O_3, NO_2 and SO_2, only stations with at least 75 % of valid data per calendar year are used. That is, in the case of daily values, those having more than 274 valid daily values per calendar year (or 275 days in a leap year). And in the case of hourly values, having more than 6 570 valid hourly values per calendar year (or 6 588 hours in a leap year). For BaP, the minimum data time coverage accepted is 14 % (51 days), according to the data quality objectives related to indicative measurements in the Directive 2004/107/EU (EU, 2004).
OUTPUT TYPE	• Percentage of the area population exposed to annual $PM_{2.5}$ concentrations above 25 µg/m3. • Percentage of the area population exposed to daily PM_{10} concentrations exceeding 50 µg/m3 for more than 35 days a year. • Percentage of the area population exposed to maximum daily 8-hour mean O_3 concentrations exceeding 120 µg/m3 for more than 25 days a year. • Percentage of the area population exposed to annual NO_2 concentrations above 40 µg/m3 • Percentage of the area population exposed to annual BaP concentration above 1.0 ng/m3
EXAMPLES	• **No example**s, this indicator is proposed as an adaptation of EEA CSI 004 indicator (Exceedance of air quality limit values in urban areas) that is an indicator at European level.

LINKS AND REFERENCES	
KEYWORDS	• Air quality • Air pollution • Health • Particulate matter • NO2 • SO2 • Ozone • Benzo[a]pyrene
LINKS AND REFERENCES	• European Environment Agency – Exceedance of air quality limit values in urban areas, indicator CSI 004 : https://www.eea.europa.eu/data-and-maps/indicators/exceedance-of-air-quality-limit-3 • European Environment Agency – Exceedance of air quality limit values in urban areas, indicator CSI 004 : https://www.eea.europa.eu/data-and-maps/indicators/exceedance-of-air-quality-limit-3/assessment-2 • EU, 2004 : Directive 2004/107/EC of the European Parliament and of the Council of 15 December 2004 relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32004L0107 • EU, 2008 : Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. http://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX:32008L0050

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	3 | Air quality	3.2 | Air quality at local scale

INDICATOR	
NAME	**3.2.1 | EAQLVlocal – Exceedance of air quality limit value – local scale**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable if describing the exceedance of air quality limit values at city scale which can be considered as an initial planning problem.
R2: Policy support for policies:	This indicator is an adaptation of the indicator CSI 004 of the European Environment Agency. The initial indicator as well as the proposed adaptation are relevant for the current European air quality legislation related to the protection of human health in the Air Quality Directives 2004/107/EC and 2008/50/EC (EU, 2004, 2008). The 7th EU Environment Action Programme (EU, 2013a) includes priority objectives that aim, among others, to protect, conserve and enhance the EU's natural capital, safeguard the EU's citizens from environment-related pressures and risks to health and wellbeing, and enhance the sustainability of the EU's cities. The EU Clean Air Policy Package, adopted by the European Commission on 18 December 2013, proposes in the Communication "A Clean Air Programme for Europe" (EU, 2013b) the short-term objective of achieving full compliance with existing legislation by 2020 at the latest.
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

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ACCEPTED	
A1: Policy makers:	The initial indicator (at the level of European cities) is used to assess existing air quality policies. The calculation of the initial indicator (at the level of European cities) relies on calculations at city level. The adaptation proposed at local scale could be used to assess the policies at local scale. But it isn't the focus of policy makers.
A2: Practitioners:	The indicator has the potential to be used by urban planners in municipalities, to monitor the effect of their planning activities over time.
A3: Other stakeholders:	The indicator should be interesting for municipality officers. In fact large agglomerations already use this type of indicators but at city scale.

CREDIBLE	
C1: Unambiguous results:	Yes, both the decision makers and the general public understand the message conveyed by the indicator.
C2: Transparency:	This indicator is usually used at city scale where averaging effects come to play. These averaging effects won't be effective ate a smaller scale. Thus the allocation of populations to the different monitoring stations becomes a key issue. A proper methodology with this regard has to be developed; number of monitoring stations, locations of the monitoring stations, allocation of population to the different station, …
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions can be fully disclosed. But some assumptions still need to be decided.

EASY	
E1: Availability of data to calculate the indicator:	The acquisition of air quality data at local scale requires the deployment of new air quality monitoring stations.
E2: Technical feasibility:	No, very complex topic.
E3: Reproducibility:	The indicator is fully reproducible. It has not been used at local level.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	The indicator addresses the local scale only.

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4 | BIODIVERSITY AND URBAN SPACE

Short description of UC: The major part of urban areas are actually strongly anthropized or in the dense urban environment and this is where almost 70% of human beings are expected to live by 2050 (Burghardt et al., 2015; Morel et al., 2017). Also, there are a number of significant factors that are converging and forcing a re-examination of the way cities are planned, designed and lived in (James et al., 2009). One of this way is to reconsider the management of the urban areas in using more green or natural spaces.

Many urban areas contain sites of significant nature conservation value such as wetlands, grassland or and ancient woodlands, which can often be of local, regional or national importance. However, urban landscape is more often characterised by fragmented sites, which only have local community importance such as gardens, allotments, churchyards and school grounds. The remaining biodiversity in these urban areas can be found in small remnant pockets of habitat that have intense development pressure on them due to their urban nature.

4.1 | BIODIVERSITY

Short description of USC: Biodiversity has been defined in various ways (Salwasser, 1990) but the term has generally been used in a very comprehensive manner meaning the variability of life (composition, structure and function). Biodiversity can be represented as an inter-locked hierarchy of elements on several levels of biological organization (Noss, 1992). Since the term `biodiversity' transcends all levels of life from genes to communities and all spatial and temporal scales (Noss, 1990; Savard, 1994), it has generated a lot of confusion and misunderstanding (Lautenschlager, 1997).

4.1.1 | UGSP – URBAN GREEN SPACE PROP.

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.1 | UGSP - Urban Green Space Proportion**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION(☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DESCRIPTION	Different indicators may represent proportion of green space v:s built areas and can be derived from land use and land cover geodatabases at different scales. In this case, we use the ratio of green or natural space on the total space
OBJECTIVES	The objective is to determine if the NBS solution increases or maintains the proportion of areas supporting biodiversity (which could be named Green Areas) in the city

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• geographical data of land use / land cover • typology of areas supporting biodiversity : depending on the type of biodiversity supposed to be considered in the region and the type of habitats • cartography of the areas supporting biodiversity within the NBS solution
TYPE OF DATA	• spatial data
SOURCE	Different sources may be used, depending on the NBS scale and the type of habitats defined in the attended typology • Corine Land Cover (at the big city scale) • National databases (ex. Urban Atlas (only for big cities) ; OSGE in France…) • Local spatial databases • Statistic databases (without spatialization)
FREQUENCY	
MEASUREMENT UNIT	Surface or proportion
REQUIRED TOOL	• GIS
CALCULATION METHOD	Gis analysis
FORMULA	(Surface of "green areas" in the city or neighbourhood after NBS - Surface of "green areas" in the city or neighbourhood before NBS) / Surface of the city or neighbourhood
OUTPUT	• numerical value • maps
EXAMPLES	• UGS • BULF

LINKS AND REFERENCES	
KEYWORDS	• Green areas • Green spaces • Proportion of land use • Typology of green areas depending on land cover or land use
LINKS AND REFERENCES	• Badiu, D. L., Iojă, C. I., Pătroescu, M., Breuste, J., Artmann, M., Niță, M. R., ... & Onose, D. A. (2016). Is urban green space per capita a valuable target to achieve cities' sustainability goals? Romania as a case study. Ecological Indicators, 70, 53-66. • Cochard, A., Pithon, J., Jagaille, M., Beaujouan, V., Pain, G. et Daniel, H. (2017) Grassland plant species occurring in extensively managed road verges are filtered by urban environments. Plant Diversity & Ecology.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.1 | UGS - Urban Green Space Proportion**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. maintain a green/grey ratio.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) Report on Mitigation of Climate Change (2014)
R3: Comparability:	It is possible to standardise the methodology, in order to provide fully comparable results if standardised cartographies exist

ACCEPTED	
A1: Policy makers:	Yes, see for example Badiu et al., (2016)
A2: Practitioners:	Yes, it is used in planning documents to avoid urban sprawl
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message and coherences of the Urban Green Space Proportion
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes and no, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states, but spatial databases describing semi-natural areas may differ between cities and biodiversity conservation objectives

EASY	
E1: Availability of data to calculate the indicator:	Need of typology and maps
E2: Technical feasibility:	If maps exist, calculation is easy with GIS and tools provided by Landscape Ecology extensions
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized typologies,).

ROBUST	
R1: Data quality:	Input data for calculation are land cover and land use maps or other data (satellite or aerial images) from which areas favourable for biodiversity can be derived, but interpretation may differ depending on biodiversity objectives.
R2: Sensitiveness:	Not really
R3: Scale:	Yes, depending actually on the used resolution.

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4 | BIODIVERSITY AND URBAN SPACE

4.1 | BIODIVERSITY

4.1.2 | SDIH – Shannon Div. Ind. of Habitats

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.2 | SDIH – Shannon Diversity Index of Habitats**
COMPLEXITY LEVEL (□ | ☒) see legend below	☒ 1 □ 2 □ 3 □ 4 □ 5
INDICATOR LEVEL (□ | ☒)	□ 1st ☒ 2nd □ 3rd
AGGREGATION(□ | ☒)	☒ Yes □ No
TYPE (□ | ☒)	☒ Descriptive ☒ Assessment ☒ Monitoring
SCALE (□ | ☒)	□ City □ Neighbourhood ☒ Object
DESCRIPTION	This indicator correspond to Shannon diversity index (Nagendra, 2002) between the proportion of bare and turf grass, of rough grassland and herbs, of shrubs, of trees and of built environment.
OBJECTIVES	• Complexity of the vegetation structure • Potential for others taxa biodiversity

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Proportion of each class of habitat
TYPE OF DATA	• quantitates
SOURCE	• field survey or NBS project • or digital GIS-based models when suffieciently accurate data are available (spatial resolution of 1 meter)
FREQUENCY	• One to several times in planning process.

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MEASUREMENT UNIT	• No unit
REQUIRED TOOL	• spreadsheet methods • or GIS-based models (spatial resolution of 1 meter)
CALCULATION METHOD	• Measurement, but difficult to extract effect of NBS
FORMULA	$D = -\sum_{i=1}^{5} (p_i \log_2 p_i)$ … Where pi correspond to the proportion of each of the five kind of habitat
OUTPUT	• numerical value • graphics

EXAMPLES

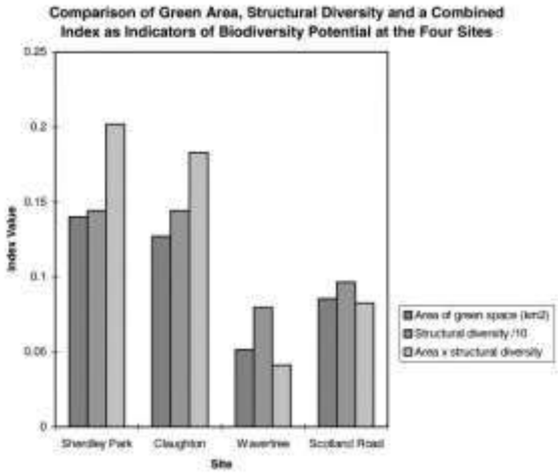

Figure from Whitford et al., (2001)

LINKS AND REFERENCES

KEYWORDS	• Green space biodiversity • Plant communities structure
LINKS AND REFERENCES	• Cornelis, Johnny, and Martin Hermy. “Biodiversity Relationships in Urban and Suburban Parks in Flanders.” Landscape and Urban Planning 69, no. 4 (October 30, 2004): 385–401. doi:10.1016/j.landurbplan.2003.10.038. • Nagendra, H. (2002). Opposite trends in response for the Shannon and Simpson indices of landscape diversity. *Applied Geography*, *22*(2), 175-186. • Whitford, V., A. R. Ennos, and J. F. Handley. “‘City Form and Natural Process’—indicators for the Ecological Performance of Urban Areas and Their Application to Merseyside, UK.” Landscape and Urban Planning 57, no. 2 (November 20, 2001): 91–103. doi:10.1016/S0169-2046(01)00192-X

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	4.1.2 | SDIH – Shannon Diversity Index of Habitats

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. vegetation characteristics.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure
R3: Comparability:	Yes, it's possible to standardise the methodology, in order to provide fully comparable results

ACCEPTED	
A1: Policy makers:	So far it is not known.
A2: Practitioners:	Yes
A3: Other stakeholders:	Yes

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public can understand this indicator which is at least partially consistent with visual perception of the NBS
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying field methodologies are available, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Need of rapid field survey.
E2: Technical feasibility:	Calculation is very easy but need field data
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, …).

ROBUST	
R1: Data quality:	Input data are real data collected on the field.
R2: Sensitiveness:	Not specifically for this indicator, but it exist for other field cover estimate.
R3: Scale:	No, mainly at local scale (object lower than 1 meter).

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4.1.3| IAS

4 | BIODIVERSITY AND URBAN SPACE

4.1 | BIODIVERSITY

4.1.3 | IAS - Number of invasive alien species

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.3 | IAS - Number of invasive alien species**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION	„Invasive Alien Species (IAS) are animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative consequences for their new environment. They represent a major threat to native plants and animals [...]" http://ec.europa.eu/environment/nature/invasivealien/index_en.htm
OBJECTIVES	• No alien invasive species within NBS or at least limit their number and ecological impact

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Regional, national and international lists of alien invasive species
TYPE OF DATA	• Field inventories of species
SOURCE	• International and national species list
FREQUENCY	
MEASUREMENT UNIT	Species richness
REQUIRED TOOL	• Liste of alien invasive species at several scales
CALCULATION METHOD	Count of species
OUTPUT	• numerical value
EXAMPLES	• Pyšek, Petr, and David M. Richardson. “Invasive Species, Environmental Change and Management, and Health.” Annual Review of Environment and Resources 35, no. 1 (2010): 25–55. doi:10.1146/annurev-environ-033009-095548. • Delivering Alien Invasive Species Inventories for Europe - http://www.europe-aliens.org/

LINKS AND REFERENCES	
KEYWORDS	• Green areas • Green spaces • Invasive species
LINKS AND REFERENCES	• Kohsaka, R., Pereira, H.M., Elmqvist, T., Chan, L., Moreno-Peñaranda, R., Morimoto, Y., Inoue, T., Iwata, M., Nishi, M., Mathias, M. da L., Cruz, C.S., Cabral, M., Brunfeldt, M., Parkkinen, A., Niemelä, J., Kulkarni-Kawli, Y., Pearsell, G., 2013. Indicators for Management of Urban Biodiversity and Ecosystem Services: City Biodiversity Index, in: Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Springer, Dordrecht, pp. 699–718. doi:10.1007/978-94-007-7088-1_32. • Lososová, Z., Chytrý, M., Tichý, L., Danihelka, J., Fajmon, K., Hájek, O., ... & Řehořek, V. (2012). Native and alien floras in urban habitats: a comparison across 32 cities of central Europe. Global Ecology and Biogeography, 21(5), 545-555.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	4.1.3 | IAS - Number of invasive alien species

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, at the design NBS step.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Regulation 1143/2014 on Invasive Alien Species • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure
R3: Comparability:	Yes, it’s possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Yes, mainly at more local scales.
A2: Practitioners:	Yes
A3: Other stakeholders:	Yes, there is a very extensive bibliography on this subject. While several articles discuss the consequences of biological invasions, many authors advocate avoiding invasive alien species because of potential management problems.

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public can understand this indicator.
C2: Transparency:	Yes, it has. It's important to be able to refer to clearly defined lists of invasive alien species on a national or European scale
C3: Documentation of assumptions and limitations:	Yes, underlying field methodologies are available, interpretable and reproducible and can be applicate in all EU member states. It's important to be able to refer to clearly defined lists of invasive alien species on a national or European scale

EASY	
E1: Availability of data to calculate the indicator:	Need of field survey and alien invasive species list. For the European scale the DAISIE list of species can be used (http://www.europe-aliens.org/)
E2: Technical feasibility:	Calculation is very easy but need field data
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, …).

ROBUST	
R1: Data quality:	Input data are real data collected on the field.
R2: Sensitiveness:	Not specifically for this indicator, but attention should be given to taxonomic groups included in the analysis.
R3: Scale:	No, mainly at local scale.

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4.1.4| PALHB

4 | BIODIVERSITY AND URBAN SPACE

4.1 | BIODIVERSITY

4.1.4 | PALHB – POTENTIAL AREA HOST BIODIVERSITY

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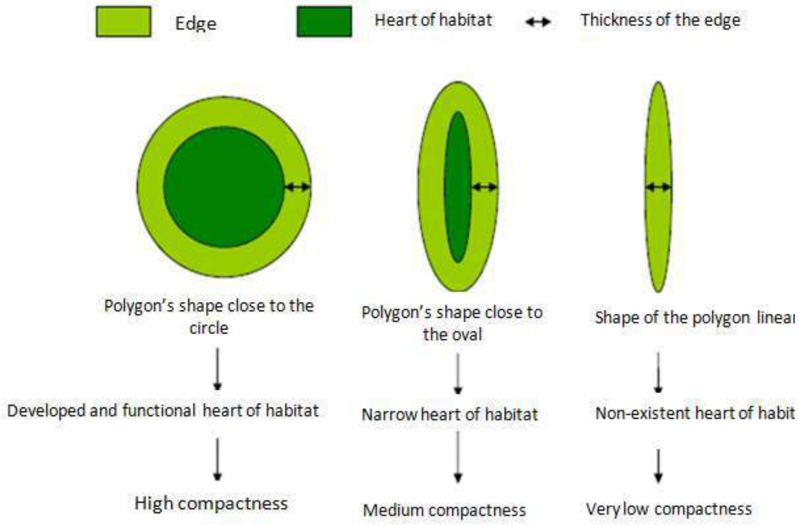
Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	**4 | Biodiversity and urban space**	**4.1 | Biodiversity**

INDICATOR	
NAME	**4.1.4 | PALHB - Potential of areas likely to host biodiversity**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DESCRIPTION	This indicator enables to highlight the natural areas susceptible to accommodate a higher level of biodiversity due to their size and shape. Moreover, the use of a DHM can make it possible to highlight the mineralized areas (such as city squares for example). 
OBJECTIVES	• Indicate the level of compactness-surface of green spaces • indicate the green spaces likely to accommodate a higher level of diversity

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	• indicate mineralized areas that may be more vegetated (like major city squares)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Geodatabase of land use / land cover
TYPE OF DATA	• GIS Files : shape
SOURCE	• Corine Land Cover • National databases (ex. Urban Atlas (only for big cities) ; OSGE in France…) ; BD TOPO • Local spatial databases / green cadastre
FREQUENCY	
MEASUREMENT UNIT	Compactness-surface of green spaces from 1 (very low) to 5 (very high) Mineralized areas likely to accommodate vegetation (flat areas)
REQUIRED TOOL	• GIS
CALCULATION METHOD	Gis analysis
FORMULA	Compactness-Surface = ((4*Area*pi) / (Periemter²)) * Area
OUTPUT	• numerical value • maps
EXAMPLES	• AUAT → planning agency of Toulouse • GREET ingénerie → Nord-Pas-de-Calais

LINKS AND REFERENCES	
KEYWORDS	Green areas Green spaces Connectivity
LINKS AND REFERENCES	AUAT. (2015). Pour une approche globale du fonctionnement écologique potentiel des territoires, 8. Direction Régionale de l'Environnement Nord-Pas-de-Calais. (2008). *Analyse des potentialités écologiques du territoire régional,* 66. Greet Ingenierie, & Conservatoire Botanique National de Bailleul. (2008). Actualisation de l'inventaire des sites d'intérêt écologique de l'arrondissement de Lille, 33.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	4.1.4 | PALHB - Potential of areas likely to host biodiversity

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. lack of biodiversity and lack of habitats.
R2: Policy support for policies:	It is related to environmental policies that objectives are to maintain and restore habitats and biodiversity
R3: Comparability:	Yes, it's possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes and no, it is a very good and potential indicator for easy communication purpose, because people understand it, but the data generating and calculation requires GIS expert knowledge so far.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. territorial communities, planning agencies, …)

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message and coherences of the potential of areas likely to host biodiversity
C2: Transparency:	The part concerning the compactness-surface has a clear methodology based on land cover and land use data the value is calculated. But not the part on the "mineralized areas that may be more vegetated". This part has not a clear methodology yet.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states except for the part using the DNH because this data is not provided for all cities and it is very expensive.

EASY	
E1: Availability of data to calculate the indicator:	Basically a part of the indicator can be calculated with data that has already been collected, for example Urban atlas, or IGN product like BD topo, OCSGE. It can be calculated with land use and land cover database that describe enough the green spaces. If we study more precisely the mineralize area, the DNH has to be produced.
E2: Technical feasibility:	It requires special software (GIS software). But have a clear input and methodology to avoid ambiguity and implementation errors.
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases. The Compactness-surface of green spaces has been used in different location (different cities in France) and it delivered reasonable results. The second part of this indicator has not been used in different cases yet.

ROBUST	
R1: Data quality:	Input data for simulation model are robust data because they are produced by public institutions.
R2: Sensitiveness:	No such assessments or estimations. The uncertainty of the result resides in the accuracy of the input land cover and land use dataset.
R3: Scale:	Yes, depending actually on the resolution.

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4.1.5| RNPS

4 | BIODIVERSITY AND URBAN SPACE

4.1 | BIODIVERSITY

4.1.5 | RNPS – RATIO NATIVE PLANT SPECIES

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.5 | RNPS - Ratio of Native Plant Species**
COMPLEXITY LEVEL (□ | ☒) see legend below	□ 1 ☒ 2 □ 3 □ 4 □ 5
INDICATOR LEVEL (□ | ☒)	□ 1st ☒ 2nd □ 3rd
AGGREGATION(□ | ☒)	☒ Yes □ No
TYPE (□ | ☒)	☒ Descriptive ☒ Assessment ☒ Monitoring
SCALE (□ | ☒)	□ City □ Neighbourhood ☒ Object
DESCRIPTION	The ratio between the number of native plant species and the total plant species richness (total number of species). Native species are naturally present in the considered biogeographical area.
OBJECTIVES	• Increase the number of native species. • Increase the degree of naturality of NBS. • Increase the potential of biodiversity

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	● Plant species composition (identification of each species) ● Total plant species richness ● Plant species richness in native species (national or regional indigenous species list)
TYPE OF DATA	● Field data (quantitative and qualitative)
SOURCE	● List of regional or national native flora
FREQUENCY	Before (description) and after the creation of NBS (assessment and monitoring)
MEASUREMENT UNIT	Percentage of species
REQUIRED TOOL	● Botanical skills
CALCULATION METHOD	Simple mathematical formula
FORMULA	(Number of native species / total number of species)*100
OUTPUT	● Numerical value ● Vegetation characteristics
EXAMPLES	● Kohsaka, R., Pereira, H. M., Elmqvist, T., Chan, L., Moreno-Peñaranda, R., Morimoto, Y., ... & Cruz, C. S. (2013). Indicators for management of urban biodiversity and ecosystem services: City Biodiversity Index. In Urbanization, biodiversity and ecosystem services: challenges and opportunities (pp. 699-718). Springer Netherlands. ● Lososová, Z., Chytrý, M., Tichý, L., Danihelka, J., Fajmon, K., Hájek, O., ... & Řehořek, V. (2012). Native and alien floras in urban habitats: a comparison across 32 cities of central Europe. Global Ecology and Biogeography, 21(5), 545-555.

LINKS AND REFERENCES	
KEYWORDS	● Species richness ● Native species (or indigenous species) ● Naturality ● Plant species ● Biodiversity potential
LINKS AND REFERENCES	● Kohsaka, R., Pereira, H. M., Elmqvist, T., Chan, L., Moreno-Peñaranda, R., Morimoto, Y., ... & Cruz, C. S. (2013). Indicators for management of urban biodiversity and ecosystem services: City Biodiversity Index. In Urbanization, biodiversity and ecosystem services: challenges and opportunities (pp. 699-718). Springer Netherlands. ● Lososová, Z., Chytrý, M., Tichý, L., Danihelka, J., Fajmon, K., Hájek, O., ... & Řehořek, V. (2012). Native and alien floras in urban habitats: a comparison across 32 cities of central Europe. Global Ecology and Biogeography, 21(5), 545-555.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.5 | RNPS - Ratio of Native Plant Species**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. maintain native plant species.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure
R3: Comparability:	Yes, it’s possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	I think so but I don’t have example.
A2: Practitioners:	Yes, but it requires botanical skills.
A3: Other stakeholders:	Yes, but it requires botanical skills.

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public can understand and accept this indicator which is a least partially consistent with the desire to improve the level of biodiversity.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying field methodologies are available, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Need of rapid field survey, and a national or regional list of native species.
E2: Technical feasibility:	Calculation is very easy but need field data
R3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, different climate region).

ROBUST	
R1: Data quality:	Input data are real data collected on the field.
R5: Sensitiveness:	No applicable for this indicator. This indicator is based on the ratio between data directly collected in the fied (number of species). The uncertainty lies in the ability to identify plants species and to find out whether they are native or not.
R8: Scale:	No, mainly at local scale.

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4 | BIODIVERSITY AND URBAN SPACE

4.1 | BIODIVERSITY

4.1.6 | PSL – LAND USE IMPACTS BIODIVERSITY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.6 | PSL - Land Use and associated impacts on biodiversity**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood *Can be adapted to the system under study* ☒ Object
DEFINITION	The indicator selected is the potential species loss (PSL) from land use based on the method described by Chaudhary et al. (2015). The indicator represents regional species loss taking into account the effect of land occupation displacing entirely or reducing the species that would otherwise exist on that land, the relative abundance of those species within the ecoregion, and the overall global threat level for the affected species. The indicator can be applied both as a regional indicator (PSLreg), where changes in relative species abundance within the ecoregion is included, and as a global indicator (PSLglo) where also the threat level of the species on a global scale is included. The indicator covers five taxonomic groups; birds, mammals, reptiles, amphibians, and vascular plants. The taxonomic groups can be analyzed separately or can be aggregated to represent the potentially disappeared fraction (PDF) of species. Land use types covered by the method include intensive forestry, extensive forestry, annual crops, permanent crops, pasture, and urban land. The reference state is a current natural or close to natural habitat in the studied ecoregion
FOCUS/OBJECTIVES	● Prevent biodiversity losses ● Consider land use as a proxy for biodiversity

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Land occupation and transformation flows
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Urban metabolism/Material Flow Analysis • Life cycle inventory databases
FREQUENCY (how often to use this indicator?)	• Updates are needed when land occupation and/or transformation is changing
MEASUREMENT UNIT	• Global species equivalent lost
REQUIRED TOOL	• LCA tools such as openLCA • EPESUS tool • Simple matrix based calculation (MS Excel possible)
CALCULATION METHOD	• The model provides characterization factors down to 804 ecoregions based on Olson et al. (2001), as well as country level and global average characterisation factors. The characterization factors are provided by taxon for both land occupation in global species eq. lost/m^2 and land transformation in global species eq. lost × year/m^2, or aggregated across taxa as global PDF/m^2 and land transformation in global PDF × year/m^2. The model includes both average and marginal factors.
OUTPUT TYPE	• Numerical value
EXAMPLES	• Chaudhary et al. (2016), Impact of forest management on species richness: global meta-analysis and economic trade-offs. • Chaudhary et al. (2016), Land use biodiversity impacts embodied in international food trade.

LINKS AND REFERENCES	
KEYWORDS	• Resource • Resource depletion • Life Cycle Assessment • Land Occupation • Land Transformation • Land Use • Biodiversity

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

LINKS AND REFERENCES	• Chaudhary et al. (2015), Quantifying Land Use Impacts on Biodiversity: Combining Species–Area Models and Vulnerability Indicators, *Environ. Sci. Technol.*, 49 (16), pp 9987–9995 • Olson et al. (2001), Terrestrial Ecoregions of the World: A New Map of Life on Earth, *BioScience*, 51(11):933-938

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and green space	4.1 | Biodiversity

INDICATOR	
NAME	**4.1.6 | PSL - Land Use and associated impacts on biodiversity**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable of describing initial planning problems (through comparison with references). The indicator includes local (regional) specificities.
R2: Policy support for policies:	• 2011 Road Map for Resource-Efficient Europe (part of Europe 2020 strategy) • EU Land Policy • EU biodiversity strategy to 2020
R3: Comparability:	Although this indicator is recommended by the UNEF-SETAC Life Cycle Initiative, few existing studies have been performed using this indicator. Thus, comparability with this indicator can be difficult.

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ACCEPTED	
A1: Policy makers:	Not yet. This indicator is related to some policies but not directly applied/tested in their development.
A2: Practitioners:	The indicator is not used by urban planners for the time being but it definitively has the potential to be used. It could provide an interesting information about land use (even though it is, for the time being, probably not sufficiently detailed to be relevant for urban areas)
A3: Other stakeholders:	This indicator is described and discussed in several peer-reviewed publications. He is accepted by the scientific community but not known by other stakeholders (local authorities, etc.)

CREDIBLE	
C1: Unambiguous results:	Results are unambiguous. The potential use of the PDF (Potentially Disappeared Fraction) unit can facilitate the understanding of this indicator by the general public.
C2: Transparency:	Yes and available in peer reviewed papers and also in other international publications.
C3: Documentation of assumptions and limitations:	Yes, the references given in the indicator factsheet are fully disclosed and ensure a uniform application in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Most of the data needed are existing or are expected to be available within the project. Some data refinements might be needed depending on the system under study (but these refinements are planned in the project)
E2: Technical feasibility:	Even though, in comparison to other LCA-based indicators, this one is not implemented in commercially available software, it can be easily calculated. All the needed information has been document both by the authors and by the UNEP-SETAC Life Cycle Initiative while recommending this indicator.
E3: Reproducibility:	

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	The uncertainty associated with this indicator can be easily calculated using statistical methods such as Monte-Carlo analysis.
R3: Scale:	Yes, it could.

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4 | BIODIVERSITY AND URBAN SPACE

4.2 | URBAN SPACE DEVELOPMENT AND REGENERATION

Short description of USC: Urban green space development can be defined as the voluntary action of the urban planners to organize and equip the spaces in the city. Applying NBSs during urban regeneration, the role of Biodiversity is rather important, as it is the basis of a well functioning green space. The complexity of an ecosystem should be the model for the concept of planning and implementation process. If biodiversity is rich, it can serve well the long-term maintenance and self regeneration processes. By measuring the distribution and connection of green spaces in a city, indicators can help to determine where the green network requires development.

4.2.1 | BAF – BIOTOPE AREA FACTOR

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.2 | Urban space development and regeneration

INDICATOR	
NAME	**4.2.1 | BAF - BIOTOPE AREA FACTOR**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DESCRIPTION	The BAF is calculated by dividing the amount of surface area available for nature and vegetation by the total surface area considered. Each type of soil / ground cover / land use is affected a coefficient related to its potential for vegetation growth & nature implementation (e.g. sealed surface = 0; semi-permeable = 0.3; green wall = 0.5; green roof = 0.7; in-ground plantations = 1). Thresholds and goals can then be determined based on the expected performance or current land use / urban planning objectives (e.g. the City of Berlin expects BAF to be produced for each new project – the result must be between 0.3 and 0.6, depending of the project's nature). The BAF takes values between 0 and 1. It increases with in-ground planted areas.
OBJECTIVES	• To describe / maximize the amount of surface area available for greening / planting • To set goals or thresholds relative to expected performances, local urban planning rules, soil preservation, local offer in nature / open space / green space

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data

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4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Land use map • Ground cover / surface materials
TYPE OF DATA	• surface area
SOURCE	• Geodatabase of land use / land cover
FREQUENCY	• Once, during conception, to characterize the project • Before / after the project's implementation, to characterize it is effects on the local environment
MEASUREMENT UNIT	• %
REQUIRED TOOL	• GIS
CALCULATION METHOD	• GIS analysis
FORMULA	$\text{BAF} = \dfrac{\text{ecologically-effective surface areas}}{\text{total land area}}$
OUTPUT	• Numerical value • Map
EXAMPLES	• In Berlin: http://www.berlin.de/senuvk/umwelt/landschaftsplanung/bff/index_en.shtml • In Paris (French): http://www.dailymotion.com/video/x1k7qby

LINKS AND REFERENCES	
KEYWORDS	• Land use • Green potential • Green spaces / open spaces • Ground cover
LINKS AND REFERENCES	• Becker, G. M. R., & Mohren, R. (1990). The Biotope Area Factor as an Ecological Parameter. *Landschaft Planen & Bauen, Berlin. Available: http://www. stadtentwicklung. berlin. de*, 24. • Liénard, S., & Clergeau, P. (2011). Trame Verte et Bleue: Utilisation des cartes d'occupation du sol pour une première approche qualitative de la biodiversité. *Cybergeo: European Journal of Geography* . • Huang, P.-S., Tsai, S.-M., Lin, H.-C., Tso, I.-M., 2015. Do Biotope Area Factor values reflect ecological effectiveness of urban landscapes? A case study on university campuses in central Taiwan. Landsc. Urban Plan. 143, 143–149. doi:10.1016/j.landurbplan.2015.07.004 • Pao-Shen Huang, Su-Mei Tsai, Hui-Chen Lin, I-Min Tso, Do Biotope Area Factor values reflect ecological effectiveness of urban landscapes? A case study on university campuses in central Taiwan, In Landscape and Urban Planning, Volume 143, 2015, Pages 143-149, ISSN 0169-2046, https://doi.org/10.1016/j.landurbplan.2015.07.004. (http://www.sciencedirect.com/science/article/pii/S0169204615001425) • Taking biodiversity into account in local urban planning rules : a synthesis from the French Ministry for Housing and Territorial Equality (French) – (link)

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.2 | Urban space development and regenaration

INDICATOR	
NAME	4.2.1 | BAF - BIOTOPE AREA FACTOR

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. green / grey ratio ; proportion of artificialized area...
R2: Policy support for policies:	Indicator mentioned in French regulations on urban planning (loi ALUR – optional use of the BAF); Used in several local urban planning rules across Europe • Berlin • Paris & several French cities • Other?
R3: Comparability:	Yes, it's possible to standardise the methodology, in order to provide fully comparable results. Limitations: similar knowledge of land occupation across the evaluated areas / sites / projects. Need for standardized maps?

ACCEPTED	
A1: Policy makers:	Yes, with local success apparently. Further investigations needed to confirm that.
A2: Practitioners:	Yes & it is used already in this context.
A3: Other stakeholders:	No info found on how urban development project's managers feel on the subject…

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CREDIBLE	
C1: Unambiguous results:	Yes, clear and unambiguous message = "how 'well' is the project's area used regarding nature's implementation" Clear interpretation by political decision makers. Don't know if the general public would find it easy to understand though.
C2: Transparency:	Yes. The calculation method is public, as are the target values set by city planners.
C3: Documentation of assumptions and limitations:	Yes, needed data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applied in all (I think) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator needs data which has to be generated (see Indicator sheet). For a data update you need new model/calculation.
E2: Technical feasibility:	Yes, BAF is simple enough to be calculated using standard software, as long as the required data is available.
E3: Reproducibility:	Yes to both.

ROBUST	
R1: Data quality:	Input data for calculation are real data.
R2: Sensitiveness:	No such assessments or estimations. The uncertainty of the result resides in the accuracy of the surface area measures.
R3: Scale:	It can be applied to the object and neighbourhood scales.

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4.2.2| CGS

4 | BIODIVERSITY AND URBAN SPACE

4.2 | URBAN SPACE DEVELOPMENT AND REGENERATION

4.2.2 | CGS – CONNECTIVITY GREEN SPACES

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.2 | Urban space development and regeneration

<table>
<tr><th colspan="2">INDICATOR</th></tr>
<tr><td>NAME</td><td>4.2.2 | CGS - Connectivity of green spaces</td></tr>
<tr><td>COMPLEXITY LEVEL
(☐ | ☒)
see legend below</td><td>☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5</td></tr>
<tr><td>INDICATOR LEVEL
(☐ | ☒)</td><td>☐ 1st
☐ 2nd
☒ 3rd</td></tr>
<tr><td>AGGREGATION (☐ | ☒)</td><td>☒ Yes
☐ No</td></tr>
<tr><td>TYPE (☐ | ☒)</td><td>☐ Descriptive
☒ Assessment
☐ Monitoring</td></tr>
<tr><td>SCALE (☐ | ☒)</td><td>☒ City
☐ Neighbourhood
☐ Object</td></tr>
<tr><td>DESCRIPTION</td><td>This indicator enables to assess natural habitats best connected to each other on the study area. It takes into account the fragmentation of the habitat. Thus, this indicator will help to know where to focus efforts, where to improve the connectivity (where it is the lowest) and where to maintain green spaces in priority (where connectivity is the highest because these areas are more favourable to species) → decision-making tool. The efforts to be made will depend on the objectives of each city.

<table>
<tr><th>Poor ecological functioning, low biodiversity</th><th>Good ecological functioning, high biodiversity</th></tr>
<tr><td>
</td><td>
</td></tr>
</table></td></tr>
<tr><td>OBJECTIVES</td><td>• Indicate the level of connectivity of green spaces</td></tr>
</table>

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Geodatabase of land use / land cover
TYPE OF DATA	• GIS files : shape
SOURCE	• Corine Land Cover • National databases (ex. Urban Atlas (only for big cities) ; OSGE in France…) ; BD TOPO • Local spatial databases / green cadastre
FREQUENCY	
MEASUREMENT UNIT	• Connectivity from 1 (very low) to 5 (very high)
REQUIRED TOOL	• GIS
CALCULATION METHOD	• GIS analysis
FORMULA	• Buffer (polygon i) = sqrt (Areapolygon i/π)
OUTPUT	• numerical value • maps
EXAMPLES	• AUAT → planning agency of Toulouse • GREET ingénerie → Nord-Pas-de-Calais

LINKS AND REFERENCES	
KEYWORDS	• Green areas • Green spaces • Connectivity
LINKS AND REFERENCES	• AUAT. (2015). Pour une approche globale du fonctionnement écologique potentiel des territoires, 8. • Direction Régionale de l'Environnement Nord-Pas-de-Calais. (2008). *Analyse des potentialités écologiques du territoire régional*, 66. • Greet Ingenierie, & Conservatoire Botanique National de Bailleul. (2008). Actualisation de l'inventaire des sites d'intérêt écologique de l'arrondissement de Lille, 33.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.2 | Urban space development and regeneration

INDICATOR	
NAME	4.2.2 | CGS - Connectivity of green spaces

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. lack of biodiversity and connectivity between habitats.
R2: Policy support for policies:	It is related to environmental policies that objectives are to maintain and restore habitats and biodiversity
R3: Comparability:	Yes, it’s possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes and no CONNECTIVITY is a very good and potential indicator for easy communication purpose, because people understand it, but the data generating and calculation requires GIS expert knowledge so far.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. territorial communities, planning agencies , …)

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message and coherences of the CONNECTIVTY OF GREEN SPACES
C2: Transparency:	Yes, it has. Based on land cover and land use data the value is calculated.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Basically the indicator can be calculated with data that has already been collected, for example Urban atlas, or IGN product like BD topo, OCSGE. It can be calculated with land use and land cover database that describe enough the green spaces.
E2: Technical feasibility:	It requires special software (GIS software). But have a clear input and methodology to avoid ambiguity and implementation errors.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases. The indicator has been used in different location (different cities in France) and it delivered reasonable results

ROBUST	
R1: Data quality:	Input data for simulation model are robust data because they are produced by public institutions.
R2: Sensitiveness:	No such assessments or estimations. The uncertainty of the result resides in the accuracy of the input land cover and land use dataset.
R3: Scale:	Yes, depending actually on the resolution.

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4.2.3| LUsom

4 | BIODIVERSITY AND URBAN SPACE

4.2 | URBAN SPACE DEVELOPMENT AND REGENERATION

4.2.3 | LUsom – LAND USE and SOIL ORGANIC MATTER

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity	4.2 | Urban space development and regeneration

INDICATOR	
NAME	**4.2.3 | LUsom – Land use related to Soil organic matter changes**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood *Can be adapted to the system under study* ☒ Object
DEFINITION	This indicator provides the changes in the Soil Organic Matter (SOM) content based on land occupation and transformation. Depending on the land occupation or transformation (from one land use to another), this indicator provides default values of changes in the SOM which is considered to be a good proxy for "ecosystem quality" in the broad sense. This indicator provides values per land use type but does not include any geographical specificity.
FOCUS/OBJECTIVES	• Consider land as a resource which has to be preserve (both in terms of occupation and transformation)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Land occupation and transformation flows
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Urban metabolism/Material Flow Analysis • Life cycle inventory databases
FREQUENCY (how often to use this indicator?)	• Updates are needed when land occupation and/or transformation is changing
MEASUREMENT UNIT	• kg C deficit/m2/year
REQUIRED TOOL	• LCA tools such as Simapro, Gabi, openLCA • EPESUS tool • Simple matrix based calculation (MS Excel possible)
CALCULATION METHOD	• The indicator is calculated by multiplying the flows of land occupied or transformed by a given processes (in m^2 for transformation and m^2.year for occupation) into kg C deficit using characterisation factors expressed in kg C deficit/m^2 and kg C deficit/m^2.year for transformation and occupation respectively.
OUTPUT TYPE	• Numerical value
EXAMPLES	• Anton et al. (2014), Assessing the land use impacts of agricultural practices on ecosystems, in Proceedings of the 9th International Conference on Life Cycle Assessment in the Agri-Food sector.

LINKS AND REFERENCES	
KEYWORDS	• Resource • Resource depletion • Life Cycle Assessment • Land Occupation • Land Transformation • Land Use
LINKS AND REFERENCES	• Milà i Canals L, Romanyà J, Cowell SJ (2007). Method for assessing impacts on life support functions (LSF) related to the use of 'fertile land' in Life Cycle Assessment (LCA). J Clean Prod 15 1426-1440 • Milà i Canals L, Bauer C, Depestele J, Dubreuil A, Freiermuth Knuchel R, Gaillard G, Michelsen O, Müller-Wenk R, Rydgren B (2007): Key elements in a framework for land use impact assessment in LCA. Int J Life Cycle Ass 12(1)5-15 DOI:10.1065/lca2006.05.250

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.2 | Urban space development and regeneration

INDICATOR	
NAME	**4.2.3 | LUsom – Land use related to Soil organic matter changes**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable of describing initial planning problems (through comparison with references). The indicator includes local (national) specificities.
R2: Policy support for policies:	• 2011 Road Map for Resource-Efficient Europe (part of Europe 2020 strategy) • EU Land Policy
R3: Comparability:	Although this indicator is recommended by the EC JRC, few existing studies have been performed using this indicator. Thus, comparability with this indicator can be difficult.

ACCEPTED	
A1: Policy makers:	Not yet. This indicator is related to some policies but not directly applied/tested in their development.
A2: Practitioners:	The indicator is not used by urban planners for the time being but it definitively has the potential to be used. It could provide an interesting information about land use (even though it is, for the time being, probably not sufficiently detailed to be relevant for urban areas)
A3: Other stakeholders:	This indicator is described and discussed in several peer-reviewed publications. He is discussed in the scientific community and not known by other stakeholders (local authorities, etc.)

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CREDIBLE	
C1: Unambiguous results:	Results are unambiguous. However, they are not accepted/understand by the general public.
C2: Transparency:	Yes and available in peer reviewed papers and also in other international publications.
C3: Documentation of assumptions and limitations:	Yes, the references given in the indicator factsheet are fully disclosed and ensure a uniform application in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Most of the data needed are existing or are expected to be available within the project. Some data refinements might be needed depending on the system under study (but these refinements are planned in the project)
E2: Technical feasibility:	This indicator is already present in commercially available software.
E3: Reproducibility:	Yes, the indicator is perfectly reproducible. It has been recognised by the EC JRC as the most relevant LCA based indicator for land use.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	The uncertainty associated with this indicator can be easily calculated using statistical methods such as Monte-Carlo analysis.
R3: Scale:	Yes, it could.

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4 | BIODIVERSITY AND URBAN SPACE

4.2 | URBAN SPACE DEVELOPMENT AND REGENERATION

4.2.4 | NDVI – NORMALIZED VEG. INDEX

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.2 | Urban space development and regeneration

INDICATOR	
NAME	**4.2.4 | NDVI - Normalized Difference Vegetation Index (NDVI)**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DESCRIPTION	NDVI is widely used by the bio-geophysical community to monitor the vegetation state and disturbances to address a large range of applications, including forestry, agriculture, food security, water management or residential proximity to major green spaces
OBJECTIVES	Access to major green spaces

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	Landsat imagery
TYPE OF DATA	multi-band netCDF4 files with metadata according to the Climate and Forecast (CF) conventions
SOURCE	Landsat
FREQUENCY	One to several times
MEASUREMENT UNIT	pixel_longitude – angular_resolution/2
REQUIRED TOOL	GIS tools
CALCULATION METHOD	Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.
FORMULA	NDVI = (NIR — VIS)/(NIR + VIS)
OUTPUT	numerical value
EXAMPLES	• YUAN, Fei; BAUER, Marvin E. Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery. Remote sensing of Environment, 2007, vol. 106, no 3, p. 375-386. • KASPERSEN, Per Skougaard; FENSHOLT, Rasmus; DREWS, Martin. Using Landsat vegetation indices to estimate impervious surface fractions for European cities. Remote Sensing, 2015, vol. 7, no 6, p. 8224-8249.

LINKS AND REFERENCES	
KEYWORDS	• VEGETATION COVER • MAJOR GREEN AREAS • ENVIRONMENTAL QUALITY
LINKS AND REFERENCES	• YUAN, Fei; BAUER, Marvin E. Comparison of impervious surface area and normalized difference vegetation index as indicators of surface urban heat island effects in Landsat imagery. Remote sensing of Environment, 2007, vol. 106, no 3, p. 375-386. • KASPERSEN, Per Skougaard; FENSHOLT, Rasmus; DREWS, Martin. Using Landsat vegetation indices to estimate impervious surface fractions for European cities. Remote Sensing, 2015, vol. 7, no 6, p. 8224-8249.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Biodiversity and urban space	4.2 | Urban space development and regeneration

INDICATOR	
NAME	4.2.4 | NDVI - Normalized Difference Vegetation Index

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. UHI-Islands or residential proximity to major green spaces
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014) • EU Urban agenda
R3: Comparability:	Yes, it's possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Yes, it has been used in Copernicus Global Land Service Providing bio-geophysical products of global land surface
A2: Practitioners:	Yes, for future urban planning, climate adaptation and cloudburst management is essential. For many such applications, remote sensing techniques including satellite imagery provides superior temporal and spatial coverage facilitating systematic,
A3: Other stakeholders:	Yes, a lot

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the different models for vegetative and climatic conditions while allowing researchers and practitioners to investigate the spatial transferability of city-specific regression models and the development of regional / urban quantification models The Normalized Difference Vegetation Index (NDVI) is the difference between maximum (in NIR) and minimum (round the Red) vegetation reflectance, normalized to the summation (CEOS)
C2: Transparency:	Yes, it has. Based on Landsat data
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	The methodology is depending on the availability of LANDSAT images. Since NDVI is defined as a mathematical index, the NDVI cannot be validated following exactly the procedure used for the validation of vegetation physical properties: the comparison with ground measurements is not relevant and the comparison with other satellites must be considered carefully since the NDVI is, by definition, sensor-dependent.
E2: Technical feasibility:	Yes, the indicator is simple enough using any GIS software. For that it does not require special equipment. It also has a clear input and methodology to avoid ambiguity and implementation errors. The FP7 geoland2/BioPar project defined user requirements for NDVI in terms of acceptable differences with existing satellite-derived product
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different standardized persons, …). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	Input data for simulation model are real data.
R2: Sensitiveness:	Since NDVI is defined as a mathematical index, the NDVI cannot be validated following exactly the procedure used for the validation of vegetation physical properties: the comparison with ground measurements is not relevant and the comparison with other satellites must be considered carefully since the NDVI is, by definition, sensor-dependent.
R3: Scale:	Yes, the minimum scale is a 30x30m pixel raster.

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4 | BIODIVERSITY AND URBAN SPACE

4.3 | URBAN SPACE MANAGEMENT

Short description of USC: In last decades a gradually increasing demand has been emerging for reconsidering urban spaces where more residents requires more efficient solutions in public utilities, traffic and generally in urban spaces. Urban planners are being under pressure to find sustainable solutions to develop livable cities in areas like increase or diversify biodiversity, rainwater management, waste management, increase energy efficiency. To encourage the spreading of good practices and participatory planning are essential during this process.

4.3.1 | SPI – SUSTAINABLE PRACTICE INDICA.

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Green space management and biodiversity	4.3 | Urban space management

INDICATOR	
NAME	**4.3.1 | SPI - SUSTAINABLE PRACTICES INDICATOR**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION USC	Several notation grids exist in France regarding sustainable green space management practices. They stem mainly from labels and certifications. The 'EcoJardin' label already provides such a tool to evaluate management practices at the object's scale. In this case, numerous criteria are assessed, resulting in individual evaluation / notation and an overall score, after examination of which the label is given or not (Micand and Larramendy, 2014). It is then proposed to gather different such grids '(EcoJardin', 'EcoQuartier', 'Terre Saine' + other outside of France?) to propose a notation grid specific to the N4C project and complementary with the other indicators (Faure et al., 2016). The aim of this would be to provide easy evaluation of several criteria, to obtain an aggregated score describing the overall sustainability of the management practices. Identified sources have been tested and validated in France, and have been used for several years now. They even stand as references in their fields. Work is needed to select the criteria of interest from source, check applicability to other countries, and stabilizing a notation method satisfactory for the project. The proposed method will then take the form of a questionnaire. The respondent's answers are translated into as many index numbers. The final score is a weighted mean of those index numbers.
OBJECTIVES	Answer to questions such as: ● How sustainable are the management practices? ● Are resources (both human and financial) & political intent put into defining good practices for the project or into bettering them? ● Does the project's design allow / facilitate sustainable practices?

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Precise knowledge of the NBS: Ground cover / surface materials, Equipments, Land use… • Precise knowledge of the management practices: how is each component maintained, when & by whom, How is relevant information transmitted between management actors, … • Knowledge of the type & amount of consumables used for object's management
TYPE OF DATA	• Maps, lists of materials, equipments, consumables, project's documents, management plans, …
SOURCE	• Documents & knowledge detained by the owners & managers of the NBS
FREQUENCY	• Specific audit during the conception to ensure sustainable management practices are planned • Regularly (e.g. once every 3 years) to ensure continuity and bettering
MEASUREMENT UNIT	To be defined (grade A/B/C/… or percentage)
REQUIRED TOOL	• no tool required
CALCULATION METHOD	$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},$ Where n is the total number of index numbers to be assessed through the questionnaire ; w_i is the weight of the i^{th} index ; x_i is the score obtained to the i^{th} index ; $\bar{x}$ is the weighted mean and overall grade for the SPI.
OUTPUT	• Numerical values: overall score + scores by theme (to identify strength & weaknesses + improvable practices)
EXAMPLES	• Label EcoJardin: http://www.label-ecojardin.fr/ • Label EcoQuartier: http://www.cohesion-territoires.gouv.fr/les-ecoquartiers

LINKS AND REFERENCES	
KEYWORDS	• Green space / open space • Management practices • Good practices • Sustainable management practices
LINKS AND REFERENCES	Faure, E., Aurenche, M., Provendier, D., 2016. Guide pour l'évaluation de la biodiversité dans les EcoQuartiers. Plante & Cité, Angers, France. Micand, A., Larramendy, S., 2014. Référentiel de gestion écologique des espaces verts EcoJardin. Plante & Cité.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	4 | Green space management and biodiversity	4.3 | Green space management

INDICATOR	
NAME	4.3.1 | SPI - SUSTAINABLE PRACTICES INDICATOR

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. * does the project's design allow for sustainable management practices * are such practices planned for the life of the project.
R2: Policy support for policies:	Proposed sources are: • Label EcoQuartier: sustainable housing, supported by the French Ministry for Housing and Territorial Equality • Label Terre Saine: zero pesticides cities, supported by the French Ministry for the Environment
R3: Comparability:	Proposed sources are, at the French scale. Further work would be needed to ensure comparability at the European scale.

ACCEPTED	
A1: Policy makers:	Yes, for proposed sources have been scientifically validated and have been used by officials for several years now (Ministries, Local authorities…)
A2: Practitioners:	Yes if 'practitioners' = open space managers. Unknown for urban planners.
A3: Other stakeholders:	Proposed sources are French references for sustainable management practices. Reviews and peer opinions are technical and professional rather than scientific, but in this domain the sources fit the A3 criteria.

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CREDIBLE	
C1: Unambiguous results:	Yes, clear and unambiguous message = "how sustainable are the management practices" Clear interpretation by political decision makers. Don't know if the general public would find it easy to understand though.
C2: Transparency:	Yes – for the sources. Should we choose to adapt our own evaluation grid, it would be our responsibility to set a clear and transparent methodology.
C3: Documentation of assumptions and limitations:	It would depend on the dissemination status of the data owned by the owners / managers of the NBS. It would surely need to be determined on a case-by-case basis.

EASY	
E1: Availability of data to calculate the indicator	Basically the indicator needs data which has to be generated (see Indicator sheet). For a data update you need new model/calculation.
E2: Technical feasibility:	Yes, SMP is simple enough to be calculated using standard software, as long as the required data is available.
E3: Reproducibility:	Yes to both – for the identified sources.

ROBUST	
R1: Data quality:	Input data for calculation are real data.
R2: Sensitiveness:	No such assessments or estimations. Does not seem relevant to this evaluation method though, because criteria would often be assessed arbitrarily and/or quantitatively (Yes/No ; on a scale from 1 to 3, etc.)
R3: Scale:	It can be applied to the object and neighbourhood scales.

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UC 5 | SOIL MANAGEMENT AND QUALITY

5.1.1 | Cfer

5 | SOIL MANAGEMENT

Short description of UC: In the urban areas, the soils are most of time stripped, filled, mixed, compacted and supplemented with artificial materials, soil profiles are strongly modified, leading to high spatial and vertical heterogeneity (Meuser, 2010). At the same time, a strong spatial heterogeneity characterizes the urban soil at the urban environment from physical, chemical and biological aspects (Morel et al., 2005; Béchet et al., 2009). This heterogeneity can be explained by a wide range of applications (support for buildings, road infrastructure, recreational areas, kitchen gardens and parklands) (Blanchart et al., 2017). However, the structure of the urban soil is frequently altered from a pedo-geochemical point of view (Joimel et al., 2016). In effect, these soils could either lost their structures and constitutions (aggregation) because of (1) compaction due to traffic and (2) the presence of large particles natural and/or anthropogenic sourced, which contain a high pollutant content as opposed to agricultural soils (El Khalil et al., 2008; Nehls et al., 2013).

5.1 | SOIL MANAGEMENT AND QUALITY

Short description of USC: Soil management is required and essential to improve the quality of the soil in the urban area. Urban construction requires prior knowledge of the quality of soil and subsoil, generally acquired through a set of diagnostics (lithology, geotechnics, physico-chemistry ...). The capitalization of these data, often collected and exploited by different actors, is a major stake in a logic of implementation of a consistent, reasoned and sustainable use of the subsoil for planning purposes.

5.1.1 | Cfer – CHEMICAL FERTILITY OF SOIL

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.1 | Cfer - Chemical fertility of soil**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☒ 2nd (for one of the parameter C/N) ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION	**Cfer** relates to the mineral nutrition of plants via the concepts of biodisponibility of elements, deficiencies, toxicities and equilibria
OBJECTIVES	Evaluation of the quality of soil, in this case chemical soil fertility : o to assess the ability of soil to grow ornamental plants and food (vegetables) o to improve the soil properties if necessary (1) addition of limestone to adjust pH, (2) addition of compost to increase the organic carbon content, (3) addition of mineral nutrients if there is a risk of chlorosis...

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Organic C, Total N, K, C/N, pH method : (water, CaCl2), CaCO3,, CEC (methods : Metson, CobaltiHexamine), P (Olsen method)
TYPE OF DATA	• physicochemical measurements • chemical analyses
SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	• Initial diagnostic/ assessment in case of hardly growth of vegetation
MEASUREMENT UNIT	• depend on the parameter, either no unit or [W.W-1]
REQUIRED TOOL	• soil sampling materials • laboratory analytical tools
CALCULATION METHOD	• measurement of each parameter • global evaluation from evaluation of each parameter
FORMULA	• No formula
OUTPUT	• qualitative (poor, moderate or optimal) or 0 to 1
EXAMPLES	• measurement of soil pH (-) or carbonates [mg kg-1] of a reconstructed soil

LINKS AND REFERENCES	
KEYWORDS	• fertility • nutrients • physical parameters
LINKS AND REFERENCES	• Damas, O., & Rossignol, J. P. (2009, June). Identification of mineral and organic waste resources as alternative materials for fertile soil reconstitution. In II International Conference on Landscape and Urban Horticulture 881 (pp. 395-398). • Vidal-Beaudet, L., Rokia, S., Nehls, T., & Schwartz, C. (2016). Aggregation and availability of phosphorus in a Technosol constructed from urban wastes. Journal of Soils and Sediments, 1-11. • Rokia, S., Séré, G., Schwartz, C., Deeb, M., Fournier, F., Nehls, T., ... & Vidal-Beaudet, L. (2014). Modelling agronomic properties of Technosols constructed with urban wastes. Waste management, *34*(11), 2155-2162.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.1 | Cfer - Chemical fertility of soil

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil nutrient deficiency for plant growth
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Not really. it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Yes. This basic indicator is considering mainly in farming policies
A2: Practitioners:	Yes the concept of fertility of soil is broadly shared and could be used quite easily
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on soil analysis standard methods
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	The data could have been already collected in case of soil characterisation but usually not. Measuring the parameters is the best way to calculate this indicator, because urban soil properties are very spatially heterogeneous.
E2: Technical feasibility:	This indicator requires laboratory or on-site measurements
R3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (various locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a "basic" soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale Require a number of samples adapted to soil heterogeneity

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5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.2 | EcoF – ECOTOXICOLOGY FACTOR

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.2 | EcoF - Ecotoxicology factor**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION	**EcoF** is based on (i) an evaluation of the concentration of pollutants for which an effect is measured in 50% of a population (EC50) and (ii) the time needed for 50% of a pollutant disappears (DT 50)
OBJECTIVES	• Evaluation of the effect of contaminants on soil organisms (microorganisms, micro- meso- or macro-fauna) • Evaluation of the dissipation (sorption, full or partial degradation) of contaminant over time These indicators give an assessment of the environmental risk due to soil pollution and will help urban planners in choosing the best soil management solution according to the intended use

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT

REQUIRED DATA	• Soil or water content in pollutant
TYPE OF DATA	• quantitative data
SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	• Initial diagnostic • At least 2 times of sampling for being able to measure DT50
MEASUREMENT UNIT	• for EC 50 : mg/L (for water), mg/kg (for soil) • for DT 50 : in days
REQUIRED TOOL	• soil sampling materials
CALCULATION METHOD	• calculations must be done to get EC50
FORMULA	see references
OUTPUT	• EC50 and DT50

EXAMPLES

Natural Product	Commercial Formulation	DT50 of soil	DT50 of water	DT50 of foliage	Leaching Potential
Phosphinothricin	Ignite	4.3	43-63	-	not significant
Azadirachtin	Neemix	< 1	26-29 1.5 1.5-2	5.-7.	mobile (lab soil column leaching study)
Spinosad	Success, Conserve	2.-12.	-	7.8	not significant
Glyphosate (reference herbicide)	Vision	10.-12.	4.-26.	2	not significant
Tebufenozide (reference insecticide)	Mimic	31-68	32-35	30-59	not significant

Figure:Comparative Fate of Natural Pesticides Based on Canadian Field Research (Thompson and Kreutzweiser, 2007)

LINKS AND REFERENCES

KEYWORDS

- Ecotoxicity
- EC50
- DT50

LINKS AND REFERENCES

- Hommen, U., Baveco, J. M., Galic, N., & van den Brink, P. J. (2010). Potential application of ecological models in the European environmental risk assessment of chemicals I: review of protection goals in EU directives and regulations. Integrated environmental assessment and management, 6(3), 325-337.
- Garcia, M. (2004). Effects of pesticides on soil fauna: development of ecotoxicological test methods for tropical regions (Vol. 19). Cuvillier Verlag.
- Thompson, Dean G., and David P. Kreutzweiser. "A review of the environmental fate and effects of natural" reduced-risk" pesticides in Canada." 2007. 245-274.
- van Gestel, C. A., van der Waarde, J. J., Derksen, J. G. M., van der Hoek, E. E., Veul, M. F., Bouwens, S., ... & Stokman, G. N. (2001). The use of acute and chronic bioassays to determine the ecological risk and

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bioremediation efficiency of oil-polluted soils. Environmental Toxicology and Chemistry, 20(7), 1438-1449.

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.2 | EcoF - Ecotoxicology factor

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is able to describe initial planning problems, like ecotoxicity for plant growth, soil microorganisms, micro- meso- and macro- fauna
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Not really. it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	More or less. It depends at which scale.
A2: Practitioners:	Yes, if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, water supply agency…)

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers understand the described message, not most public
C2: Transparency:	Yes, it has. Based on ISO standards
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Calculating CE50 and DT50 require to collect soil samples and to perform experiments in laboratory.
E2: Technical feasibility:	This indicator requires laboratory analysis
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	Yes (ISO method)
R3: Scale:	No, it is appropriate at the entity scale Require a number of samples adapted to soil heterogeneity

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5.1.3| SWI

5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.3 | SWI – SOIL WATER INFILTRATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.3 | SWI - Soil water infiltration**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DESCRIPTION	SWI represents the capacity of the soil to let water draining into the soil
OBJECTIVES	• Avoid soil anoxic conditions due to a low infiltration capacity

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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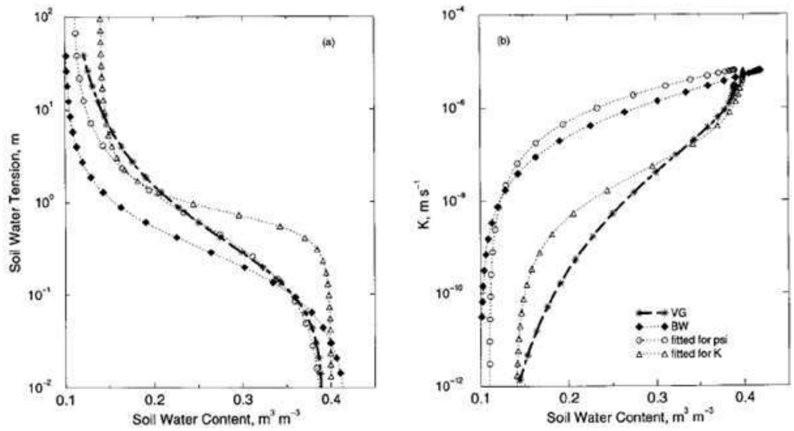
DATA AND MEASUREMENT	
REQUIRED DATA	• Soil hydraulic conductivity at saturation (Ksat)
TYPE OF DATA	• Soil physical property
SOURCE	• Bibliography • Measurement
FREQUENCY	In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	Water height / time
REQUIRED TOOL	• No required tool
CALCULATION METHOD	• no calculation method
FORMULA	No formula, it's a measured parameter
OUTPUT	• numerical value
EXAMPLES	 Figure from Shao and Irannejad, 1999

LINKS AND REFERENCES	
KEYWORDS	• SOIL • DRAINAGE
LINKS AND REFERENCES	• Shao, Y., & Irannejad, P. (1999). On the choice of soil hydraulic models in land-surface schemes. *Boundary-Layer Meteorology*, *90*(1), 83-115. • Yilmaz, D., Cannavo, P., Séré, G., Vidal-Beaudet, L., Legret, M., Damas, O., & Peyneau, P. E. (2016). Physical properties of structural soils containing waste materials to achieve urban greening. Journal of Soils and Sediments, 1-14

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.3 | SWI - Soil water infiltration

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil compaction and anoxia
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes, if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on soil analysis standard methods
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator	This indicator does not need calculation
E2: Technical feasibility:	Yes
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a “basic” soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale

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5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.4 | SBA – SOIL BIOLOGICAL ACTIVITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.4 | SBA - Soil biological activity**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DESCRIPTION	**SBA** represents the rate of decomposition of 2 different organic matter quality mainly by microbes
OBJECTIVES	• Biological activity reflecting the health of a soil • nutrient availability depends on this global C cycle

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• assessment of the mass loss of a known quantity of organic matter (green tea and rooibos tea) buried in the soil (10cm)
TYPE OF DATA	• % Mass loss expressed on an oven dry mass basis after 3 months incubation in the soil (field)
SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	In concept and detailed design phase of urban and object planning.

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MEASUREMENT UNIT	% of the initial mass (from 100% to 0%, no mass remaining)
REQUIRED TOOL	TBI uses the common teabags from the international brand lipton and is found anywhere in the world
CALCULATION METHOD	
FORMULA	Constant of decomposition k resulting from the following equation $W(t) = a \cdot e^{-kt} + (1-a)$ where a is the decomposable fraction (limit value) Stabilisation factor $S = 1 - a_g/H_g$ (ag is the decomposable fraction, Hg is the hydrolysable fraction)
OUTPUT	• numerical value
EXAMPLES	 Figure 1 from Keuskamp et al., 2013  Figure 2 from Dingeman, 2014 (link)

LINKS AND REFERENCES

KEYWORDS	• CLIMATE • MICROCLIMATE • Temperature • Humidity • Microbial catabolism • C cycle • Nutrient availability

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LINKS AND REFERENCES	• Keuskamp, J.A., Dingemans, Bas, J.J., Lehtinen, T., Sarneel, J.M., Hefting, M.M. (2013). Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. Methods in Ecology and Evolution 4, 1070–1075

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.4 | SBA - Soil biological activity

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil biological activity
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Yes, measurement can be expressed on a surface basis in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes, if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on a technical system of analysis (more frequently with a an infra-red gas analyser)
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states. However, environmental conditions such as temperature and humidity can modify (catalyst or inhibitor) the response of this biological indicator. Mathematical correction can be performed with microclimatic records

EASY	
E1: Availability of data to calculate the indicator:	Data need to be generated since most of them resulted from scientific literature obtained in natural land or lab conditions But world wide data are currently obtained with international programs (See TBI call, Teatime4soil…)
E2: Technical feasibility:	This indicator is available to everyone and easy to implement
E3: Reproducibility:	Yes, it is possible to apply the indicator at the surface of any soil

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a “basic” soil biological property indicator
R3: Scale:	Yes

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5.1.5| ScF

5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.5 | ScF – SOIL CLASSIFICATION FACTOR

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.5 | ScF - Soil Classification Factor**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION	**ScF** (Soil classification) is the overall characterization of soil used to define at local (object)scale, the type of soil that is going to be used as NBS support and to define potential improvement of soil quality, at neighbourhood or city scale, helpful in urban planning to have an overview of the land-use potential of surfaces
OBJECTIVES	• Soil classification is required when the NBS are defined during urban planning • Soil classification aims at: o checking that the nature of the soil is suitable as regards the expected functions of the NBS o applying relevant) improvements of soil properties after evaluation of these specific properties by other indicators

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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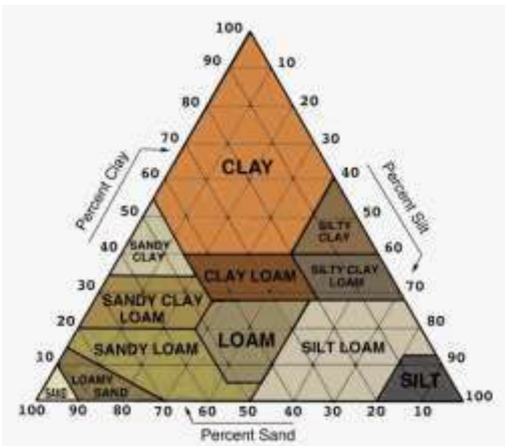
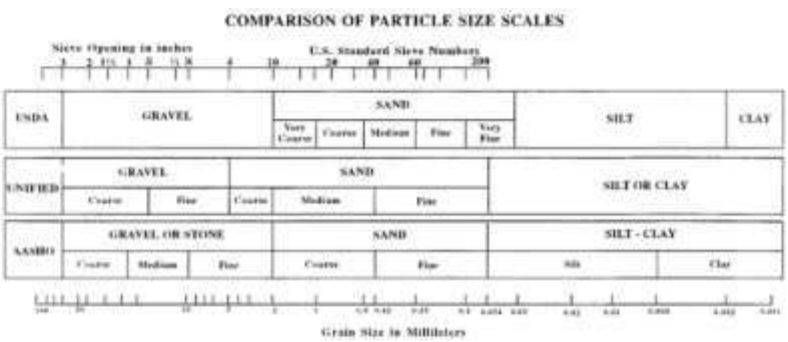
DATA AND MEASUREMENT	
REQUIRED DATA	● pedological description ● pH, electrical conductivity (EC) ● CaCO3, Fe - Mn content ● texture (sand, loam, clay content)
TYPE OF DATA	● soil pedology and chemical properties
SOURCE	● Bibliography ● Description/Measurement/Monitoring
FREQUENCY	● Initial diagnostic
MEASUREMENT UNIT	● electrical conductivity: dS m-1 ● elemental composition ● CaCO3 (mass%)
REQUIRED TOOL	● on site observation ● soil sampling materials
CALCULATION METHOD	● Data are directly usable
FORMULA	● No formula
OUTPUT	● numerical value ● type of soil (U.S. classification or taxonomy and the W.R.B. classification)
EXAMPLES	● Methanogenic soil: more than 1.6 ppb of methanethiol odor of nonpersistent artifacts or evidence of the collection and/or burning methane gas ● Spolic a horizon or layer 50 cm or more think of human-transported materials  

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	Figure: Soil texture triangle, showing the 12 major textural classes, and particle size scales as defined by the USDA. (Soil Science Division Staff. 2017)

LINKS AND REFERENCES	
KEYWORDS	• WRB classification • inorganic and organic pollutants and contaminants • soil sediment • electrical conductivity of water • soil texture • sand, silt, and clay
LINKS AND REFERENCES	• El Khalil, H., Schwartz, C., Elhamiani, O., Kubiniok, J., Morel, J.L., Boularbah, A., 2008. Contribution of technic materials to the mobile fraction of metals in urban soils in Marrakech (Morocco). J. Soils Sediments 8, 17–22 • Gerakis, A., & Baer, B. (1999). A computer program for soil textural classification. *Soil Science Society of America Journal*, *63*(4), 807-808. • IUSS Working Group. (2014). World reference base for soil resources 2014 international soil classification system for naming soils and creating legends for soil maps. *FAO, Rome*. • Nehls, T., Rokia, S., Mekiffer, B., Schwartz, C., Wessolek, G., 2013. Contribution of bricks to urban soil properties. J. Soils Sediments 13, 575–584. • Soil Science Division Staff. 2017. Soil survey manual. C. Ditzler, K. Scheffe, and H.C. Monger (eds.). USDA Handbook 18. Government Printing Office, Washington, D.C.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.5 | ScF - Soil Classification Factor

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil infiltration capacity soil fertility/nutrient deficiency for plant growth, soil compaction
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Yes. The methodology used to provide data is already world-wide used.

ACCEPTED	
A1: Policy makers:	Yes. Use a basic indicator when considering contamination
A2: Practitioners:	Yes, if urban planner has some fundamental skills about soils the indicator has the potential to be used.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public may understand the described message
C2: Transparency:	Yes, it has. Based on international soil classification
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator	Not sure that the informations/data are already available. Data are usually partly gathered by private developers/planners
E2: Technical feasibility:	This indicator requires skills that could be acquired quite rapidly (for being able to get a minimum data set)
R3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R5: Sensitiveness:	This indicator is a “basic” soil property
R8: Scale:	No it is appropriate at the entity or neighbourhood scale Require a number of samples adapted to soil heterogeneity

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5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.6 | SCr – SOIL CRUSTING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.6 | ScR - Soil Crusting**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DESCRIPTION	**ScR** is a consequence of soil getting a poor aggregation capacity/stability. A crust at the soil surface is created, limiting water infiltration and favouring water runoff
OBJECTIVES	• Ensure/Improve soil physical properties to favour water infiltration efficiency

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Soil organic matter content (SOM) • Clay content (CLAY) • Fine silt content (Sf) • Coarse silt content (Sc) • Soil pH (pH)
TYPE OF DATA	• Soil physical properties

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SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	No unit
REQUIRED TOOL	
CALCULATION METHOD	
FORMULA	SCr = [(1.5*Sf+075*Sc)/(CLAY+10*SOM)] – 0.2*(pH-7) if pH>7 SCr = [(1.5*Sf+075*Sc)/(CLAY+10*SOM)] if pH<= 7 Where Sf is the % fine silt, Sc is the % coarse silt, CLAY is the % clay in soil, SOM is % soil organic matter content. pH is the potential of hydrogen in soil[0-14]
OUTPUT	• numerical value
EXAMPLES	 Figure: Layer of grain size on soil crust (Šimanský et al. 2014)

LINKS AND REFERENCES

KEYWORDS	• SOIL • INFILTRATION • RUNOFF
LINKS AND REFERENCES	• Šimanský V, Polláková N, Halmo S (2014) . Soil crust in agricultural land, Acta fytotechn. zootechn., 17(4): 109–114

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.6 | ScR - Soil Crusting

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil erosion problems
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes, if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on soil analysis standard methods
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Soil granulometry and organic matter content are required. Measuring these parameters is the best way to calculate this indicator, because urban soil properties are very heterogeneous. If it can't be measured, parameters estimation is possible thanks to the bibliography
E2: Technical feasibility:	This indicator is available to everyone and easy to implement
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a "basic" soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale

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5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.7 | Sct – SOIL CONTAMINATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.7 | Sct - Soil contamination**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION	**Sct** is the diffuse and the point source soil contamination by inorganic contaminants (trace metals, metalloids, radionuclides...), by nutrients and pesticides, by persistent organic pollutants, by soil acidifying
OBJECTIVES	• Evaluation of contamination level: ○ to conduct risk assessment ○ to apply relevant soil management: (1) pollutant stabilization (dust control, amendement to control pollutant mobility), (2) soil decontamination (phytoremediation [phytoextraction, phytodegradation, phytovolatilization], bioremediation)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Site description (GPS coordinates, land use, parent material, local geochemical background); profile descriptions (soil type, horizons, horizon depth, sampling depth, fine earth, texture), no. of identified sites per management step; estimated total no. of sites per management step • Analyses (content of heavy metals and organic pollutant, method of analyses, detection limits) • inorganic pollutants uptake by plants • mobility of pollutants,
TYPE OF DATA	• % or area or plots exceed local geochemical background (no background value for organic pollutants)
SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	• Initial diagnostic
MEASUREMENT UNIT	• [W W-1]
REQUIRED TOOL	• soil sampling materials • direct measurements
CALCULATION METHOD	• Data are directly usable
FORMULA	
OUTPUT	• % or area or concentration of pollutants
EXAMPLES	• measurement of trace metal concentration in urban allotment garden soil in [mg kg-1]

LINKS AND REFERENCES	
KEYWORDS	• inorganic and organic pollutants and contaminants • soil sediment • mobility
LINKS AND REFERENCES	• Huber, S., Prokop, G., Arrouays, D., Banko, G., Bispo, A., Jones, R.J.A., Kibblewhite, M.G., Lexer, W., Möller, A., Rickson, R.J. and Shishkov, T., 2008. Environmental assessment of soil for monitoring: volume I, indicators & criteria. *Office for the Official Publications of the European Communities, Luxembourg*. • Jean-Soro, L., Le Guern, C., Bechet, B., Lebeau, T., & Ringeard, M. F. (2015). Origin of trace elements in an urban garden in Nantes, France. *Journal of soils and sediments*, *15*(8), 1802-1812.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.7 | Sct - Soil contamination

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil nutrient deficiency for plant growth, soil compaction
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Not really. it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Yes. Use a basic indicator when considering contamination
A2: Practitioners:	Yes if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on soil analysis standard methods
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Measuring this parameter is the best way to calculate this indicator, because urban soil properties are very heterogeneous.
E2: Technical feasibility:	This indicator requires laboratory or on-site measurements
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a “basic” soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale Require a number of samples adapted to soil heterogeneity

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730468

5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.8 | SMP – SOIL MACRO-POROSITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.8 | SMP - Soil macro-porosity**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DESCRIPTION	**SMP** represents the capacity of the soil to provide air for root respiration
OBJECTIVES	• Provide soil aerobic conditions for root respiration, microbial processes such as organic matter biodegradation and nutrient production • Favour water infiltration into the soil (water circulates in the macro-porosity)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Soil water field capacity (Hfc) • Soil bulk density (Bd) • Soil particle density (Bp)
TYPE OF DATA	• Soil physical properties
SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	Volume of air / Volume of soil
REQUIRED TOOL	
CALCULATION METHOD	
FORMULA	SMP = [(Bp-Bd)/Bp] - Hfc with Bd is the soil bulk density (kg m^{-3}), Bp is the soil particle density (kg m^{-3}), Hfc is soil water field capacity (m^3 m^{-3})
OUTPUT	• numerical value

EXAMPLES

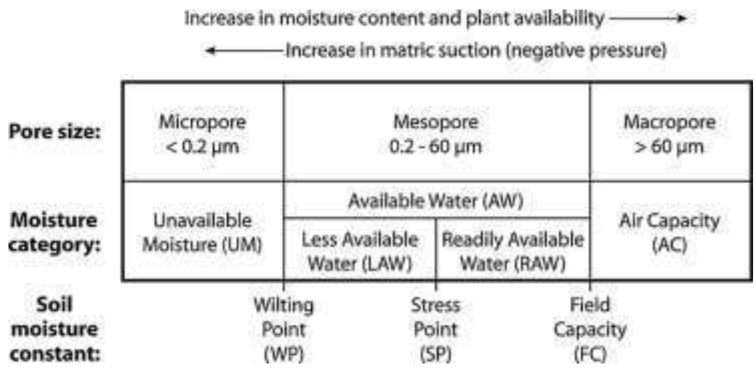

Figure from Jim and Peng, 2012

LINKS AND REFERENCES	
KEYWORDS	• SOIL • AERATION • INFILTRATION
LINKS AND REFERENCES	• Jim, C. Y., & Peng, L. L. (2012). Substrate moisture effect on water balance and thermal regime of a tropical extensive green roof. *Ecological Engineering*, *47*, 9-23. • Yilmaz, D., Cannavo, P., Séré, G., Vidal-Beaudet, L., Legret, M., Damas, O., & Peyneau, P. E. (2016). Physical properties of structural soils containing waste materials to achieve urban greening. Journal of Soils and Sediments, 1-14

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Urban regeneration	5.1 | Soil management

INDICATOR	
NAME	5.1.8 | SMP - Soil macro-porosity

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim: (Green)	Indicator is capable to describe initial planning problems, like soil compaction and water infiltrability
R2: Policy support for policies: (Yellow)	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability: (Green)	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers: (Red)	No, not so far, but expected to be in the near feature.
A2: Practitioners: (Green)	Yes, if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders: (Green)	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results: (Green)	Yes, decision makers and general public understand the described message
C2: Transparency: (Green)	Yes, it has. Based on soil analysis standard methods
C3: Documentation of assumptions and limitations: (Green)	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Soil bulk density and soil water field capacity are required. Measuring these parameters is the best way to calculate this indicator, because urban soil properties are very heterogeneous. If it can't be measured, parameters estimation is possible thanks to the bibliography
E2: Technical feasibility:	This indicator is available to everyone and easy to implement
R3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a "basic" soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale

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5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.9 | SOM – SOIL ORGANIC MATTER

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.9 | SOM - Soil Organic Matter**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DESCRIPTION	**SOM** is a crucial parameter of soil biological, chemical and physical quality. All soil properties are highly depending on this parameter (soil aggregation, soil nutrients, soil decomposers…)
OBJECTIVES	• Ensure/Improve soil organic matter content to allow long-term soil quality

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Soil organic matter content (SOM)
TYPE OF DATA	• Soil physical-chemical properties
SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	g of organic matter / kg of soil
REQUIRED TOOL	• No required tool
CALCULATION METHOD	
FORMULA	• No formula, direct parameter
OUTPUT	• numerical value
EXAMPLES	• Acín-Carrera, M., José Marques, M., Carral, P., Álvarez, A. M., López, C., Martín-López, B., & González, J. A. (2013). Impacts of land-use intensity on soil organic carbon content, soil structure and water-holding capacity. *Soil Use and Management*, *29*(4), 547-556.

LINKS AND REFERENCES	
KEYWORDS	• SOIL • FERTILITY • NUTRIENTS • POROSITY • BIODEGRADATION
LINKS AND REFERENCES	• Acín-Carrera, M., José Marques, M., Carral, P., Álvarez, A. M., López, C., Martín-López, B., & González, J. A. (2013). Impacts of land-use intensity on soil organic carbon content, soil structure and water-holding capacity. *Soil Use and Management*, *29*(4), 547-556. • Šimanský V, Polláková N, Halmo S (2014) . Soil crust in agricultural land, Acta fytotechn. zootechn., 17(4): 109–114

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.9 | SOM - Soil Organic Matter

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil nutrient deficiency for plant growth, soil compaction
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on soil analysis standard methods
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Measuring this parameter is the best way to calculate this indicator, because urban soil properties are very heterogeneous. If it can't be measured, parameters estimation is possible thanks to the bibliography
E2: Technical feasibility:	This indicator is available to everyone and easy to implement
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a "basic" soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale

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5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.10 | SR – SOIL RESPIRATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.10 | SR - Soil respiration**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DESCRIPTION	**SR** represents respiration rates of soil microbes, fauna and roots compared with a control soil (absence of human pressure or impact).
OBJECTIVES	- Biological activity reflecting the health of a soil - nutrient availability depends on this global C cycle

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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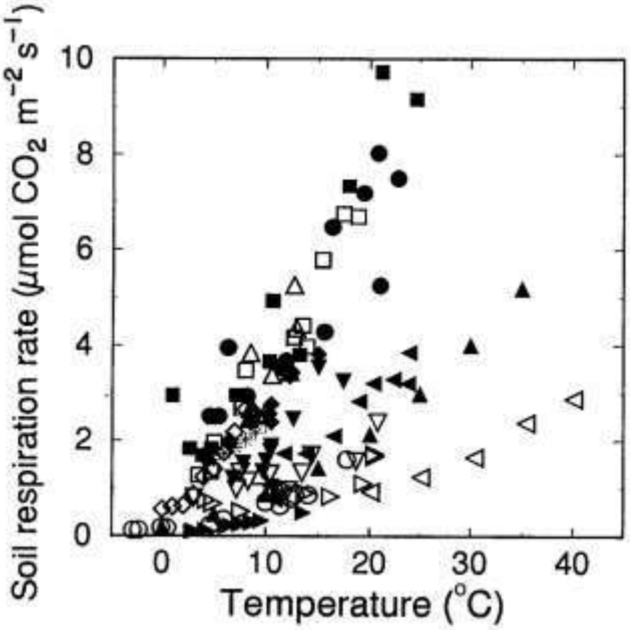
DATA AND MEASUREMENT	
REQUIRED DATA	● recording CO_2 production at surface scale ● humidity and temperature of soil which are monitored with sensors
TYPE OF DATA	● Soil biological properties assessed as CO_2 released
SOURCE	● Bibliography ● Measurement/Monitoring
FREQUENCY	In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	(%) or Ppm CO_2 cm^{-2} min^{-1} / Ppm CO_2 cm^{-2} min^{-1}
REQUIRED TOOL	A infra-red gas analyser
CALCULATION METHOD	No calculation but conversion unit can be performed (e.g. µg C-CO_2 m^{-2} h^{-1})
FORMULA	
OUTPUT	● numerical value (rates)
EXAMPLES	 Figure of The relationship between soil respiration rate and temperature (either surface soil or ambient air from Lloyd and Taylor, 1994 To compare 2 different soils with distincts soil respiration rates, SRE, each soil should presents a reference level (e.g. control in absence of human pressure) and be expressed on relative value of this control Example 1: Soil 1: cambisol would have SRE= 20 µg C-CO2 g-1 soil DW h-1 and would correspond to 100 % of activity without human pressure

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	Soil 2: histosol would have SRE = 50 µg C-CO_2 g^{-1} soil DW h^{-1} and would correspond to 100 % of activity without human pressure With human pressure, let s say a decrease in 10 units for each soil Soil 1: SRE = 20 - 10 = 10 (units) and would be expressed as 50 % of control soil Soil 2: SRE = 50-10 X = 40 (units) and would be expressed as 40 *100/50= 80% of control soil Or 10 % decrease would let Soil 1 and 2 at 90 % of their respective control soils (thus same level of human pressure but soil having very different ecological values)

LINKS AND REFERENCES	
KEYWORDS	• CLIMATE • MICROCLIMATE • Temperature • Humidity • Microbial catabolism • C cycle • Nutrient availability
LINKS AND REFERENCES	• Anderson, J.P.E., Domsch, K.H., 1978. A physiological method for the quantitative measurement of microbial biomass in soils. Soil Biology and Biochemistry 10, 215-221. • Lloyd, J., & Taylor, J. A. (1994). On the temperature dependence of soil respiration. *Functional ecology*, 315-323. • Miao et al 2017. Nonlinear responses of soil respiration to precipitation changes in a semiarid temperate steppe Nature Scientific reports 77, DOI: 10.1038/srep45782

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.10 | SR - Soil respiration

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like soil biological activity
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Yes, measurement can be expressed on a surface basis in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes, if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on a technical system of analysis (more frequently with an infra-red gas analyser)
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states. However, environmental conditions such as temperature and humidity can modify (catalyst or inhibitor) the response of this biological indicator. Mathematical correction can be performed with microclimatic records

EASY	
E1: Availability of data to calculate the indicator:	Data need to be generated since most of them resulted from scientific literature obtained in natural land or lab conditions
E2: Technical feasibility:	This indicator need special equipment
E3: Reproducibility:	Yes, it is possible to apply the indicator at the surface of any soil

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a “basic” soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale

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5.1.11 | SWR

5 | SOIL MANAGEMENT

5.1 | SOIL MANAGEMENT AND QUALITY

5.1.11 | SWR – SOIL WATER RESERVOIR

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	**5.1.11 | SWR - Soil water reservoir for plants**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DESCRIPTION	SWR represents the capacity of the soil to provide water for plant uptake
OBJECTIVES	• Provide water for plants growth • Favor plant transpiration and cooling effect

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Soil water field capacity (Hfc) • Soil water content at the wilting point (Hwp) • Soil thickness (z) • Soil bulk density (Bd) • Stone fraction content (F)
TYPE OF DATA	• Soil physical properties
SOURCE	• Bibliography • Measurement/Monitoring
FREQUENCY	In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	mm water / cm of soil
REQUIRED TOOL	
CALCULATION METHOD	
FORMULA	SWR = (Hfc-Hwp)*Bd*z*F with Hfc is the massic water content at field capacity (in kg_{water} $kg_{dry\ soil}^{-1}$), Hwp the volumetric water content at the wilting point (m^3 m^{-3}), Bd is the bulk density in (kg m^{-3}), z is the depth of soil in (m), F is the stone fraction content (in m^3 of small soil per m^3 of total soil)
OUTPUT	• numerical value
EXAMPLES	

LINKS AND REFERENCES	
KEYWORDS	• SOIL • PLANT WATER UPTAKE • WATER STRESS • TRANSPIRATION
LINKS AND REFERENCES	• Bouzouidja, R., Rousseau, G., Galzin, V., Claverie, R., Lacroix, D., & Séré, G. (2016). Green roof ageing or Isolatic Technosol's pedogenesis?. Journal of Soils and Sediments, 1-8. • Yilmaz, D., Cannavo, P., Séré, G., Vidal-Beaudet, L., Legret, M., Damas, O., & Peyneau, P. E. (2016). Physical properties of structural soils containing waste materials to achieve urban greening. Journal of Soils and Sediments, 1-14.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ENVIRONMENT	5 | Soil management	5.1 | Soil management and quality

INDICATOR	
NAME	5.1.11 | SWR - Soil water reservoir for plants

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator can be capable to describe initial planning problems, like soil compaction. However it is an important indicator to assess plant water uptake
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Yes. Use a basic indicator when considering plant water uptake
A2: Practitioners:	Yes if soil analysis is performed or if bibliography research is undertaken
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message
C2: Transparency:	Yes, it has. Based on soil analysis standard methods
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Several input data is required. Measuring these parameters is the best way to calculate this indicator, because urban soil properties are very heterogeneous. If it can't be measured, parameters estimation is possible thanks to the bibliography
E2: Technical feasibility:	This indicator is available to everyone and easy to implement
R3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases (different locations). The indicator has been used in different circumstances (different soil uses) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	This indicator is a "basic" soil physical property indicator
R3: Scale:	No it is appropriate at the entity scale

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.1 | EE – ENERGY EFFICIENCY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.1 | EE - Energy efficiency**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator illustrates the percent change of consumed energy in relation to fuel demand per capita or per selected timeframe to the baseline levels.
FOCUS/OBJECTIVES	Energy efficiency can be approached on the demand/consumption and generation side. On the consumption side the energy consumption from the built environment and from municipal purposes are accounted for. The energy consumption and energy performance of built environment, then can be extrapolated to neighbourhood and city-scale. With addition of municipal energy consumption for instance for lighting or water treatment, the city scale energy consumption can be estimated. This indicator excludes the industrial energy consumption within the city limits. On the generation side, enhancement of local renewable energy production is the focus. Systems aiming local renewable energy production can be combined with NBS and would count as an additional benefit under resource efficiency and energy challenges.
NOTES	According to the type of the NBS implemented, the priority of this indicator may change.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data

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5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT

REQUIRED DATA	• For direct estimation: Information on the energy consumption from built environment and municipal services
	  ○ Non-renewable (fossil) fuels (in energy equivalents)
	  ○ Renewable energy sources (in energy equivalents)
	• Local energy generation from renewable sources
	• For indirect estimation of building energy consumption:
	  ○ Building types
	  ○ Unit energy consumption for each building types (per m2)
	  ○ Area of built environment based on building types

INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Energy bills (direct estimation) • Public Administration, Municipalities • Statistical institutions
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• % (change)
REQUIRED TOOL	• If unit energy consumption is going to be obtained via building energy simulations, BIM tools can be used.

CALCULATION METHOD	• Evaluate the energy consumption per capita or per time by direct or indirect estimation
	  ○ Energy bills from buildings, energy bills from municipalities or statistical data on energy consumption can be used for direct estimation.
	  ○ Energy consumption factors per m2 of buildings can be estimated by building energy simulations or literature factors can be used observing different building types or building energy classes.
	• Calculate the percent change with the baseline data

OUTPUT TYPE	• Quantitative value
EXAMPLES	• Energy efficiency on the consumption side: Localized Energy – The Meadows. URL: http://www.oppla.eu/casestudy/17559 Date of access: Orctober 2017. • Energy efficiency on the consumption side: Nottingham: Sustainable housing in times of climate change and resource scarcity. URL: http://www.oppla.eu/casestudy/17492 Date of access: October 2017. • Energy efficiency on energy generation side: Bioenergy production in Saxony, Germany. URL: http://www.oppla.eu/casestudy/17245 Date of access: October 2017.

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	• Fink, H.S:, 2016. Human-Nature for Climate Action: Nature Based Solutions for Urban Sustainability. Sustainability, 8, 254 – 275.

LINKS AND REFERENCES	
KEYWORDS	• Energy demand • Fuel consumption • Raw material efficiency
LINKS AND REFERENCES	• Fink, H.S:, 2016. Human-Nature for Climate Action: Nature Based Solutions for Urban Sustainability. Sustainability, 8, 254 – 275. • Mudgal, S., Tan, A., Lockwood, S., Eisenmenger, N., Fischer-Kowalski, M., Giljum, S., Brucker, M., 2012. Assessment of Resource Efficiency Indicators and Targets – Annex Report URL: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/annex_report.pdf Date of access: October 2017

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.1 | EE - Energy efficiency

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Energy efficiency indicators are relevant for the Nature4Cities project to investigate resource efficiency and in particular energy challenges. These indicators reveal the level of enhancement of energy performance on building and city level with implementation of NBS and also the added value that may be created through generation of local renewable energy.
R2: Policy support for policies:	The European Union has set itself a target for 2020 of saving 20% of its primary energy consumption compared to baseline projections. This objective was identified in the Commission's Communication on Energy 2020 as a key step towards achieving long-term energy and climate goals. The proposed indicator therefore has high relevance in the context of the Europe 2020 Initiative.
R3: Comparability	Due to possible differences in underlying assumption for estimation of energy consumption with indirect methodology, potential for standardization of methodology and obtaining comparable results can be troublesome. Generation of renewable energy, on the other hand, can provide comparable data.

ACCEPTED	
A1: Policy makers:	Energy consumption is a standard indicator widely accepted and long used by the EU and national policy makers in economic and environmental context. Renewable energy generation also has significant value for policy makers.
A2: Practitioners:	-
A3: Other stakeholders:	Both consumption and renewable energy generation indicators are widely accepted by statisticians, academia and business society.

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CREDIBLE	
C1: Unambiguous results:	A change of aggregate energy consumption cannot be associated directly with a change of related environmental impacts, as different fuels may be responsible for different impacts. Fuel switching may cause significant changes in total energy consumption even though final energy demand remains constant, as for different fuels and technologies efficiencies of transformation from primary in useful energy vary widely. Direct estimation of the indicator has high transparency and a basic methodology. However, whenever direct information is missing and indirect estimation methodology is used, determination of building types and energy consumption factors may change based on the practitioner. Unambiguity for renewable local energy production is higher.
C2: Transparency:	Direct estimation of the indicator has high transparency and a basic methodology. Indirect estimation methodology is less clear and transparent.
C3: Documentation of assumptions and limitations:	Care should be taken to clearly identify the assumptions used during indirect estimation. Uniformity might be lacking for direct estimation of energy consumption in municipal services as these may change variety among Member States.

EASY	
E1: Availability of data to calculate the indicator:	Availability of data shows variation whether direct and indirect estimation for energy consumption is being used.
E2: Technical feasibility:	The consumption indicator estimation methodology is straightforward for the practitioners except for the cases where building energy simulations are required. In these cases, it would be necessary to utilize BIM tools, which requires a higher degree of expertise to run.
R3: Reproducibility:	For national energy consumption cases, a well established and harmonised methodology jointly used by Eurostat and the IEA guarantees high comparability and reproducibility of results. Sub-national data especially on city-level are more difficult to obtain.

ROBUST	
R1: Data quality:	Data on energy consumption and generation are provided by several official national and international statistics.
R2: Sensitiveness:	Energy consumption is highly sensitive to short term policy changes, as far as they affect demand, availability or prices of energy carriers.
R3: Scale:	Yes.

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6 | RESOURCE EFFICIENCY

Short description of UC: Resource Efficiency Indicators are classified as Environmental Indicators that assess the water-energy-raw materials relation with respect to the various Sustainable Development Goals, namely; Ensure access to affordable, reliable, sustainable and modern energy for all (Goal 7), promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (Goal 8), Ensuring sustainable consumption and production patterns (Goal 12). The scope of the Resource Efficiency here is set as Food-Energy-Water nexus, waste efficiency, raw material efficiency, life cycle indicators and energy efficiency for Nature based Solutions. Food-Energy-Water nexus analyses the interconnections existing not only in natural resources but also among different levels or scales of assessment; between local and global processes of resources use, and between social and economic aspects of a society, highlights the complex issues involved in addressing these challenges in ways that also make effective use of the possible changes resulting from new policies or new interventions. Waste efficiency covers the non-hazardous waste generated, hazardous waste produced and by-products and recyclable portion of the total waste amount.

6.1 | FOOD, ENERGY AND WATER

Short description of USC: Water, energy and food are inextricably linked. Water is an input for producing agricultural goods in the fields and along the entire agro-food supply chain. Energy is required to produce and distribute water and food: to pump water from groundwater or surface water sources, to power tractors and irrigation machinery, and to process and transport agricultural goods (UN, 2017). FAO recognizes the FWE nexus as a new approach to support food security and sustainable agriculture.

6.1.2 | ES – ENERGY SECURITY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.2 | ES - Energy security**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DEFINITION	The indicator is a combination of the “Import Dependency - Primary Sources” as per the definition of the European Commission in the Occasional Paper on European Economy and the specific energy consumption of the NBS. The Import Dependency – Primary Sources shows the extent to which a country relies upon imports in order to meet its energy needs (dimensionless - %). The EC source calculates Import dependency for the following energy products: natural gas, crude oil, solid fuels (hard coal and derivatives, and lignite and derivatives) plus the total that is all of the above products together. The specific energy consumption is the energy consumption required by a specific selected unit of measurement of a NBS (piece, m^2, litre, etc.).
FOCUS/OBJECTIVES	• applicable to NBS linked to energy security • describe the resilience of the national context where the NBS is inserted (descriptive, country level) • check of the effect of reduction/increase of the need of energy to be imported as a consequence of the implementation of a NBS

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data

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5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT

REQUIRED DATA	• See “calculation method”
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• Eurostat
FREQUENCY (how often to use this indicator?)	• In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	• kWh/m^2, kWh/m^3, kWh/piece, kWh/kg, kWh/l, etc.
REQUIRED TOOL	• own calculation
CALCULATION METHOD	“Import Dependency – Primary Sources” $\frac{M_j - X_j}{GIC_j + Bunk_j}$ - X = Export - M = Import - j = energy product - GIC = consumption of international bunkers Specific Energy Consumption - Energy Consumption of the NBS per specific selected unit of measurement in order to be significant.
OUTPUT TYPE	• numerical value
EXAMPLES	• World Bank indicators of energy imports • European Environment Agency databases

LINKS AND REFERENCES

KEYWORDS	• ENERGY • ENERGY SECURITY • IMPORT
LINKS AND REFERENCES	• https://www.eea.europa.eu/data-and-maps/indicators/net-energy-import-dependency • https://data.worldbank.org/indicator/EG.IMP.CONS.ZS • http://ec.europa.eu/economy_finance/publications/occasional_paper/2013/op145_en.htm

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.2 | ES - Energy security

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, the indicator is fully capable to describe initial planning problems. It is able to indicate expected increase or decrease of needs of energy import.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • European Energy Security Strategy • UN Sustainable development goals (nr. 7)
R3: Comparability:	Yes, it is indeed a common methodology, already in use for the EC and also adopted by international players such as, for example, the EEA and World Bank.

ACCEPTED	
A1: Policy makers:	Not for urban level policies, but the relevance of the indicator and of its source are internationally recognized.
A2: Practitioners:	This is a widely used indicator at country level. Its application at urban level can be a smooth customization.
A3: Other stakeholders:	Yes, the indicator is accepted by numerous stakeholders and, in fact, it is used as a solid reference.

CREDIBLE	
C1: Unambiguous results:	The information provided by the indicator is univocal and can not be subject to misinterpretation or ambiguous understanding
C2: Transparency:	Yes, it is calculated based on national statistical data and on production data.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

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EASY	
E1: Availability of data to calculate the indicator:	Data for the calculation of the indicator are already available at country level, whereas local information for customization has to be gathered.
E2: Technical feasibility	Once availability of local data and of the specific data for the NBS is achieved, the calculation is feasible without any specific tools/software/model.
E3: Reproducibility:	Yes. No barriers are found.

ROBUST	
R1: Data quality:	Data are robust and drawn from Eurostat national databases.
R2: Sensitiveness:	There is no.
R3: Scale:	The indicator can be straightforwardly used at country level scale in order to define the national context hosting the NBS and therefore to justify its relevance. At urban scale, the indicator needs tailoring to evaluate ex-ante and ex-post situations related to the NBS impacts.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.3 | EIWS – ENERGY INTENSITY OF WATER SUPPLY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.3 | EIWS - Energy intensity of water supply**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	The definition of energy intensity is the amount of energy used in producing a given level of output or activity. It is measured by the quantity of energy required to perform a particular activity (service), expressed as energy per unit of output or activity measure of service. Thus, it is the quantity of energy required to supply one cubic metre of water to urban areas.
FOCUS/OBJECTIVES	• interconnections water-energy • identify areas of investigation for the improvement of energy consumption for water uses • characterization of energy uses for water delivery

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• energy consumption for each phase of water management (extraction, treatment, delivery, etc.)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• public utilities • technology manufacturers • energy agencies
FREQUENCY (how often to use this indicator?)	• In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	• kWh/m^3
REQUIRED TOOL	• own calculation
CALCULATION METHOD	Total energy intensity, or the amount of energy required to process the use of a given amount of water in a specific location, may be calculated by accounting for the energy requirements for factors such as: • imported supplies (surface and groundwater) • local supplies (surface and groundwater) • regional conveyance • treatment • local distribution • on-site thermal (heating or cooling) • on-site pumping • wastewater collection • wastewater treatment • wastewater discharge
OUTPUT TYPE	• numerical value
EXAMPLES	• Energy for Conventional Water Supply and Wastewater Treatment in Urban China: A Review • An Analysis of the Energy Intensity of Water in California: Providing a Basis for Quantification of Energy Savings from Water System Improvements • Energy-Water Nexus: The Water Sector's Energy Use

LINKS AND REFERENCES	
KEYWORDS	• ENERGY • WATER • WATER SUPPLY
LINKS AND REFERENCES	• http://onlinelibrary.wiley.com/doi/10.1002/gch2.201600016/full • https://fas.org/sgp/crs/misc/R43200.pdf • http://aceee.org/files/proceedings/2006/data/papers/SS06_Panel12_Paper14.pdf

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.3 | EIWS - Energy intensity of water supply

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is fully capable to describe initial planning problems.
R2: Policy support for policies:	The indicator is not directly linked to a specific policy or a Directive; however, it has general relations with: • Water policies, • Infrastructural policies (wastewater, sewerage), • Energy Policies.
R3: Comparability:	Yes, it is able to provide fully comparable results. The comparison of results is possible once the boundary conditions are fixed univocally.

ACCEPTED	
A1: Policy makers:	Not specifically as driving force; it is typically used in a basket of indicators for the assessment of the water-related issues.
A2: Practitioners:	Yes, it is used by practitioners as a solid indicator for the energy consumptions of a system. Being a general indicator, the boundaries for its application can be easily set at urban level, with no reservations.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders

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CREDIBLE	
C1: Unambiguous result:	Yes. Nevertheless, due to the specialized fields which the indicator relates to, a restricted public is the actual target for understanding.
C2: Transparency:	Yes, it is calculated based on local reference information at the level of public utilities.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states. The differentiators are in the boundary conditions, to set properly.

EASY	
E1: Availability of data to calculate the indicator:	Data for the calculation of the indicator have to be collected for the specific case based on the extent of the NBS. However, numerous datasets are available for the several factors.
E2: Technical feasibility:	Once availability of local data is achieved, the calculation is feasible without any specific tools/software/model.
E3: Reproducibility:	Yes. No barriers are found.

ROBUST	
R1: Data quality:	Data are robust and drawn from publicly available information from international databases, research, datasheets and local administrations.
R2: Sensitiveness:	No information is available.
R3: Scale:	The indicator can be used for the calculation of impacts in any evaluation of ex-ante and ex-post situations related to the NBS.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.4 | EUA – ENERGY USE AGRICULTURE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.4 | EUA - Energy use in agriculture**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	The indicator, addressing to the energy-food relation within the Food-Energy Water Nexus, is defined as: agriculture and forestry energy used as a % of total energy use. Agriculture consumes energy directly for crop and livestock production (machinery, etc.) but also indirectly through fertilizers and pesticides. Agriculture also produces energy as biofuels and biomass production. As an energy user, agriculture contributes to global warming (mainly through CO_2 emissions, but also CH_4 and N_2O emissions), air pollution (mainly through NO_x and SO_2 emissions) and to the depletion of fossil energy resources. Important energy users are glasshouse horticulture, floriculture and dairy production. Agriculture can make a contribution to the mitigation of climate change and air pollution effects through more efficient energy use and through the production of renewable energy (bio-energy production).
FOCUS/OBJECTIVES	• applicable to NBS linked to food security • describe the resilience of the national context where the NBS is inserted (descriptive, country level) • check of the effect of depletion/improvement of energy use in favour of the implementation of a NBS (assessment, city level)

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Energy used in agriculture (ktoe-Kilotonne of Oil Equivalent) • All country data originate from the International Energy Agency (IEA): Energy Balances of OECD Countries, Energy Balances of Non-OECD Countries-2011 editions. Flow Agriculture/Forestry, and flow Total. Total bioenergy production from International Energy Agency (IEA) (Energy Balances of OECD Countries, Energy Balances of Non-OECD Countries-2011 editions): Flow Production.
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• IEA • FAOSTAT • city statistical database
FREQUENCY (how often to use this indicator?)	• In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	• %
REQUIRED TOOL	• own calculation based on Energy Balances
CALCULATION METHOD	• The indicator is calculated at country level in FAOSTAT database. References in EUROSTAT and OECD framework • Supporting indicator: Annual use of energy at farm level by fuel type (GJ/ha). OECD: Direct on-farm energy consumption in national total energy consumption.
OUTPUT TYPE	• numerical value
EXAMPLES	• EFFICIENT USE AND CONSERVATION OF ENERGY – Vol. II - Efficient Use and Conservation of Energy in the Agricultural Sector - Clark W. Gellings, Kelly E. Parmenter (http://www.eolss.net/Sample-Chapters/C08/E3-18-04.pdf)

LINKS AND REFERENCES	
KEYWORDS	• FOOD • ENERGY • FOOD SECURITY • ENERGY USE • AGRICULTURE
LINKS AND REFERENCES	• http://www.fao.org/faostat/en/#data/EE • EUROSTAT: AEI n.8; OECD: n.9. Definition in the original frameworks: EUROSTAT: Total energy use at farm level in GJ per ha per year • EUROSTAT: IRENA indicator factsheet; DireDate Task 1 Report

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.4 | EUA - Energy use in agriculture

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is not fully capable to describe initial planning problems, only side effects. On one side, it can be straightforwardly used to describe the resilience of the national context where the NBS is inserted, at country level. On the other side, it can be used to assess the effect of depletion/improvement of energy use in favour of the implementation of a NBS, at city level.
R2: Policy support for policies:	Relations with national agriculture policies
R3: Comparability:	It is indeed a standardised methodology by FAO and IEA. Geographical comparability is limited, except for countries in, for instance, EU or the OECD. Reasonably good comparability over time can be expected, at least in the short run.

ACCEPTED	
A1: Policy makers:	Not for urban level policies, but the relevance of the indicator and of its source are internationally recognized.
A2: Practitioners:	This is a widely used indicator at country level. The main users are FAO analysts, other international organizations, ministries and government agencies, agro-industry, trade and professional associations, research institutes and universities, journalists and general public. The objectives of these users vary, but these types of agriculture statistics are especially useful for market management/monitoring, production forecasts and policy-making in agriculture and food. Its application at urban level can be a smooth customization.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results	Yes, but provided that a proper customization is made to tailor it to urban scale instead of country level.
C2: Transparency:	Yes, it is calculated based on statistical population of energy use values.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Data for the calculation of the indicator are already available at country level, whereas local information for customization has to be gathered.
E2: Technical feasibility:	Once availability of local data is achieved, the calculation is feasible without any specific tools/software/model.
R3: Reproducibility:	Yes. No barriers are found.

ROBUST	
R1: Data quality:	Data are robust and drawn from FAO/IEA estimations.
R2: Sensitiveness:	No information is available on EUROSTAT database.
R3: Scale:	The indicator can be straightforwardly used at country level scale in order to define the national context hosting the NBS and therefore to justify its relevance. At urban scale, the indicator needs tailoring to evaluate ex-ante and ex-post situations related to the NBS impacts.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.5 | PCFPV – PER CAPITA FOOD PRODUCTION VARIABILITY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.5 | PCFPV - Per Capita Food Production Variability**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	Per capita food supply variability corresponds to the variability of the "food net per capita production value in constant 2004-2006 international $" as disseminated in FAOSTAT. The per capita food production variability compares the variations of the food production across countries and time.
FOCUS/OBJECTIVES	• applicable to NBS linked to food security • describe the resilience of the national context where the NBS is inserted (descriptive, country level) • check of the effect of depletion/improvement of food production in favour of the implementation of a NBS (assessment, city level)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Average values of food production (in constant 2004-2006 I$ per caput)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• FAOSTAT • ESS calculation • city statistical database
FREQUENCY (how often to use this indicator?)	• In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	• Constant 2004-2006 thousand international $ per capita
REQUIRED TOOL	• own calculation based on Food Security Statistics by FAO
CALCULATION METHOD	• Missing values in the food net per capita production value are interpolated using a linear trend. The series is then de-trended by fitting a cubic spline by ordinary least squares to the series. The difference between the cubic fit and the actual values are then calculated. Lastly, the volatility for a specific year is defined as the standard deviation of these differences over the previous five years. The aggregates are computed applying the same methodology to the aggregates of the per capita food production variable.
OUTPUT TYPE	• numerical value
EXAMPLES	• Sustainable indicators of food, nutritional and health outcomes in India. A Amarender Reddy – Yojana Archives

LINKS AND REFERENCES	
KEYWORDS	• FOOD • FOOD SECURITY • FOOD PRODUCTION • NET PRODUCTION VALUE • STABILITY
LINKS AND REFERENCES	• http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.Wc4dJmiCzcs

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.5 | PCFPV - Per Capita Food Production Variability**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is not fully capable to describe initial planning problems, only side effects. One benefit of this indicator is its usefulness for observing trends in the stability of a food production over time and its comparability across regions and countries. Depending on the data available, food production variability could be calculated at a local, sub-national, national, or regional level. However, this indicator does not measure the effect of changes in the food production on individual or consumption. Furthermore, since this indicator reflects annual data, it cannot be used to assess the results of short-term shocks to the food system in a country, and is therefore more valuable for assessing long term trends.
R2: Policy support for policies:	High score for policy support Europe-wide and international: ● 2010 EU policy framework on food security ● UN Sustainable development goals (nr. 2)
R3: Comparability:	Yes, it is indeed a standardised methodology by FAO, able to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Not for urban level policies, but the relevance of the indicator and of its source are internationally recognized.
A2: Practitioners:	This is a widely used indicator at country level. Its application at urban level can be a smooth customization.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results:	Yes, but provided that a proper customization is made to tailor it to urban scale instead of country level.
C2: Transparency:	Yes, it is calculated based on historical values of food production.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator	Data for the calculation of the indicator are already available at country level, whereas local information for customization has to be gathered.
E2: Technical feasibility	Once availability of local data is achieved, the calculation is feasible without any specific tools/software/model.
E3: Reproducibility:	Yes. No barriers are found.

ROBUST	
R1: Data quality:	Data are robust and drawn from FAO datasets.
R2: Sensitiveness:	By definition of the indicator, the concept of standard deviation is the core of the indicator in terms of variability.
R3: Scale:	The indicator can be straightforwardly used at country level scale in order to define the national context hosting the NBS and therefore to justify its relevance. At urban scale, the indicator needs tailoring to evaluate ex-ante and ex-post situations related to the NBS impacts.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.6 | PCFSV – PER CAPITA FOOD SUPPLY VARIABILITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.6 | PCFSV - Per Capita Food Supply Variability**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	Per capita food supply variability corresponds to the variability of the "food supply in kcal/caput/day" as disseminated in FAOSTAT. The per capita food supply variability compares the variations of the food supply across countries and time. Volatility in the food supply, presumably reflected in price volatility, affects vulnerable households' ability to make long-term adjustments to their resource constraints. Understanding the degree of instability or volatility within a food system can help researchers, project managers, and policy makers advocate for measures to be taken to improve the food system's (and population's) resiliency to shocks. This indicator is included in the FAO's annual State of Food Insecurity in the World report.
FOCUS/OBJECTIVES	• applicable to NBS linked to food security • describe the resilience of the national context where the NBS is inserted (descriptive, country level) • check of the effect of depletion/improvement of food supply in favour of the implementation of a NBS (assessment, city level)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data

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4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• dietary energy supply (DES)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• FAOSTAT • ESS calculation • city statistical database
FREQUENCY (how often to use this indicator?)	• In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	• kcal/caput/day
REQUIRED TOOL	• own calculation based on Food Balance Sheets (by FAO)
CALCULATION METHOD	• Missing values in the dietary energy supply are interpolated using a linear trend. The series is then de-trended by fitting a cubic spline by ordinary least squares to the series. The difference between the cubic fit and the actual values are then calculated. Lastly, the volatility for a specific year is defined as the standard deviation of these differences over the previous five years. The aggregates are computed applying the same methodology to the aggregates of the food supply variable.
OUTPUT TYPE	• numerical value
EXAMPLES	• Trends in Agricultural Production Efficiency and Its Implications for Food Security in Sub-Saharan African Countries (African Finance & Economics Association Meeting/ASSA Annual Meeting, 2017)

LINKS AND REFERENCES	
KEYWORDS	• FOOD • FOOD SECURITY • FOOD SUPPLY • DIETARY ENERGY • STABILITY
LINKS AND REFERENCES	• http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.Wc4dJmiCzcs • http://www.fao.org/fileadmin/user_upload/fsin/docs/1_FSIN-TWG_UsersGuide_12June2016.compressed.pdf

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.6 | PCFSV - Per Capita Food Supply Variability**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is not fully capable to describe initial planning problems, only side effects. One benefit of this indicator is its usefulness for observing trends in the stability of a food supply over time and its comparability across regions and countries. Depending on the data available, food supply variability could be calculated at a local, sub-national, national, or regional level. However, this indicator does not measure the effect of changes in the food supply on individual or overall food prices or consumption. Nor does it measure the impact on households of bearing the risk of shocks due to instability in the food supply or of the shocks themselves. Furthermore, since this indicator reflects annual data, it cannot be used to assess the results of short-term shocks to the food system in a country, and is therefore more valuable for assessing long term trends
R2: Policy support for policies:	High score for policy support Europe-wide and international: ● 2010 EU policy framework on food security ● UN Sustainable development goals (nr. 2)
R3: Comparability:	Yes, it is indeed a standardised methodology by FAO, able to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Not for urban level policies, but the relevance of the indicator and of its source are internationally recognized.
A2: Practitioners:	This is a widely used indicator at country level. Its application at urban level can be a smooth customization.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

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CREDIBLE	
C1: Unambiguous results:	Yes, but provided that a proper customization is made to tailor it to urban scale instead of country level.
C2: Transparency:	Yes, it is calculated based on historical dietary energy supply values.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Data for the calculation of the indicator are already available at country level, whereas local information for customization has to be gathered.
E2: Technical feasibility:	Once availability of local data is achieved, the calculation is feasible without any specific tools/software/model.
R3: Reproducibility:	Yes. No barriers are found.

ROBUST	
R1: Data quality:	Data are robust and drawn from FAO/WHO/UNU estimations.
R2: Sensitiveness:	By definition of the indicator, the concept of standard deviation is the core of the indicator in terms of variability.
R3: Scale:	The indicator can be straightforwardly used at country level scale in order to define the national context hosting the NBS and therefore to justify its relevance. At urban scale, the indicator needs tailoring to evaluate ex-ante and ex-post situations related to the NBS impacts.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.7 | WS – WATER SECURITY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.7 | WS - Water security**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The proportion of urban water supply coverage is the most fundamental indicator of a city's water security. The urban water security index is a composite of three sub-indices addressing water supply coverage, wastewater treatment, and urban flooding. The urban water security index is a composite of three sub-indices and adjustment factors representing urban growth rate and river basin health: ● urban water supply (%) ● wastewater treated (%) ● drainage (measured as the extent of economic damage caused by floods and storms) ● adjustment factors for urban growth rate and river health.
FOCUS/ OBJECTIVES	● overall methodology applicable to Household WS, Economic WS, Urban WS, Environmental WS and Resilience to water related disasters ● awareness/management of water resources and services in societies ● combinations can be made to assess linkages, for example, between water and energy or water and industry or water and agriculture

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data

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4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• proportion of the urban population provided with piped water services • population served by sewerage system • economic damages caused by floods • statistics • expert opinion where insufficient information is available
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• The majority of data for this indicator was sourced from the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (2012) • local data from public utilities • FAO AQUASTAT (FAO, 2013) • EUROSTAT • local statistics
FREQUENCY (how often to use this indicator?)	• In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	• dimensionless
REQUIRED TOOL	• own calculation
CALCULATION METHOD	• The indicator is calculated at country level • The urban water security index is a composite of three sub-indices and adjustment factors: • urban water supply (%) • wastewater treated (%) • drainage (measured as the extent of economic damage caused by floods and storms) • adjustment factors for urban growth rate and river health
OUTPUT TYPE	• numerical value
EXAMPLES	• https://www.adb.org/publications/series/asian-water-development-outlook

LINKS AND REFERENCES	
KEYWORDS	• FOOD • WATER • WATER SECURITY • WATER WITHDRAWAL • RESILIENCE
LINKS AND REFERENCES	• http://www.gwp.org

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.7 | WS - Water security**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is fully capable to describe initial planning problems. It can be straightforwardly used to describe the resilience of the national context where the NBS is inserted, at country level. It can also be used to assess the effect of depletion/improvement of water withdrawal in favour of the implementation of a NBS, at city level.
R2: Policy support for policies:	The indicator has relations with: ● Water policies, ● Infrastructural policies (wastewater, sewerage), ● Main elements of the water and land regulations (access to water and land, fiscal regime) status, implementation, changes.
R3: Comparability:	Yes, it is able to provide fully comparable results.

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ACCEPTED	
A1: Policy makers:	Not for urban level policies, but the relevance of the indicator and of its source are internationally recognized and applicable.
A2: Practitioners:	This indicator offers several possibilities at country level, with possible application on: • Household Water Security, • Economic Water Security, • Urban Water Security, • Environmental Water Security, • Resilience to water related disasters. The original definition is at country level, whereas the application at urban level can be a smooth customization.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results:	Yes, but provided that a proper customization is made to tailor it to urban scale instead of country level.
C2: Transparency:	Yes, it is calculated based on local reference information at the level of public utilities.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator	Data for the calculation of the indicator are available at country level, whereas local information for customization has to be gathered. Only few episodes of data gaps to be filled with expert opinion are expected.
E2: Technical feasibility:	Once availability of local data is achieved, the calculation is feasible without any specific tools/software/model.
E3: Reproducibility:	Yes. No barriers are found.

ROBUST	
R1: Data quality:	Data are robust and drawn from publicly available information from FAO, EUROSTAT and local administrations.
R2: Sensitiveness:	No information is available on EUROSTAT, FAOSTAT and AQUASTAT database.
R3: Scale:	The indicator can be straightforwardly used at country level scale in order to define the national context hosting the NBS and therefore to justify its relevance. At urban scale, the indicator needs tailoring to evaluate ex-ante and ex-post situations related to the NBS impacts.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.8 | AWW – AGRICULTURE WATER WITHDRAWAL

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.8 | AWW - Agricultural water withdrawal**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	The indicator, addressing to the water-food relation within the Food-Energy Water Nexus, is defined as: agricultural water withdrawal as percentage of total water withdrawal (summed by sector). The agricultural sector uses a considerable share of the available water resources. An increase of irrigated area in a country or region could imply an increase of water use for agriculture. Knowing that a certain area is equipped to be irrigated does not mean that it has been irrigated in a specific year. The indicator Agricultural Water Withdrawal assesses the total amount of water used for irrigation. Irrigation represents the main use of water in agriculture and one of the main uses of water resources in general. Trends in water abstraction may depend on several factors, such as crop type, irrigation technology, water prices, and climatic conditions. Agricultural water withdrawal is a serious concern especially in arid and semi-arid areas, where water is scarce and highly variable from year to year. In dry regions it is necessary to irrigate certain crops to obtain reasonable yields. In addition to lower income for the farmer, low yields will also mean that less fertilizer nitrogen is removed from the fields with harvested crops, and thereby leaving excess nitrogen (N) in the soil resulting in potentially higher risk for leaching during the following period. Furthermore, increased water abstraction may also cause salinisation and contamination of water with other pollutants.
FOCUS/OBJECTIVES	• applicable to NBS linked to food security

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	• describe the resilience of the national context where the NBS is inserted (descriptive, country level) • check of the effect of depletion/improvement of water withdrawal in favour of the implementation of a NBS (assessment, city level)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Agricultural water withdrawal (Volume per year (10^9 m^3/yr): from AQUASTAT: Agricultural Water Withdrawal (AQUASTAT code 4250) • Total water withdrawal: from AQUASTAT: Total water withdrawal (sum of agricultural, municipal, and industrial sector) (AQUASTAT code 4253)
INPUT TYPE (qualitative, quantitative, …)	• quantitative
DATA SOURCE	• FAO AQUASTAT • city statistical database
FREQUENCY (how often to use this indicator?)	• In concept and detailed design phase of urban and object planning.
MEASUREMENT UNIT	• %
REQUIRED TOOL	• own calculation based on trends in water abstraction
CALCULATION METHOD	• The indicator is calculated at country level in FAOSTAT – database, based on the supporting indicators available in AQUASTAT database. • Frameworks: Eurostat: AEI n.20 and OECD: AEI n.1 • Definition in the original frameworks: EUROSTAT: Main indicator: Share of agriculture in water use; supporting indicator; Water use for irrigation (m3/yr) - OECD: Pesticide use (or sales) in terms of tonnes of active ingredients and related trends.
OUTPUT TYPE	• numerical value
EXAMPLES	• http://www.fao.org/nr/water/aquastat/tables/WorldData-Withdrawal_eng.pdf

LINKS AND REFERENCES	
KEYWORDS	• FOOD • WATER • FOOD SECURITY • WATER WITHDRAWAL • AGRICULTURE

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LINKS AND REFERENCES	● http://www.fao.org/faostat/en/#data/EE ● http://www.fao.org/nr/water/aquastat/main/index.stm ● EUROSTAT: IRENA indicator factsheet; DireDate Task 1 Report ● OECD: OECD Environmental Indicators for Agriculture Vol.3 Environmental Performance mof Agriculture since 1990.

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.8 | AWW - Agricultural water withdrawal**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is not fully capable to describe initial planning problems, only side effects. On one side, it can be straightforwardly used to describe the resilience of the national context where the NBS is inserted, at country level. On the other side, it can be used to assess the effect of depletion/improvement of water withdrawal in favour of the implementation of a NBS, at city level.
R2: Policy support for policies:	Relations with: ● Water and irrigation policies, laws, codes, decrees, etc., ● Agriculture-related policies having an effect on water management; main principles and goals (food security, economic development, equity, liberalization, privatization etc.) ● Main elements of the water and land regulations (access to water and land, fiscal regime) status, implementation, changes; role of traditional ruling systems in water management
R3: Comparability	Yes, it is indeed a standardised methodology by FAO, able to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Not for urban level policies, but the relevance of the indicator and of its source are internationally recognized.

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A2: Practitioners:	This is a widely used indicator at country level, with possible application on: • Impact of recent policy changes in water resources, irrigation management, integration of irrigation in other sectors, and the role of irrigation in food production/food security • Existing policies/strategies for natural hazards mitigation (drought or floods) • Policies for funding of irrigation infrastructure, donor involvement • Institutional changes (irrigation sector reform, irrigation management transfer) • Impact of international initiatives on national policies Its application at urban level can be a smooth customization.
A3: Other stakeholders:	Yes, the indicator is accepted by other stakeholders (e.g. Academia, …)

CREDIBLE	
C1: Unambiguous results	Yes, but provided that a proper customization is made to tailor it to urban scale instead of country level.
C2: Transparency:	Yes, it is calculated based on statistical population of water withdrawal values.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Data for the calculation of the indicator are already available at country level, whereas local information for customization has to be gathered.
E2: Technical feasibility:	Once availability of local data is achieved, the calculation is feasible without any specific tools/software/model.
E3: Reproducibility:	Yes. No barriers are found.

ROBUST	
R1: Data quality:	Data are robust and drawn from FAO estimations.
R2: Sensitiveness:	No information is available on FAOSTAT and AQUASTAT database.
R3: Scale:	The indicator can be straightforwardly used at country level scale in order to define the national context hosting the NBS and therefore to justify its relevance. At urban scale, the indicator needs tailoring to evaluate ex-ante and ex-post situations related to the NBS impacts.

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6.1.9 | BEN

6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.9 | BEN – BUILDING ENERGY NEEDS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.9 | BEN - Building energy needs**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DEFINITION	NBS can have thermal impacts on buildings' energy consumptions (for cooling in summer and heating in winter). One can distinguish direct and indirect impacts. Direct impacts are obtained if NBS are applied to the building (ex. green roof), indirect impacts are caused by NBS applied at the district scale when it modifies the local climate and thus buildings energy need. These impacts are measured from the difference in their consumption/needs.
FOCUS/OBJECTIVES	• minimize effect of climate on energy needs/consumption • improve indoor comfort

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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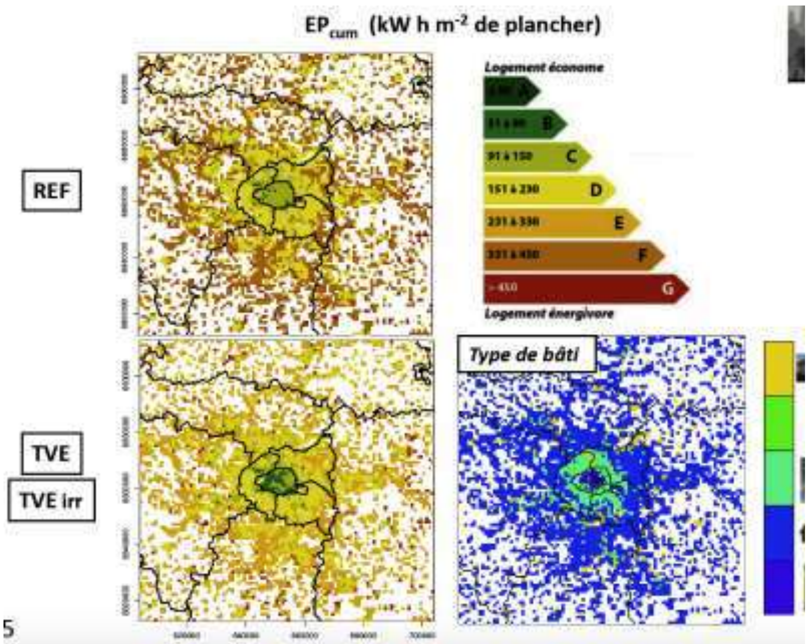
DATA AND MEASUREMENT	
REQUIRED DATA	Direct impacts ● weather data ● building model (geometry +materials) ● occupancy model Indirect impacts ● weather data ● building model (geometry +materials) ● occupancy model ● district model (buildings, streets, trees, ground…)
INPUT TYPE (qualitative, quantitative, …)	● quantitative: weather data ● qualitative: simulation model
DATA SOURCE	● Building simulation/modelling + District thermal modeling ● Measurement/Monitoring
FREQUENCY (how often to use this indicator?)	● One to several times in planning process.
MEASUREMENT UNIT	● kWh/m2.an (calculated for Summer and/or winter)
REQUIRED TOOL	● Building simulation(+urban climate), like: EnergyPlus, SOLENE-microclimat, EnviBatE, Envi-met ● Town Energy Balance at urban scale (SURFEX online mode)
CALCULATION METHOD	● Modelling and calculating indoor temperatures (air, surfaces), humidity and solar fluxes ● Measurement, but difficult to extract effect of NBS
OUTPUT TYPE	● numerical value (impact on summer and winter needs) from the building scale to the city scale
EXAMPLES	 Impact on energy consumptions (year/m2) of having green roofs (TVE) irrigated (TVE irr) or not (TVE) on flat building in Paris. From de Munck et al., 2017.

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LINKS AND REFERENCES	
KEYWORDS	• Energy consumption • Buildings
LINKS AND REFERENCES	• BOUYER, J., et al. (2011): Microclimatic coupling as a solution to improve building energy simulation in an urban context . *Energy and Buildings* 43, nº 7 (juillet 2011): 1549–1559. • C. Munck et al., Evaluating the impacts of greening scenarios on thermal comfort and energy and water consumptions for adapting Paris city..., Urban Climate (2017), http://dx.doi.org/10.1016/j.uclim.2017.01.003 • de Munck, Cécile de. « Modélisation de la végétation urbaine et stratégies d'adaptation pour l'amélioration du confort climatique et de la demande énergétique en ville ». Ph. D. Thesis, Université de Toulouse, 2013. • Donovan, Geoffrey H., et David T. Butry. « The value of shade: Estimating the effect of urban trees on summertime electricity use ». *Energy and Buildings* 41, nº 6 (2009): 662–668. • Cheng, C. Y, Ken K. S Cheung, et L. M Chu. « Thermal performance of a vegetated cladding system on facade walls ». *Building and Environment* 45, nº 8 (août 2010): 1779–1787. • Hongbing, Wang, Qin Jun, Hu Yonghong, et Dong Li. « Optimal tree design for daylighting in residential buildings ». *Building and Environment* 45, nº 12 (décembre 2010): 2594–2606. • Sawka, Michelle, Andrew A. Millward, Janet Mckay, et Misha Sarkovich. « Growing summer energy conservation through residential tree planting ». *Landscape and Urban Planning* 113, nº 0 (mai 2013): 1–9.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.9 | BEN - Building energy needs

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g impact of landscape on building energy needs and then GGE and climate mitigation
R2: Policy support for policies:	High score for policy support Europe-wide Many research and application programs.
R3: Comparability	Yes, methodologies are standardized, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	Yes, it’s fully integrated
A2: Practitioners:	Yes, it’s fully integrated
A3: Other stakeholders:	Yes, the indicator is used in the building sector.

CREDIBLE	
C1: Unambiguous results:	Yes, decision makers and general public understand the described message and coherences of impacts on buildings energy consumption
C2: Transparency:	Yes, it has. Based on climate data, and buildings data, the indicator can be calculated
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all EU member states.

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EASY	
E1: Availability of data to calculate the indicator	Basically the indicator needs data which has to be generated (see Indicator sheet) but tools are already used by all consulting firms. The real problem will be to take into account the effect of NBS that are not always included in this tools or in local climate data.
E2: Technical feasibility:	Same answer as above.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases (different locations, different buildings...). The indicator has been used in different circumstances (different climate conditions) and delivered reasonable results.

ROBUST	
R1: Data quality:	Input data for simulation model are projet and climate data
R2: Sensitiveness:	There are existing several scientific validation papers from the 20 last years
R3: Scale:	Not really and depending actually on the used software and resolution.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.10 | CED – CUMULATIVE ENERGY DEMAND

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.10 | CEM - Cumulative energy demand**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood *Can be adapted to the system under study* ☒ Object
DEFINITION	Cumulative Energy Requirements Analysis (CERA) aims to investigate the energy use throughout the life cycle of a good or a service. This includes the direct uses as well as the indirect or grey consumption of energy due to the use of, e.g. construction materials or raw materials. This method has been developed in the early seventies after the first oil price crisis and has a long tradition (Boustead & Hancock 1979; Pimentel 1973).
FOCUS/OBJECTIVES	• Reduce overall energy consumption (including both non-renewable and renewable energy)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Amount of raw resources (kg or m^3) and energy (MJ) consumed by the system under study
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Urban metabolism/Material Flow Analysis • Life cycle inventory databases
FREQUENCY (how often to use this indicator?)	• Updates are needed when metal/mineral consumption is changing
MEASUREMENT UNIT	• MJ eq
REQUIRED TOOL	• LCA tools such as Simapro, Gabi, openLCA • EPESUS tool • Simple matrix based calculation (MS Excel possible)
CALCULATION METHOD	• The indicator is calculated by multiplying the flows of raw resources and energy (in kg, m^3 and MJ) by the characterisation factor. Values are then summed to get the total value for the indicator in MJ equivalent.
OUTPUT TYPE	• Numerical value
EXAMPLES	• Frischknecht et al. (2015), Cumulative energy demand in LCA: the energy harvested approach • Patel (2003), Cumulative Energy Demand (CED) and cumulative CO_2 emissions for products of the organic chemical industry.

LINKS AND REFERENCES	
KEYWORDS	• Resource • Resource depletion • Life Cycle Assessment • Non-renewable energy • Renewable energy
LINKS AND REFERENCES	• Boustead, I. and Hancock, G.F., Handbook of Industrial Energy Analysis (1979), 422 pp. • Pimentel, D., Food and the energy crisis (1973)

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TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.10 | CEM - Cumulative energy demand

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable of describing initial planning problems (through comparison with references). A significant number of studies has been performed using this indicator.
R2: Policy support for policies:	• EU Target for Renewable Energy by 2020 • Intergovernmental Panel on Climate Change (IPCC) - Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • EU Roadmap 2050 • Energy Performance of Building Directive (and associated national regulations) • 2011 Road Map for Resource-Efficient Europe (part of Europe 2020 strategy)
R3: Comparability:	The methodology is well described and already standardised. This indicator is part of the recommended indicator for the environmental assessment of building products (EN 15804) and buildings (EN 15978).

ACCEPTED	
A1: Policy makers:	This indicator is included in the Energy Performance of Buildings Directive and is already known by policy makers.
A2: Practitioners:	Being included in the EPB Directive, this indicator is already known by urban planners and is already integrated in their practices.
A3: Other stakeholders:	Same comment as before. Considering its inclusion in the EPB Directive (and association national regulations), this indicator is well known from a wide range of stakeholders.

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CREDIBLE	
C1: Unambiguous results:	The results convey a clear and unambiguous message. The only caution is to separate the non-renewable and renewable cumulative energy demand in order to give a clear picture and an unambiguous message to decision makers. Another point is that the calculation method in national regulations can differ slightly from the life cycle approach. Hence, the calculation method has to be explicitly mentioned when using this indicator.
C2: Transparency:	Yes. Clear and widely accepted methodology.
C3: Documentation of assumptions and limitations:	All the calculation methods and underlying data are well documented, accepted and available in existing commercial software.

EASY	
E1: Availability of data to calculate the indicator:	Most of the data are already available. Some data refinements might be needed depending on the system under study (but these refinements are planned in the project)
E2: Technical feasibility:	This indicator is already implemented in existing commercial software.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No
R3: Scale:	No, but adaptable.

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.11 | WSc – WATER SCARCITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.11 | WSc - Water scarcity**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood *Can be adapted to the system under study* ☒ Object
DEFINITION	The AWARE method assesses the relative potential of water deprivation, to either humans or ecosystems. The indicator in the AWARE method builds on the assumption that the less water remaining available per area, the more likely another user will be deprived (Boulay et al. 2016). Water remaining available per area refers to water remaining after human water consumption and environmental water demand has been subtracted from the natural water availability in the drainage basin
FOCUS/OBJECTIVES	• Reduce water consumption considering its use and remaining availability in the drainage basin.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Amount (flows) of water coming from different natural ecosystems (river, lake, ocean...)
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Urban metabolism/Material Flow Analysis • Life cycle inventory databases
FREQUENCY (how often to use this indicator?)	• Updates are needed when water use is changing
MEASUREMENT UNIT	• m^3 of world water equivalent
REQUIRED TOOL	• LCA tools such as Simapro, Gabi, openLCA • EPESUS tool • Simple matrix based calculation (MS Excel possible)
CALCULATION METHOD	• The indicator is calculated by multiplying the water flows (in m^3) by a factor in m^3 world water equivalent/m^3 expressing the scarcity of water in the local (watershed level) context. Values are then summed to get the total value for the indicator in m^3 world water equivalent.
OUTPUT TYPE	• Numerical value
EXAMPLES	• UNEP-SETAC Life Cycle Initiative (2016), Global guidance for life cycle impact assessment indicators – Vol 1.

LINKS AND REFERENCES	
KEYWORDS	• Resource • Resource depletion • Life Cycle Assessment • Water scarcity • Water use
LINKS AND REFERENCES	• Boulay et al., 2016. The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). • UNEP-SETAC Life Cycle Initiative (2016), Global guidance for life cycle impact assessment indicators – Vol 1., http://www.lifecycleinitiative.org/applying-lca/lcia-cf/

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.11 | WSc - Water scarcity

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable of describing initial planning problems (through comparison with references).
R2: Policy support for policies:	• European Innovation Partnership on Water • River Basin Management Plans • Blue Print for Safeguarding European Waters • Policy Review for water scarcity and droughts
R3: Comparability:	This indicator is recommended by the UNEP-SETAC Life Cycle Initiative which has recently (2016) conducted a work to define the most relevant LCIA method to assess water scarcity considering scientific and stakeholders point of views. Thus, even though the methodology is not part of any standard, it is quite standardised. However, it shall be mentioned that so far, few studies have been performed using this methodology.

ACCEPTED	
A1: Policy makers:	Very similar indicators are used in the development of water-related policies (especially freshwater consumption related policies)
A2: Practitioners:	The indicator is not used by urban planners for the time being but it definitively has the potential to be used. In comparison to other existing indicators, the inclusion of local water aspects is of particular interest for urban planners.
A3: Other stakeholders:	Yes. This indicator has been recognised by the UNEP-Life Cycle Initiative as the most relevant existing indicators to assess water scarcity. As mentioned above, this recognition has included both a scientific and a stakeholder assessment.

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CREDIBLE	
C1: Unambiguous results:	Yes. Results are clear both for decision makers and the general public. They are expressed in m^3 of water which is more or less understandable by everybody.
C2: Transparency:	Yes and available in peer reviewed papers and also in other international publications.
C3: Documentation of assumptions and limitations:	Yes, the references given in the indicator factsheet are fully disclosed and ensure a uniform application in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Data needed for the calculation of the indicator are elaborated in all “classical” water related studies in urban planning. Some data refinements might be needed depending on the system under study (but these refinements are planned in the project)
E2: Technical feasibility:	Easy technical feasibility as all the data needed are available and the calculation procedure is not complex.
E3: Reproducibility:	Yes, the indicator is perfectly reproducible. It has been tested on different case studies within the work performed by the UNEP-SETAC Life Cycle Initiative.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	The work of the UNEP-SETAC Life Cycle Initiative includes an uncertainty estimate. A detailed calculation procedure (Monte Carlo Analysis) can also be implemented to calculate the uncertainty of the indicator when applied to a specific case study.
R3: Scale:	Yes

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6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.12 | AWC – ABSOLUTE WATER CONSUMPTION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.12 | AWC - Absolute water consumption**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator presents the average annual value calculated by the aggregation of two values: • Indoor water use • External water use
FOCUS/OBJECTIVES	• To control water consumption • To improve water management
NOTES	This indicator is qualitative indicator and it is measured in m^3 but it can be also presented in € knowing the price of potable water (€/m^3) and greywater (€/m^3).

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Consumption of potable water • Total value of rainwater and greywater that is collected in the area • Consumption of non-potable water (WC, heating systems, gardens …etc.) • Amount of building occupants • Green surface • Weather data • Local rainfall • Type of plants
INPUT TYPE (qualitative, quantitative)	Quantitative
DATA SOURCE	• District/Urban data • Survey questionnaires (a total of more than 1000 surveys sent to municipalities) • GIS data • Demographic data • Weather data
FREQUENCY (how often to use this indicator?)	Annually
MEASUREMENT UNIT	M^3
REQUIRED TOOL	• WaterCAD, • SewerCAD
CALCULATION METHOD	Measurement/Modelling and calculating of water, with respect to baseline values Where rainwater is collected for both internal and external use, it must be mentioned to determine whether sufficient volume has been collected.
OUTPUT	• numerical value • graphic presentation
EXAMPLES	• Water footprint calculator: http://www.gracelinks.org/1408/water-footprint-calculator • Water Usage Calculator: https://www.hunterwater.com.au/Save-Water/Water-Usage-Calculator.aspx • Water calculator: http://www.home-water-works.org/calculator • Water calculation methodology guidance: www.communities.gov.uk/publication /planningandbuilding/watercalculator

LINKS AND REFERENCES	
KEYWORDS	• WATER • GREYWATER • POTABLE WATER • NON-POTABLE WATER • REINWATER
LINKS AND REFERENCES	• BROWN, S. et al (2016): Sowing Seeds in the City Ecosystem and Municipal Services; Springer • COMMUNITIES AND LOCAL GOVERNMENT (2009); The Water Efficiency Calculator for new dwellings

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	• SCHUETZE, T. & Santiago-Fandiño, V. (2013); Quantitative Assessment of Water Use Efficiency in Urban and Domestic Buildings; Water (5); 1172-1193

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.12 | AWC - Absolute water consumption**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable to describe the absolute water consumption (both potable and non-potable water, like grey and rain water) in the city and neighbourhood scale. Main problem is identified in the non-potable water measurement
R2: Policy support for policies:	The indicator is related the following policies and/or objectives: • EN 15643-2:2011: Sustainability of construction works. Assessment of buildings. Framework for the assessment of environmental performance • ISO 21931-1:2010: Sustainability in building construction -- Framework for methods of assessment of the environmental performance of construction works -- Part 1: Buildings • ISO 21929-1:2011: Sustainability in building construction -- Sustainability indicators -- Part 1: Framework for the development of indicators and a core set of indicators for buildings • ISO 37120:2014: Sustainable development of communities -- Indicators for city services and quality of life • HQE for Urban Planning and Development • LEED for Neighbourhood Development • BREEAM Communities • The EU Water Framework Directive (2000/60/EC) is based on the idea that modern water management • Sustainable Building Alliance • EU Water Framework Directive (WFD) (2000/60/EC)

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R3: Comparability:	The indicator depends also on survey data, but theoretically it is possible to standardise the methodology, in order to provide comparable results.

ACCEPTED	
A1: Policy makers:	It was studied but only partially.
A2: Practitioners:	The indicator could be used at the municipality and neighbourhood level.
A3: Other stakeholders:	The indicator can be used by central government, planners, municipal waterworks, building owners, individual and collective farms ….

CREDIBLE	
C1: Unambiguous results:	This indicator is able to describe of the absolute water consumption, although final results depends on many factors, such as: access to the data, survey data, whether conditions, data processing…etc.
C2: Transparency:	Yes, although some of specific data will be needed, such as: climate data, green area, type of plants...etc.
C3: Documentation of assumptions and limitations:	YES

EASY	
E1: Availability of data to calculate the indicator:	The methodology needs some specific data, such as: climate data, green surface, type of plants, consumption of non-potable water (WC, heating systems, gardens …etc.) etc. that will be available in: • District/Urban data • Survey questionnaires (a total of more than 1000 surveys sent to municipalities) • GIS data • Weather data That depends on the introduction of this information to the methodology
E2: Technical feasibility:	The indicator requires special software and database. It has a clear input and methodology to avoid ambiguity and implementation errors.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases. The indicator can be used in different circumstances (different climate conditions, green surface …) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	There are existing some possibilities of uncertainty in the data if the survey is carried out with the due guarantees. Such for example to assume the irrigation requirements of green areas that can be calculated parametrically by green

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	surface as for example assuming 0.4 m^3/m^2 from the April to September months (European conditions).
R3: Scale:	Yes, depending actually on the used software and resolutions.

6.1.13 | WE

6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.13 | WE – WATER EFFECIENCY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.13 | WE - Water efficiency**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Water efficiency is reducing water wastage by measuring the amount of water required for a particular purpose and the amount of water used or delivered. Solutions for water efficiency focuses on the reduction of the amount of potable water as well as non-potable water where appropriate (i.e. WC, watering landscape, et.).
FOCUS/OBJECTIVES	• Water use reduction • Innovative wastewater technologies • Water reuse • Irrigation system • Water efficient landscaping
NOTES	• Measurement of this indicator depends on the availability of the database and capability of the NBS tool

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	

REQUIRED DATA	• Measurement of water consumption
	• Data of reduction in consumption of water distributed
	  ○ Delayed inlet valves
	  ○ Flow restrictors – to restrict water flow and reduce the outlet flow and pressure. The flow devices should be reported on their quality (certification, label, marking..etc.)
	  ○ Low flush WCs – are specially designed to reduce the volume of water consumed during flushing. These systems must pass the discharge performance requirements of EN 997:2012 for class 2 WC suites.
	  ○ Mains potable water – drinking quality water taken from a connection to the mains water supply
	  ○ Potable water – is taken from the public water supply or private supply such as from groundwater via a borehole
	• Wastewater data
	  ○ Grey water recycling – treatment and storage of used shower, bath and tap water for use instead of potable water in WC and/or washing machine
	• Rainwater data:
	  ○ Rainwater recycling – to appropriate collection and storage of rain for use instead of potable water in WCs and/or washing machines..etc.
	• Data of reduced overall Irrigation demand

INPUT TYPE (qualitative, quantitative,...)	• Quantitative
DATA SOURCE	• Measurement/Monitoring • Theoretical values
FREQUENCY (how often to use this indicator?)	Annual
MEASUREMENT UNIT	%
REQUIRED TOOL	• WaterCAD, • SewerCAD
CALCULATION METHOD	Measurement/Modelling and calculating of water efficient with respect to baseline values. Calculation can be based on the Water Efficiency Calculator for New Dwellings : Or Simple equation that can be used for calculation: $x\ (\%) = \frac{\text{Total water consumption [m3]}}{\text{Total adequate consumption [m3]}}\ x\ 100\%$
OUTPUT TYPE	• numerical value (low, mean, peak or difference scenarios) • graphic map
EXAMPLES	• Water Efficiency Calculator for New Dwellings - is the Government´s national calculation method for the assessment of water efficiency in new dwellings in support of Building Regulations Part G 2009 and the Code for Sustainable Homes, May 2009 and subsequent versions. This calculator asses the contribution that each internal water fitting

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	has on the water consumption of the whole house, measured in litres per person per day based on research into typical water use.

LINKS AND REFERENCES	
KEYWORDS	• WATER EFFICIENCE • WATER CONSUMPTION • WATER REDUCTION • WATER MANAGEMENT
LINKS AND REFERENCES	• Communities and Local Government (Nov.2010); Code for Sustainable Homes. Technical Guide. • HQE™ Certified by Cerway Certification scheme for building under construction • LEED® for Homes Rating Systems

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.13 | WE - Water efficiency

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable to describe Water efficiency by measuring the amount of water required for a particular purpose and the amount of water used or delivered.
R2: Policy support for policies:	The indicator is related the following policies and/or objectives: • Water Efficiency Certificate • The Federal Energy Management Program (FEMP) worked with the U.S. Environmental Protection Agency (EPA) • The Alliance for Water Efficiency is supported by the U.S. Environmental Protection Agency (EPA) • Waterwise Organisation - the leading authority on water efficiency in the UK and Europe • The California Water Efficiency Partnership (formerly the California Urban Water Conservation Council) • Communities and Local Government (Nov.2010); Code fpr Sustainable Homes. Technical Guide. • HQE™ Certified by Cerway Certification scheme for building under construction • LEED® for Homes Rating Systems • EU [2002] Directive 2002/91/EC of the European Parliament and of the Council on the energy performance of buildings • EU [2011] Blueprint to safeguard Europe´s water resources • Gobierno de España (2006) Código Técnico de la Edificación [Real Decreto 314/2006] Ministerio de Vivienda, Madrid, España • Gobierno de España (2007) Real Decreto 1620/2007, de 7 de diciembre, por el que se establece el régimen jurídico de la reutilización de las aguas depuradas, Ministerio de la Presidencia, Madrid, Spain

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	• INAG (2001) National Programme for the Efficient Use of Water [PNUEA], Instituto de Água, Ministério de Ambiente e do Ordenamento de Território, Lisbon, Portugal • Portugal (1995) Regulatory Decree 23/95 - General Regulation of Public and Building Systems for Water Distribution and Wastewater Drainage, Ministério das Obras Públicas, Transportes e Comunicaçoes, Lisbon, Portugal • Portugal [2006] PEAASAR II – Strategie Plan for the Supply of Water and Sanitation of Waste Water 2007-2013, Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimiento Regional, Lisbon, Portugal
R3: Comparability:	The indicator depends also on survey data, but theoretically it is possible to standardise the methodology, in order to provide comparable results.

ACCEPTED	
A1: Policy makers:	It was studied but only partially.
A2: Practitioners:	The indicator could be used at the municipality and neighbourhood level.
A3: Other stakeholders:	The indicator can be used by Central Government, Planners, Municipal Waterworks, Building Owners, Individual and Collective farms, Environment Agency, Internal Drainage Boards….

CREDIBLE	
C1: Unambiguous results:	This indicator is able to describe of the absolute water consumption, although final results depends on many factors, such as: access to the data, survey data, weather conditions, data processing…etc.
C2: Transparency:	Yes, although some of specific data will be needed, mainly related to implanted new efficient technologies
C3: Documentation of assumptions and limitations:	YES

EASY	
E1: Availability of data to calculate the indicator:	The methodology needs some specific data, such as: climate data, green surface, type of plants, consumption of non-potable water (WC, heating systems, gardens …etc.) etc. that will be available in: • District/Urban data • Survey questionnaires (a total of more than 1000 surveys sent to municipalities) • GIS data • Weather data • Etc. That depends on the introduction of this information to the methodology
E2: Technical feasibility:	The indicator requires special software and database. It has a clear input and methodology to avoid ambiguity and implementation errors.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases. The indicator can be used in different circumstances (different climate conditions, provided or/and planned data…) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data

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R2: Sensitiveness:	There are existing some possibilities of uncertainty in the data and use state of the art or hypothetic planned actions.
R3: Scale:	Yes, depending actually on the software used and sources of data, it can be multiscale.

6.1.14 | WI

6 | RESOURCE EFFICIENCY

6.1 | FOOD, ENERGY AND WATER

6.1.14 | WI – WATER INTENSITY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	**6.1.14 | WI - Water intensity**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Water Use Intensity– is all water sources divided by the building surface, including outdoor surface. The ratio between water intake and a defined unit of production.
FOCUS/OBJECTIVES	• To monitor all sources of water • To improve water management
NOTES	• This indicator can be presented as the total water consumed by the energy system, that consequently should have significance in: o Improvement in technological efficiency o Increase reuse of water in the economy o Use of alternative sources (e.g. desalinated water)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Total water intake • Studied surface • Green area • Water cover • Soil sealing • Rainfall • Flood risk • Water consumption of energy
INPUT TYPE (qualitative, quantitative,…)	• Quantitative
DATA SOURCE	• Measurement/Monitoring • GIS map • Eurostat data • Meteorological data • Municipal data • Building data
FREQUENCY (how often to use this indicator?)	Daily, Monthly, Annual
MEASUREMENT UNIT	M^3/M^2 or M^3/€
REQUIRED TOOL	• IBM TRIRIGA Version 10.5.2 • Water balance model ABIMO • City GML
CALCULATION METHOD	Measurement/Modelling and calculating of water intensity, with respect to baseline values
OUTPUT TYPE	• Numerical value • Graphic map
EXAMPLES	• ENERGY STAR Portfolio Manager • BOMA BEST Sustainable Buildings 3.0 assessment • WEAP ("Water Evaluation And Planning" system)

LINKS AND REFERENCES	
KEYWORDS	• WATER CONSUMPTION • ENERGY CONSUMPTION • WATER INTENSITY
LINKS AND REFERENCES	• OECD Better Policies for Better Lives; 01. Water intensity: https://www.oecd.org/innovation/green/toolkit/o1waterintensity.htm • ENERGY STAR Building FAQs • http://www.weap21.org • Jialiang, C. et al (2016); Impacts of industrial transition on water use intensity and energy-related carbon intensity in China: A spatio-temporal analysis during 2003–2012; Applied Energy, Vol. 183, p.1112-1122 • Spang E.S et al (2014); Multiple metrics for quantifying the intensity of water consumption of energy production; Environ. Res. Lett. 9

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.1 | Food, Energy and Water

INDICATOR	
NAME	6.1.14 | WI - Water intensity

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable to determine which sources of water or/and facilities have good or poor water use, it can analyse and compare seasonal peaks, anomalies, or trends.
R2: Policy support for policies:	The indicator is an important indicator for policies of water allocation among different sectors of the economy mainly in water-scarce regions, where there is competitions for water among various users. The indicator is related the following policies and/or objectives: • Water and Energy Efficiency: The United Nations www.un.org • The Organisation for Economic Co-operation and Development (OECD) www.oecd.org • EU Water Framework Directive (WFD) (2000/60/EC)
R3: Comparability:	The indicator depends also on data, but theoretically it is possible to standardise the methodology, in order to provide comparable results.

ACCEPTED	
A1: Policy makers:	It was studied but only partially.
A2: Practitioners:	The indicator could be used at the municipality and neighbourhood level.
A3: Other stakeholders:	The indicator can be used by Central Government, Planners, Building Owners, Environment and Energy Agency

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CREDIBLE	
C1: Unambiguous results:	This indicator is able to describe of the water intencity, although final results depends on many factors, such as: access to the data, data processing…etc.
C2: Transparency:	Yes, although some of specific data will be needed, mainly related to water consumption and energy
C3: Documentation of assumptions and limitations:	YES

EASY	
E1: Availability of data to calculate the indicator:	The methodology needs some specific data, which should be available in: • District/Urban data • Central Government • Public sector facilities and commercial users • Distribution utilities
E2: Technical feasibility:	The indicator requires special software and database. It has a clear input and methodology to avoid ambiguity and implementation errors.
R3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases. The indicator can be used in different circumstances (different climate conditions, provided or/and planned data…) and delivered reasonable results.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	There are existing some possibilities of uncertainty in the data and use state of the art or hypothetic planned actions.
R3: Scale:	Yes, depending actually on the software used and sources of data, it can be multiscale.

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6.2.1| RME

6 | RESOURCE EFFICIENCY

6.2 | RAW MATERIAL

Short description of USC: Raw materials including ferrous and non-ferrous metals and fuels are being consumed continuously in all daily operations in order to satisfy the ever-growing demand for new products and services. Raw materials not only creates pressure on the environment in the form of resource depletion but also leads to creation of waste. For this reason, particularly non-renewable natural resources need to be utilized sparingly and overstraining renewable resources should be avoided.

6.2.1 | RME – RAW MATERIAL EFFICIENCY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.2 | Raw material

INDICATOR	
NAME	**6.2.1 | RWE - Raw material efficiency**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	This indicator illustrates the percent change of consumed non-metallic minerals, metal ores, biomass and fossil energy carriers per capita to the baseline levels.
FOCUS/OBJECTIVES	The objective of the indicator is to give a percent change value in primary raw material consumption per capita as a result of strategic implementation of NBS.
NOTES	According to the type of the NBS implemented, the priority of this indicator may change.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Information on the primary raw material consumption • Information on the population • Information on the baseline raw material consumption values
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Public Administration
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• % (change)
REQUIRED TOOL	• There is no specific software required. But in order to collect the information extensive databases and software such as Excel or Access to manage them will be required.
CALCULATION METHOD	• Evaluate the primary raw material consumption per capita • Calculate the percent change with the baseline data • Required data can be obtain public administration and/or statistical databases
OUTPUT TYPE	• Quantitative value
EXAMPLES	• Integrated Sustainability Assessment of the Production and Supply of Raw Materials and Primary Energy Carriers (Dewulf et al, 2015).

LINKS AND REFERENCES	
KEYWORDS	• Raw material consumption • Raw material efficiency
LINKS AND REFERENCES	• BIO Intelligence Service, Institute for Social Ecology and Sustainable Europe Research Institute, 2012, Assessment of resource efficiency indicators and targets. Final report prepared for the European Commission, DG Environment. • Dewulf, Jo; Mancini, Lucia; Blengini, Gian Andrea; Sala, Serenella; Latunussa, Cynthia; Pennington, David. 2015. Towards an overall analytical framework for the integrated Sustainability Assessment of the Production and Supply of Raw Materials and Primary Energy Carriers. *Journal of Industrial Ecology*, 19(6) 963-977.OECD. 2011. Towards Green Growth: Monitoring Progress - OECD Indicators. OECD, Paris. • European statistics. (n.d.)., from http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/natural-resources/raw-materials, Date of Access October, 2017 • Dewulf, J., Mancini, L., Blengini, G. A., Sala, S., Latunussa, C., & Pennington, D., 2015, Toward an Overall Analytical Framework for the Integrated Sustainability Assessment of the Production and Supply of Raw

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Materials and Primary Energy Carriers. *Journal of Industrial Ecology, 19*(6), 963-977.

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.2 | Raw material

INDICATOR	
NAME	6.2.1 | RWE - Raw material efficiency

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, the indicator is related to consumption of primary and secondary raw materials whose flows can be affected by implementation of NBS.
R2: Policy support for policies:	• Indicators on material use is directly linked to resource use and resource efficiency addressed in Flagship Initiative or the Resource Strategy, which is related to monitoring of trends in total use of natural resources. Material consumption indicators also link to policies such as Raw Material Initiative or the Action Plan on Sustainable Consumption and Production.
R3: Comparability:	

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ACCEPTED	
A1: Policy makers:	With strong policy support material consumption indicators are widely accepted by policy makers.
A2: Practitioners:	Yes. Although not part of conventional urban planning practice, raw material efficiency can be integrated into sustainable urbanism studies as part of decision making on urban renewal plans, new development zones and interactions between zoning plans. This can be integrated as part of sustainability assessments that planning decisions are based on and as part of plan notes that restrict specific material uses in practice.
A3: Other stakeholders:	Raw material consumption indicator, which is the basis of raw material efficiency, is well accepted by statistical institutions, which are the main data providers for a number of resource efficiency indicators. Raw material efficiency indicators are also frequently used by academia. Companies are also very interested in monitoring their resource efficiency.

CREDIBLE	
C1: Unambiguous results:	Yes, most of the indicators under resource efficiency category provide unambiguous results and a clear message.
C2: Transparency:	Yes. Raw material efficiency indicator is calculated based on the specific amount of raw material consumed that can be reported in a transparent way.
C3: Documentation of assumptions and limitations:	

EASY	
E1: Availability of data to calculate the indicator:	Yes, data related to many resource efficiency, raw material in particular, is available from the national statistical institutes as well as EUROSTAT for the EU in general.
E2: Technical feasibility:	The indicator is estimated by basic material accounting without any need for specific software or equipment.
E3: Reproducibility:	Yes.

ROBUST	
R1: Data quality:	Statistical institutes provide robust real data on raw material consumption.
R2: Sensitiveness:	The results of raw material efficiency indicator is highly dependent on the availability and quality of data, which may lead to uncertainty and error in estimation. However, there is no inherent uncertainties in the estimation methodology.
R3: Scale:	Raw material efficiency can be disaggregated for smaller scales easily and can be reported for a number of scales.

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6 | RESOURCE EFFICIENCY

6.2 | RAW MATERIAL

6.2.2 | ARDfuels – ABIOTIC RESOURCE DEPLETION FOSSIL FUELS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.2 | Raw material

INDICATOR	
NAME	**6.2.2 | ARDfuels - Abiotic resource depletion – fossil fuels**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood *Can be adapted to the system under study* ☒ Object
DEFINITION	"Abiotic resources" are natural resources (including energy resources) such as iron ore, crude oil and wind energy, which are regarded as non-living. The indicator considered here only includes fossil energy resources as recommended by JRC and is based on the CML characterisation method. In this method, abiotic depletion of fossil fuels is related to the Lower Heating Value (LHV) expressed in MJ per kg or m3 of fossil fuel. The reason for taking the LHV is that fossil fuels are considered to be substitutable.
FOCUS/OBJECTIVES	• Reduce fossil fuel consumption and associated resource scarcity • Prevent the use of fossil fuels

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Amount of fossil fuels (Coal, Gas, Methane, Oil) consumed by the system under study
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Urban metabolism/Material Flow Analysis • Life cycle inventory databases
FREQUENCY (how often to use this indicator?)	• Updates are needed when fossil fuel consumption is changing
MEASUREMENT UNIT	• MJ equivalent
REQUIRED TOOL	• LCA tools such as Simapro, Gabi, openLCA • EPESUS tool • Simple matrix based calculation (MS Excel possible)
CALCULATION METHOD	• The indicator is calculated by multiplying the flows of fossil fuels (in kg or m^3) by the LHV expressed in MJ in kg or m^3. Values are then summed to get the total value for the indicator in MJ equivalent (MJ eq.)
OUTPUT TYPE	• Numerical value
EXAMPLES	• Martinez et al. (2009): Life-cycle assessment of a 2-MW rated power wind turbines: CML method • Klinglmair et al. (2014): Assessing resource depletion in LCA: a review of methods and methodological issues

LINKS AND REFERENCES	
KEYWORDS	• Resource • Resource depletion • Life Cycle Assessment • Fossil fuels
LINKS AND REFERENCES	• Guinée, J.B.; Gorrée, M.; Heijungs, R.; Huppes, G.; Kleijn, R.; Koning, A. de; Oers, L. van; Wegener Sleeswijk, A.; Suh, S.; Udo de Haes, H.A.; Bruijn, H. de; Duin, R. van; Huijbregts, M.A.J. Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Kluwer Academic Publishers, ISBN 1-4020-0228-9, Dordrecht, 2002, 692 pp. • Van Oers, L.; de Koning, A.; Guinée, J.B.; Huppes, G. Abiotic resource depletion in LCA, Improving characterisation factors for abiotic resource depletion as recommended in the new Dutch LCA Handbook. Road and Hydraulic Engineering Institute, 25 June 2002, 75 pp. • European Commission-Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook-Recommendations for Life Cycle Impact Assessment in the European context. First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union; 2011.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.2 | Raw material

INDICATOR	
NAME	6.2.2 | ARDfuels - Abiotic resource depletion – fossil fuels

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable of describing initial planning problems (through comparison with references). However, the indicator does not account for local specificities.
R2: Policy support for policies:	High score for policy support Europe-wide and international: ● EU Target for Renewable Energy by 2020 ● Intergovernmental Panel on Climate Change (IPCC) - Report on Climate Change Impacts, Adaptation and Vulnerability (2014) ● EU Roadmap 2050 ● 2011 Road Map for Resource-Efficient Europe (part of Europe 2020 strategy)
R3: Comparability:	Significant works have already been performed to standardise the methodology and to provide fully comparable results (e.g. ILCD Handbook developed by the Institute for Environment and Sustainability in the European Commission Joint Research Centre)

ACCEPTED	
A1: Policy makers:	Similar indicators are provided by EUROSTAT but not this one precisely.
A2: Practitioners:	The indicator is not used by urban planners for the time being but it definitively has the potential to be used (see below inclusion of the indicator in EN standards)
A3: Other stakeholders:	Not in peer reviewed paper but this indicator is used for the communication on the environmental impacts of building products (Environmental Product Declarations according to EN 15804) and the environmental of buildings (according to EN 15978).

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CREDIBLE	
C1: Unambiguous results:	A further step in the calculation could be needed to compare the results obtained (X MJ eq) to something more practical for decision makers (e.g. Y km by plane)
C2: Transparency:	Yes, and widely accepted.
C3: Documentation of assumptions and limitations:	Yes, the references given in the indicator factsheet are fully disclosed and ensure a uniform application in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Most of the data are already available. Some data refinements might be needed depending on the system under study (but these refinements are planned in the project)
E2: Technical feasibility:	Yes. Commercial software is already existing for this indicator.
E3: Reproducibility:	Yes, the indicator is perfectly reproducible.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	There are existing several scientific papers discussing the uncertainty related to this indicator and the conclusion is that it is quite low.
R3: Scale:	Not really. The indicator will be influence by NBS at the different scale but the effect of the NBS will be, in absolute terms, the same.

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6 | RESOURCE EFFICIENCY

6.2 | RAW MATERIAL

6.2.3 | ARDmetalmineral – ABIOTIC RESOURCE DEPLETION METAL AND MINERAL

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.2 | Raw material

INDICATOR	
NAME	**6.2.3 | ARDmetalmineral - Abiotic resource depletion – metal and mineral**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood *Can be adapted to the system under study* ☒ Object
DEFINITION	“Abiotic resources” are natural resources (including energy resources) such as iron ore, crude oil and wind energy, which are regarded as non-living. The indicator considered here only includes metal and mineral resources (separated from fossil fuels) as recommended by JRC and is based on the CML characterisation method. In this method, the ultimate stock reserves are considered, which refers to the quantity of resources that is ultimately available, estimated by multiplying the average natural concentration of the resources in the earth’s crust by the mass of the crust. The characterisation factors are named “abiotic depletion potential” (ADP) and expressed in kg of antimony (Sb) equivalent, which is the adopted reference element.
FOCUS/OBJECTIVES	• Reduce metal and mineral consumption and associated resource scarcity • Prevent the use of metal and mineral (considering their overall availability in the earth’s crust)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Amount of mineral and metal (e.g. nickel, phosphorus, copper) consumed by the system under study
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Urban metabolism/Material Flow Analysis • Life cycle inventory databases
FREQUENCY (how often to use this indicator?)	• Updates are needed when metal/mineral consumption is changing
MEASUREMENT UNIT	• kg antimony (Sb) equivalent
REQUIRED TOOL	• LCA tools such as Simapro, Gabi, openLCA • EPESUS tool • Simple matrix based calculation (MS Excel possible)
CALCULATION METHOD	• The indicator is calculated by multiplying the flows of metals and minerals (in kg) by the ADP factor expressed in kg Sb eq/kg of resource. Values are then summed to get the total value for the indicator in kg Sb equivalent.
OUTPUT TYPE	• Numerical value
EXAMPLES	• Martinez et al. (2009): Life-cycle assessment of a 2-MW rated power wind turbines: CML method • Klinglmair et al. (2014): Assessing resource depletion in LCA: a review of methods and methodological issues

LINKS AND REFERENCES	
KEYWORDS	• Resource • Resource depletion • Life Cycle Assessment • Metals • Minerals
LINKS AND REFERENCES	• Guinée, J.B.; Gorrée, M.; Heijungs, R.; Huppes, G.; Kleijn, R.; Koning, A. de; Oers, L. van; Wegener Sleeswijk, A.; Suh, S.; Udo de Haes, H.A.; Bruijn, H. de; Duin, R. van; Huijbregts, M.A.J. Handbook on life cycle assessment. Operational guide to the ISO standards. I: LCA in perspective. IIa: Guide. IIb: Operational annex. III: Scientific background. Kluwer Academic Publishers, ISBN 1-4020-0228-9, Dordrecht, 2002, 692 pp. • Van Oers, L.; de Koning, A.; Guinée, J.B.; Huppes, G. Abiotic resource depletion in LCA, Improving characterisation factors for abiotic resource depletion as recommended in the new Dutch LCA Handbook. Road and Hydraulic Engineering Institute, 25 June 2002, 75 pp. • European Commission-Joint Research Centre - Institute for Environment and Sustainability: International Reference Life Cycle Data System (ILCD) Handbook- Recommendations for Life Cycle Impact Assessment in the European context. First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union; 2011.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.2 | Raw material

INDICATOR	
NAME	**6.2.3 | ARDmetalmineral - Abiotic resource depletion – metal and mineral**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is capable of describing initial planning problems (through comparison with references). However, the indicator does not account for local specificities.
R2: Policy support for policies:	• EU Raw Material Initiative • EU Minerals Policy • 2011 Road Map for Resource-Efficient Europe (part of Europe 2020 strategy)
R3: Comparability:	Significant works have already been performed to standardise the methodology and to provide fully comparable results (e.g. ILCD Handbook developed by the Institute for Environment and Sustainability in the European Commission Joint Research Centre)

ACCEPTED	
A1: Policy makers:	Similar indicators are provided by EUROSTAT but not this one precisely.
A2: Practitioners:	The indicator is not used by urban planners for the time being but it definitively has the potential to be used (see below inclusion of the indicator in EN standards)
A3: Other stakeholders:	Not in peer reviewed paper but this indicator is used for the communication on the environmental impacts of building products (Environmental Product Declarations according to EN 15804) and the environmental of buildings (according to EN 15978).

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CREDIBLE	
C1: Unambiguous results:	A further step in the calculation could be needed to compare the results obtained (X kg Sb eq) to something more practical for decision makers (e.g. Y aluminium cans). The unit of the indicator is not easy to capture for non-expert.
C2: Transparency:	Yes, and widely accepted.
C3: Documentation of assumptions and limitations:	Yes, the references given in the indicator factsheet are fully disclosed and ensure a uniform application in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Most of the data are already available. Some data refinements might be needed depending on the system under study (but these refinements are planned in the project)
E2: Technical feasibility:	Yes. Commercial software are already existing for this indicator.
E3: Reproducibility:	Yes, the indicator is perfectly reproducible.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	There are existing several scientific papers discussing the uncertainty related to this indicator and the conclusion is that it is quite low. The error estimation is not an integral part of the study but scientific evidence about the order of magnitude of the uncertainty associated with this indicator is existing.
R3: Scale:	Not really. The indicator will be influence by NBS at the different scale but the effect of the NBS will be, in absolute terms, the same.

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6 | RESOURCE EFFICIENCY

6.3 | WASTE

6.3.1 | SWG – SPECIFIC WASTE GENERATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.3 | Waste

INDICATOR	
NAME	**6.3.1 | SWG - Specific waste generation**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator measures the annual municipal solid waste generation per capita. The quantities of material that leave the economy in the form of waste represent the most apparent potential for increasing resource efficiency. If society's metabolism was self-sufficient, it would produce no waste. Municipal Solid Waste (MSW): is waste generated by households, commercial activities and other sources whose activities are similar to those of households and commercial enterprises. It does not include other waste arising e.g., from mining, industrial or construction and demolition processes. MSW is made up to residual waste, bulky waste, secondary materials from separate collection (e.g., paper and glass), household hazardous waste, street sweepings and litter collections. It is made up of materials such as paper, cardboard, metals, textiles, organics (food and garden waste) and wood. MSW per capita has remained stable for many years (so relative decoupling from economic growth), but in total quantities it has not been reduced.
FOCUS/ OBJECTIVES	The amount of waste produced can be seen as an indicator of how efficient and sustainable a society is, particularly in relation to use of natural resources and waste treatment operations.
NOTES	Specific waste generation also referred as "waste intensity" in some sources.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data

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4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• MSW amount (in kg) generated in a city/ neighbourhood or object depending on the scale of the study • Population of the corresponding city/ neighbourhood or object
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• National statistics institutes • Eurostat • Urban Audit
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• kg per capita (per year)
REQUIRED TOOL	• There is no specific tool required.
CALCULATION METHOD	Specific waste generation= $\frac{W}{p}$ where; W: annual MSW (kg/yr) p: population
OUTPUT TYPE	• Quantitative value
EXAMPLES	• The European Environmental Agency has studied the possibility of developing an Urban Metabolism indicator system. This is a way to evaluate the sustainability of a city based in metabolic flows rather than performance or current status. The report *(Minx et al., 2010*) collated a wide range of indicators from various frameworks such as Urban Ecosystem Europe, all of which are based on publically available municipal datasets (the authors of the report chose to use existing data to make the indicator set easier to implement). From this, they have generated a headline data set of 15 indicators, which were chosen to be representative of the larger set. Waste intensity which is defined as “Annual amount of solid waste collected on urban territory per capita” is one of the headline indicators selected for monitoring the sustainability of urban areas.

LINKS AND REFERENCES	
KEYWORDS	• Municipal solid waste • Waste generation
LINKS AND REFERENCES	• Assessment of resource efficiency indicators and targets. Final report prepared for the European Commission, DG Environment. BIO Intelligence Service, Institute for Social Ecology and Sustainable Europe Research Institute, 2012 • Developing A Pragmatic Approach To Assess Urban Metabolism In Europe - A Report To The European Environment Agency, Minx et. al., 2011 • Gerdes, H., Bassi, S., Portale, E., Mazza, L., Srebotnjak, T:, Porsch, L., 2011. InStream D2.2. Final Report: Evaluation of Indicators for EU Policy Objectives URL: https://www.ecologic.eu/sites/files/publication/2016/1901-final-report-d2-2-evaluation-of-indicators-for-eu-policy-objectives.pdf Date of Access: October 2017

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	• Mudgal, S., Tan, A., Lockwood, S., Eisenmenger, N., Fischer-Kowalski, M., Giljum, S., Brucker, M., 2012. Assessment of Resource Efficiency Indicators and Targets – Annex Report URL: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/annex_report.pdf Date of access: October 2017

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.3 | Waste

INDICATOR	
NAME	**6.3.1 | SWG - Specific waste generation**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes. The main purpose is to represent the production of solid waste generated by all types of activity in human settlements. The amount of waste produced can be seen as an indicator of how efficient and sustainable a society is, particularly in relation to our use of natural resources and waste treatment operations.
R2: Policy support for policies:	The waste generation indicator is needed to implement waste prevention policies, an important component of sustainable development. Waste has a high relevance in the context of the European Commission's Flagship Initiative. One goal of this initiative is to make the EU a 'circular economy' based on a recycling society with the aim of reducing waste generation and using waste as a resource. This indicator tracks the overall amount of waste at the source and, complemented with other indicators on waste management such as recycling rates, percentage of waste landfilled, etc., enables decision-makers to judge the effectiveness of the process. Amount of waste generated and its management is extremely relevant for measuring the extent of environmental pressure. Waste production and disposal has a substantial impact on the everyday life of consumers and producers.
R3: Comparability:	It is argued that because of different definitions of the concept of municipal waste and the fact that some countries have reported data on municipal waste and others on household waste data in general cannot be compared between Member Countries. Therefore, care should be taken during initial definition of the indicator boundaries and benchmark definitions.

ACCEPTED	
A1: Policy makers:	Waste as a key factor for environmental issues is widely accepted and used by policy makers (many laws, directives etc. address waste issues). Concerning MSW also data for recycling rates for secondary materials (+)

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	or waste that goes directly to landfills (-) are often used. The EU's Sustainable Development Strategy and its Sixth Environment Action Programme (EAP) identify waste prevention and management as one of four top priorities
A2: Practitioners:	
A3: Other stakeholders:	The indicator is accepted by statisticians. Statistical data for MSW is provided by EUROSTAT. Statistics exist for EU and national levels. Waste in general is a common indicator used in (manufacturing) companies, but this is not necessarily municipal waste. MSW as one out of many waste streams is widely accepted and explored by the scientific community. It is a widely used and accepted indicator. Municipal waste can be easily understood by the general public and is accepted by the civil society as an environmental indicator. There is already a high level of awareness in many countries but also potential for improvement in other EU countries.

CREDIBLE	
C1: Unambiguous results:	There are some ambiguities regarding the measurement target and quantities involved in the case of municipal and industrial waste. There are many differences depending on the composition of waste: time necessary to transform them, space taken up for the same weight and future disposition (recycle, re-use or landfill).
C2: Transparency:	Data is self-reported by local authorities. Reporting is regulated by laws and directives so it can be regarded as quite transparent, although implementation and data quality vary from country to country.
C3: Documentation of assumptions and limitations:	Restrictions due to changes in the methodology are well documented.

EASY	
E1: Availability of data to calculate the indicator:	Generally, data is scattered, may be difficult to obtain, and consists of only rough estimates. Where it is available, data for municipal wastes can be obtained from studies of representative cross-sections of the population. At the national level, data sources would include ministries responsible for urban affairs and the environment and statistical agencies. Waste data are available and regularly updated. They are part of the structural indicators and collected annually. There are national and European reporting obligations for MSW. Data availability, especially at the local level, can be limited and of variable quality.
E2: Technical feasibility:	The Member States are free to decide on the data collection methods. The general options are: surveys, administrative sources, statistical estimations or some combination of methods. However, the nature of the waste itself makes it sometimes difficult to use data as indicator because wastes are often mixed and statistics do not reflect that diversity. There is no requirement for a specific software or hardware to estimate this indicator.
E3: Reproducibility:	In theory, only one harmonised methodology is applied by all users. Data collection methods are thus considered of high standards. In practice, however, differences in the implementation are observed between countries. Care should be taken during initial definition of the indicator boundaries and benchmark definitions.

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ROBUST	
R1: Data quality:	Municipal waste data is consistently collected by national statistical institutes and considered of high accuracy when comparing over time. But still consistency in reporting holds some unsolved problems and thus data may lack comparability between countries. This is not a problem while showing general trends of waste accumulation at a European level.
R2: Sensitiveness:	Measurements of municipal and industrial waste are vulnerable to the lack of standardised methodologies and measurement practices. Data availability, especially at the local level, is limited and of variable quality. There is limited scope for cross-time and cross-country comparison.
R3: Scale:	Municipal and industrial waste generated from households is measured at the international, national and local level, Waste from commerce and trade, office buildings, institutions and small businesses is also included.

6.4.1 | ERP

6 | RESOURCE EFFICIENCY

6.4 | RECYCLING

Short description of USC: Turning waste into a resource by 2020 is one of the key objectives of the EU's Roadmap to a Resource Efficient Europe. Recycling and efficiency of recycling is closely related to raw material consumption and waste generation. The recycling processes offer an alternative solution to over consumption of primary raw materials and long-term environmental impacts of waste disposal.

6.4.1 | ERP – EFFICIENCY OF VALORISATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.4 | Recycling

INDICATOR	
NAME	**6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator measures the efficiency of the recycling process used to produce the recycled feedstock (for specific materials and recycling processes). **Efficiency** of the recycling process 0-99%, while reuse is assumed to have an efficiency of 100%.
FOCUS/OBJECTIVES	To assess the improvement (or not) on valoration of waste and by-products.
NOTES	Based on the definition of Circularity Indicators https://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_Project-Overview_May2015.pdf

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	Values for efficiency will depend on a wide range of factors such as: • The material(s). • The quantity of material(s) involved • The recycling preparation process Once a range of material streams has been produced from a product with multiple components, different material recovery processes will have different efficiencies. A good understanding of the typical recovery and recycling processes for a given product will be required to obtain accurate values for E. Ideally, there should be a value for each material and for each specific recycling process (e.g. mobile phone recycling, or scrapping of vehicles). In cases where application-specific values for E are unavailable, generic values can be used, and users of the methodology should state this. Generic values for E have limitations because the real values are likely to vary with time, by application, recycling technology and demand.
INPUT TYPE (qualitative, quantitative,…)	• Qualitative
DATA SOURCE	• product data • generic industry data • computing virgin feedstock • unrecoverable waste,
FREQUENCY (how often to use this indicator?)	It will depend on a wide range of factors: material, recycling process specific and production
MEASUREMENT UNIT	mass
REQUIRED TOOL	• High calculation difficulty and requires lot of data
CALCULATION METHOD	If C_R represents the fraction of the mass of the product being collected for recycling at the end of its use phase and C_U the fraction of the mass of the product going into component reuse,[illegible] the amount of waste going to landfill or energy recovery is $W_0 = M(1 - C_R - C_U)$. (2.2) If E_C is the efficiency of the recycling process used for recycling the product at the end of its use phase, the quantity of waste generated in the recycling process is given by $W_C = M(1 - E_C)C_R$. (2.3) There will also have been waste generated to produce any recycled content used as feedstock. This is given by $W_F = M\frac{(1 - E_F)F_R}{E_F}$ (2.4) where E_F is the efficiency of the recycling process used to produce the recycled feedstock. [illegible] Component reuse refers to individual components being reused in a functional way. Reuse in this definition excludes a direct use of the product as a whole, which is taken to be part of the use phase. It is also assumed that there are no material losses in preparing components of collected products for reuse.
OUTPUT TYPE	• numerical value
EXAMPLES	• https://www.ellenmacarthurfoundation.org/assets/downloads/insight/Circularity-Indicators_Project-Overview_May2015.pdf

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LINKS AND REFERENCES	
KEYWORDS	• Material • Waste • By-products • Recycling processes
LINKS AND REFERENCES	Values for the recycling efficiency can be derived from various sources, for example: ● Reference Documents on Best Available Techniques from the European IPPC Bureau[18] ● U. Arena, *LCA of a Plastic Packaging Recycling System*, the International Journal of Life Cycle Assessment, March 2003, Volume 8, Issue 2, pp. 92-98 ● P. Shonfield, *LCA of Management Options for Mixed Waste Plastics*, WRAP, 2008

18 See http://eippcb.jrc.ec.europa.eu/reference/; for example, *Reference Document on Best Available Techniques in the Non Ferrous Metals Industries.*

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.4 | Recycling

INDICATOR	
NAME	6.4.1 | ERP - Efficiency of valorisation as a result of recycling processes

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	This indicator measures the efficiency of the recycling process used to produce the recycled feedstock. The indicator is able to assess the improvement (or not) on valoration of waste and by-products
R2: Policy support for policies:	The indicator is used as Material Circularity Indicator (An Approach to Measuring Circularity developed by ELLEN MACARTHUR FOUNDATION AND GRANTA DESIGN and Granta Design).
R3: Comparability:	It would be possible to compare the data for specific product or processes.

ACCEPTED	
A1: Policy makers:	The indicator is used as Material Circularity Indicators
A2: Practitioners:	The indicator could inform urban planners. Especially if information can be gathered also until city level. It could help to re-think urban design.
A3: Other stakeholders:	The Ellen MacArthur Foundation together with Granta Design Limited, as part of the European Life+ program has developed a methodology to measure material circularity – Material Circularity Indicator (MCI). The methodology was launched at the Royal Institution in London with its stakeholder group of academic institutions, NGOs and businesses, including HP, Unilever, Kingfisher and PWC.

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CREDIBLE	
C1: Unambiguous results:	Yes
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	This methodology is designed for use with product data representative of what actually happens in the marketplace. Data input into the model should ideally be based on knowledge of the product being assessed. Where this information is not known, generic industry data or best approximations may be used instead.

EASY	
E1: Availability of data to calculate the indicator:	shortage of available data
E2: Technical feasibility:	The indicator is quite simple to calculate. However, the calculation required inputs of data format that is limited.
E3: Reproducibility:	Yes, it’s possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	There is no possibility of uncertainty in the data if the data gathering is collected with the due guarantees.
R3: Scale:	Yes, the indicator probably is valuing other NBS impacts on more scales. It affects other impacts of interest, like energy and water impacts.

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6 | RESOURCE EFFICIENCY

6.4 | RECYCLING

6.4.2 | ROL – RATE OF LANDFILLING

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.4 | Recycling

INDICATOR	
NAME	**6.4.2 | ROL - Rate of landfilling**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ **3** ☒ **4** ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ **City** ☒ Neighbourhood ☒ Object
DEFINITION	The indicator is defined as the rate of waste landfilled (directly or indirectly) in a country per year, excluding major mineral wastes, dredging spoils and contaminated soils.
FOCUS/OBJECTIVES	The indicator allows to monitor the landfill rate over time for the EU as a whole and to compare the development of the landfill rate across countries. The indicator covers hazardous (hz) and non-hazardous (nh) waste from all economic sectors and from households, including waste from waste treatment (secondary waste).
NOTES	Based on the definition of Resource Efficiency Indicators (t2020_rt110). It is included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency. http://ec.europa.eu/eurostat/cache/metadata/FR/t2020_rt110_esmsip.htm

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• The indicator is based on data compiled according to Annex I of the Waste Statistics Regulation (Regulation 2150/2002/EC) and according to aggregates of the material-oriented statistical waste nomenclature EWC-Stat in Annex III of the Waste Statistics Regulation (WStatR).
INPUT TYPE (qualitative, quantitative,…)	• Quantitative
DATA SOURCE	• Data on the generation and treatment of waste collected from the Member States on the basis of the Regulation on waste statistics (EC) No. 2150/2002.
FREQUENCY (how often to use this indicator?)	• Annually.
MEASUREMENT UNIT	• **%** Waste generation is measured in tonnes. For the indicator the quantity of waste landfilled is divided by the total waste treated in the same year and displayed in (%)
REQUIRED TOOL	• The indicator is rather simple to calculate. No tool will be required
CALCULATION METHOD	• The indicator, expressed in percentage, is defined as the volume of waste landfilled (directly or indirectly) in a country per year divided by the volume of the waste treated in the same year. $$\frac{volume\ of\ waste\ landfilled\ (directly\ ot\ indirectly) in\ a\ country\ (pe}{Volume\ of\ waste\ treated\ (in\ the\ same\ year)}$$
OUTPUT TYPE	• numerical value
EXAMPLES	• http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=t2020_rt110&plugin=1

LINKS AND REFERENCES	
KEYWORDS	• RESOURCE EFFICIENCY • RECYCLING • RATE OF LANDFILLING
LINKS AND REFERENCES	•

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.4 | Recycling

INDICATOR	
NAME	**6.4.2 | ROL - Rate of landfilling**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is defined as the rate of waste landfilled and allows to monitor the landfill rate over time for the EU as a whole and to compare the development of the landfill rate across countries.
R2: Policy support for policies:	• It is included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.
R3: Comparability:	Comparability – geographical Due to the common definitions and classifications the comparability of the data across countries is fairly high. Differences between countries with regard to the generated and treated totals become more and more explainable. The continuous improvement of comparability is ensured by the thorough data validation by means of sector specific indicators. Some problems remain where countries have not used statistical units to link to the economic activities that generate the waste. This does not affect the total amounts of waste reported but hampers the comparability by economic sectors. Comparability - over time The data is comparable over time unless otherwise stated. A flag ´break in series´ is applied to indicate significant changes in methods. The established data validation system ensures that breaks in time series are identified and either corrected or explained. In addition, the national quality reports have proven to be a useful tool to monitor methodological changes and their impacts in Member States.

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ACCEPTED	
A1: Policy makers:	It is included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.
A2: Practitioners:	The indicator could be possible to move forward its use at municipality level in the EU. In that case it could inform urban planners. Especially if information can be gathered also until neighbourhood level. It could help to re-think urban design.
A3: Other stakeholders:	It is included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.

CREDIBLE	
C1: Unambiguous results:	The Member States perform the data collection and describe their sources and methods in a quality report. The overall accuracy is difficult to assess. Although the concepts, the classifications and the formats are clearly defined, the countries remain free to choose the sources and methods. The Member States describe the sources and methods in the quality reports. A summary of the quality information at the European level is available in the report to the European Parliament and to the Council: Quality of waste statistics (See the description of Eurostat quality grades)
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	The indicator is based on data compiled according to Annex I of the Waste Statistics Regulation (Regulation 2150/2002/EC) and according to aggregates of the material-oriented statistical waste nomenclature EWC-Stat in Annex III of the Waste Statistics Regulation (WStatR).

EASY	
E1: Availability of data to calculate the indicator:	The indicator is based on data compiled according to Annex I of the Waste Statistics Regulation (Regulation 2150/2002/EC) and according to aggregates of the material-oriented statistical waste nomenclature EWC-Stat in Annex III of the Waste Statistics Regulation (WStatR). The Member States perform the data collection and describe their sources and methods in a quality report. The Member States have to deliver the data within 18 months after the end of the reference period. Most countries do respect this deadline, some countries deliver with a small delay. In a few cases the delay is over 2 months. In such cases Eurostat will propose an imputation of the country data to be able to produce European totals. The European totals will be published end of November.
E2: Technical feasibility:	The indicator is simple to calculate. Probably no tools are needs to calculate.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data

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R2: Sensitiveness:	There is no possibility of uncertainty in the data if the survey is carried out with the due guarantees.
R3: Scale:	Yes

6.4.3 | ROR

6 | RESOURCE EFFICIENCY

6.4 | RECYCLING

6.4.3 | ROR – RATE OF RECYCLING

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.4 | Recycling

INDICATOR	
NAME	**6.4.3 | Rate of recycling**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Recycling indicator will allow measuring how much of the waste that is generated is recycled Recycling of waste is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations
FOCUS/OBJECTIVES	The recycling indicator refers to the waste treatment code 'recovery other than energy recovery except backfilling'. The indicator covers all waste categories except the following mineral waste categories: Mineral waste from construction and demolition; Other mineral wastes; Soils and Dredging spoils
NOTES	• http://ec.europa.eu/eurostat/cache/metadata/FR/t2020_rt120_esmsip.htm

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT

REQUIRED DATA	• large extent of waste generated by households, but may also include similar wastes generated by small businesses and public institutions and collected by the municipality;
INPUT TYPE (qualitative, quantitative,…)	• Quantitative
DATA SOURCE	• Statistical Office of the European Union (Eurostat), based on data from covered countries.
FREQUENCY (how often to use this indicator?)	• Annually.
MEASUREMENT UNIT	The recycling rate, expressed in percentage, is the tonnage recycled from municipal waste divided
REQUIRED TOOL	• The indicator is rather simple to calculate. No tool will be required
CALCULATION METHOD	The indicator is calculated according to the following formula: $\text{Recycling-rate EU} = \frac{(\text{Recycling of domestic waste})}{(\text{Treatment of domestic waste})}\% = \frac{(\text{Recycling in the EU} + \text{Net trade for recycling})}{(\text{Total treatment in the EU} + \text{Total net trade of waste})}\%$ with: Recycling of domestic waste: Amount of waste that is generated in the EU and recycled in the EU or elsewhere Treatment of domestic waste: Amount of waste that is generated in the EU and treated in the EU or elsewhere Recycling in the EU: Recycled waste amount (RCV_O) according to WStatR Net trade of waste for recycling: Amount of waste exported minus imported for recycling from/to non-EU countries Total treatment in the EU: Total treated waste amount (TRT) according to WStatR Total Net trade of waste: Amount of waste exported minus imported for treatment from/to non-EU countries
OUTPUT TYPE	• numerical value
EXAMPLES	• https://circabc.europa.eu/d/d/workspace/SpacesStore/a18ba39e-5826-4fdb-9582-89d5696c6eaf/7%20WASTE%20WG%207%20Recycling%20indicator_rev1%20docx.pdf • https://circabc.europa.eu/d/d/workspace/SpacesStore/67be0acc-dae8-47a4-9761-187b1ae643f5/4.2%20WASTE%20WG%20Waste%20management%20indicator%20set_v3%20(Working%20Copy).pdf • http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/resource-efficiency-indicators/resource-efficiency-scoreboard

LINKS AND REFERENCES

KEYWORDS	• RESOURCE EFFICIENCY • RECYCLING

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	• RATE OF RECYCLING
LINKS AND REFERENCES	•

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
RESOURCE	6 | Resource efficiency	6.4 | Recycling

INDICATOR	
NAME	**6.4.3 | ROR - Rate of recycling**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is defined as the rate of waste recycling and it allows monitoring how much of the waste that is generated is recycled.
R2: Policy support for policies:	It is included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.
R3: Comparability:	**Comparability – geographical** High The comparability across countries is considered relatively high as all countries apply the same definition and have high quality data sources. In all Member States, the coverage of the treatment of municipal waste is complete for the latest year available. The concept of municipal waste reflects different waste streams in different municipalities. Especially, the extent to which waste generated by offices and small businesses are included differ from municipality to municipality. Different levels of municipal waste generation can reflect different attitudes to waste generation, but also differences in the organisation of municipal waste management. **Comparability - over time** High The comparability over time is high. Restrictions in time-series are generally documented. They are mainly due to missing data and to methodological changes.

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ACCEPTED	
A1: Policy makers:	The indicator is a Resource Efficiency Indicator (t2020_rt120). It has been included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.
A2: Practitioners:	The indicator could be possible to move forward its use at municipality level in the EU. In that case it could inform urban planners. Especially if information can be gathered also until neighbourhood level. It could help to re-think urban design.
A3: Other stakeholders:	The indicator is a Resource Efficiency Indicator (t2020_rt120). It has been included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.

CREDIBLE	
C1: Unambiguous results:	Municipal waste is only a part of total waste generation; Waste statistics covering all waste generation from production and consumption activities based on the Regulation on waste statistics are freely available on the Eurostat website: Environmental Data Center on Waste.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes

EASY	
E1: Availability of data to calculate the indicator:	The indicator is based on data compiled according to Annex I of the Waste Statistics Regulation (Regulation 2150/2002/EC) and according to aggregates of the material-oriented statistical waste nomenclature EWC-Stat in Annex III of the Waste Statistics Regulation (WStatR). The Member States perform the data collection and describe their sources and methods in a quality report. The Member States have to deliver the data within 18 months after the end of the reference period. Most countries do respect this deadline, some countries deliver with a small delay. In a few cases the delay is over 2 months. In such cases Eurostat will propose an imputation of the country data to be able to produce European totals. The European totals will be published end of November.
E2: Technical feasibility:	The indicator is simple to calculate. Probably no tools are needs to calculate.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	There is no possibility of uncertainty in the data if the survey is carried out with the due guarantees.
R3: Scale:	Yes

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7 | PUBLIC HEALTH AND WELL-BEING

Short description of UC: The urban environment significantly affects the health and well-being of residents (Barton and Grant, 2006). NBS are supposed to improve the health and well-being of urban residents through the provision of ecosystem services by urban green spaces (Keniger et al., 2013). Many of the climate regulation ecosystem services address threats to environmental health posed by urbanization and climate change (Haase et al., 2014). Today noise is a major societal problem with a proven impact on health (hearing impairment, development of cardiovascular problems, stress, insomnia, etc.), particularly in urban and peri-urban areas where the noise sources are numerous and varied. *„A majority of the EU population is estimated to be exposed to outdoor road traffic noise levels above the threshold suggested by WHO for onset of negative health effects (Hosanna, 2014).“*

7.1 | ACOUSTICS

Short description of USC: Acoustic is an important topic because noise has dramatic health impacts: The World Health Organization (WHO) states that "*Excessive noise seriously harms human health and interferes with people's daily activities at school, at work, at home and during leisure time. It can disturb sleep, causes cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behavior. Traffic noise alone is harmful to the health of almost every third person in the WHO European Region. One in five Europeans is regularly exposed to sound levels at night that could significantly damage health*".

7.1.1 | L_{DEN} – DAY-EVENING-NIGHT NOISE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.1 | Acoustics

INDICATOR	
NAME	**7.1.1 | L_{DEN} – Day-evening-night noise level**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 (Medium calculation difficulty but requires lot of data)
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	The **L_{DEN}** is an acoustic indicator for sound environment. ***L_{DEN}*** is expressed in dB(A) because it is based on a combination of equivalent sound pressure levels $L_{eq,T}$ (energetic summation through logarithmic law), calculated with the *A* ponderation on 3 periods (day, evening, night), depending on the sound source emission (*i.e.* road traffic conditions). Thus L_{DEN} is a daily equivalent sound pressure level (T=00h-24h), with a 0dB(A) penalty increase for the Day period (T=6h-18h), a 5dB(A) penalty increase for the Evening period (T=18h-22h) and a 10dB(A) penalty increase for the Night period (T=22h-6h)
FOCUS/OBJECTIVES	The ***L_{DEN}*** indicator has been defined several years ago by a European expert group, in order to compare different noise situations all over European cities (noise maps of people exposed to sound pollution) through the use of a single, common and harmonized indicator. Despite the assumptions and limitations of such energetic descriptors (see reference pdf document from UN/Ifsttar/LAE/BG), the *LDEN* indicator is now stabilized and generalized.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• <u>Measured</u> L_{DEN} (*in situ* measurements): acoustic acquisition (in dB(A)) on hourly periods (with typically 1 sec sampling rate), gathered on 3 periods (Day, Evening, Night) and next aggregated on 24h (see definition above). • <u>Simulated</u> L_{DEN} (numerical predictions): acoustic simulation (in dB(A)) on hourly periods (depending on input data, *e.g.* road traffic characterization, built-up implementation through GIS, etc.), gathered on 3 periods (Day, Evening, Night) and next aggregated on 24h (see definition above).
INPUT TYPE (qualitative, quantitative, …)	• <u>Measured</u> L_{DEN} (*in situ* measurements): *quantitative* (L_{DEN} acquisition in dB(A) using sonometer) • <u>Simulated</u> L_{DEN} (numerical predictions): *quantitative* (georeferenced data, traffic counts, etc.) + *qualitative* (*e.g.* typology of NBS in urban medium)
DATA SOURCE	• Georeferenced data for built-up area: data from OPEN STREET MAP (OSM) • Road traffic counts: data from district, city or regional agencies • NBS data: qualitative information given by N4C consortium (when different scenarii will be available by other WPs and when additional functionalities will be integrated in numerical software)
FREQUENCY (how often to use this indicator?)	• Each time it is necessary, either for diagnosis (*in situ* measurement) or for scenario evaluation (numerical predictions) of sound environment
MEASUREMENT UNIT	• Decibels with A ponderation: "dB(A)"
REQUIRED TOOL	• <u>Measured</u> L_{DEN} (*in situ* measurements): integrating sonometer, either professional, low-cost or even smartphone http://noise-planet.org/noisecapture.html • <u>Simulated</u> L_{DEN} (numerical predictions): noise prediction software, e.g. open-source tool "NoiseModelling" http://noise-planet.org/noisemodelling.html
CALCULATION METHOD	• <u>Measured</u> L_{DEN} (*in situ* measurements): $Lden = 10.\lg \frac{1}{24} [12.10^{(Ld/10)} + 4.10^{((Le+5)/10)} + 8.10^{((Ln+10)/1}$ • <u>Simulated</u> L_{DEN} (numerical predictions): NMPB2008 or CNOSSOS-EU (see reference pdf document from UN/Ifsttar/LAE/BG)
OUTPUT TYPE	• ***L_{DEN}*** is an energetic indicator expressed in dB(A) because it is based on a combination of equivalent sound pressure levels $L_{eq,T}$ (energetic summation through logarithmic law), calculated with the *A* ponderation on 3 periods (day, evening, night), depending on the sound source emission (*i.e.* road traffic conditions).
EXAMPLES	• WHO (2009): Night noise guidelines for europe • https://irstv.ec-nantes.fr/partenariats-et-projets

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	• http://www.plante-et-cite.fr/n/vegdud-the-role-of-plants-in-sustainable-urban-development-impacts-on-climate-hy/n:76

LINKS AND REFERENCES	
KEYWORDS	• Sound environment • Emission, propagation, reception and perception • Acoustic indicators, L_{DEN} • Road traffic noise • In situ measurements • Numerical predictions • Open-source software • NBS scenario evaluation
LINKS AND REFERENCES	• Anderson, L.M., B.E. Mulligan, et L.S. Goodman. 1984. « Effects of vegetation on human response to sound ». *J. of Arboriculture* 10 (2): 45‑49. • Armon, R., et O. hanninen. 2015. *Environmental Indicators*. Springer. • Aumond, Pierre, Arnaud Can, Bert De Coensel, Dick Botteldooren, Carlos Ribeiro, et Catherine Lavandier. 2017. « Modeling Soundscape Pleasantness Using perceptual Assessments and Acoustic Measurements Along Paths in Urban Context ». *Acta Acustica united with Acustica* 103 (3): 430‑43. doi:10.3813/AAA.919073. • Axelsson, Östen, Mats E. Nilsson, et Birgitta Berglund. 2010. « A principal components model of soundscape perception ». *The Journal of the Acoustical Society of America* 128 (5): 2836‑46. doi:10.1121/1.3493436. • Bowles, A., et B. Schulte-Fortkamp. 2008. « Noise as an indicator of quality of life: advances in measurement of noise and noise effects on humans and animals in the environment ». *Acoustics Today* 4 (2): 35‑49 • Brambilla, G., L. Maffei, M. Di Gabriele, et V. Gallo. 2013. « Merging physical parameters and laboratory subjective ratings for the soundscape assessment of urban squares ». *J. Acoust. Soc. Amer.* 134 (1): 782‑90 • Brocolini, L., C. Lavandier, M. Quoy, et C. Ribeiro. 2013. « Measurement of acoustic environments for urban soundscapes: Choice of homogeneous periods, optimization of durations, and selection of indicators ». *J. Acoust. Soc. Amer.* 134 (1): 813‑21 • Brooks, B.M., B. Schulte-Fortkamp, K.S. Voigt, et A.U. Case. 2014. « Exploring our sonic environment through soundscape research and theory ». *Acoustics Today* 10 (1): 30‑40 • Brown, L. 2012. « A review of progress in soundscapes and an approach to soundscape planning ». *Int. J. of Acoustics and Vibration* 17 (2): 73‑81 • Can, A. 2015. « Noise pollution indicators ». In *Environmental indicators*, Springer, 501‑13. Dordrecht, The Netherlands • Can A. and Gauvreau B. 2015. « Describing and classifying urban sound environments with a relevant set of physical indicators ». *The Journal of the Acoustical*

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- http://noise-planet.org/noisecapture.html
- http://noise-planet.org/noisemodelling.html

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.1 | Acoustics

INDICATOR	
NAME	**7.1.1 | L_{DEN}– Day-evening-night noise level**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes: it is already widely used in impact studies by engineering tools and people, and urban planners.
R2: Policy support for policies:	Yes: although this indicator is not exhaustive to describe sound environments, its use is now stabilized and generalized because it has been defined several years ago by a European expert group, in order to compare different noise situations all over European cities (noise maps of people exposed to sound pollution) through the use of a single, common and harmonized indicator (see reference pdf document from UN/Ifsttar/LAE/BG).
R3: Comparability:	Yes: the methodology to provide data (either numerical predictions or *in situ* measurements) is now standardized (see reference pdf document from UN/Ifsttar/LAE/BG).

ACCEPTED	
A1: Policy makers:	Yes: it is already widely used in impact studies by engineering tools and people for the development or assessment of policies.
A2: Practitioners:	Yes: this operational indicator is widely used by urban planners (through numerical predictions or *in situ* measurements).
A3: Other stakeholders:	Yes, this indicator is well documented and now accepted by the community, although specialists (researchers and engineers) in environmental acoustics well know its limitations (see reference pdf document from UN/Ifsttar/LAE/BG).

CREDIBLE

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C1: Unambiguous results:	Yes but with some limitations, for almost 3 reasons (see reference pdf document from UN/Ifsttar/LAE/BG): • The L_{DEN} indicator is an <u>energetic</u> indicator, which expressed an equivalent <u>continuous</u> sound pressure level, so it includes no dynamic such as time evolution, periodicity, impulsive sound events, etc. • The LDEN indicator is expressed in <u>decibels</u> (dB), which is not a easily understandable unit for a large audience Last but not least, the L_{DEN} indicator is expressed in dB(A), meaning that third octave bands are <u>pondered</u> by the "A" filter in order to be as close as possible to the human ear response. Thus there is no tonal information relative to frequencies (in octave or 1/3rd octave bands).
C2: Transparency:	Yes: The L_{DEN} indicator is a daily equivalent sound pressure level (T=00h-24h), with a 0dB(A) penalty increase for the Day period (T=6h-18h), a 5dB(A) penalty increase for the Evening period (T=18h-22h) and a 10dB(A) penalty increase for the Night period (T=22h-6h): $Lden = 10.\lg \frac{1}{24} [12.10^{(Ld/10)} + 4.10^{((Le+5)/10)} + 8.10^{((Ln+10)/10)}]$
C3: Documentation of assumptions and limitations:	Yes: by construction, the L_{DEN} indicator is uniformly applicable in all the European countries and cities.
EASY	
E1: Availability of data to calculate the indicator:	Yes, data is easily available for calculating the L_{DEN} indicator (from numerical predictions or *in situ* measurements) BUT it can be sometimes difficult to have representative measurements of L_D, L_E and L_N (*e.g.* only during 1 day or 1 week period regarding long-term periods such as 1 month or even 1 year).
E2: Technical feasibility:	Yes, the L_{DEN} indicator is simple to be carried out, without special calculation software or methodology BUT, since it is particularly dedicated to road traffic noise, numerical predictions are very dependent on traffic information (% of heavy trucks *vs* passenger cars, other silhouettes, flow, speed), which can be sometimes erroneous or outdated in some cases.
E3: Reproducibility:	Since the L_{DEN} indicator do NOT take into account all the physical sound phenomena involved *in situ* (see above remarks R1, E1, E2, C1 and A3), this indicator can vary significantly in different circumstances.
ROBUST	
R1: Data quality:	Yes: the L_{DEN} indicator can be considered as a robust indicator BUT only provided the representativeness of intermediate indicators L_D, L_E and L_N, either measured or calculated (see above remarks E1 and E2, respectively).
R2: Sensitiveness:	Uncertainty of the produced data is smoothed by construction (see above remark C1) BUT some influent parameters can lead to significant discrepancies, *e.g.* road traffic characterization, SIG accuracy, parasitic sound sources, etc.) (see above remarks E1 and E2) (see also reference pdf document from UN/Ifsttar/LAE/BG).
R3: Scale:	Yes: the L_{DEN} indicator can be used at different spatial scales, *i.e.* at street, district, city and regional scales (provided adapted resources, either numerical or experimental).

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7 | PUBLIC HEALTH AND WELL-BEING

7.1 | ACOUSTICS

7.1.2 | L_{NIGHT} – NIGHT NOISE LEVEL

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-Being	7.1 | Acoustics

INDICATOR	
NAME	**7.1.2 | L_{NIGHT} - Night noise level**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 (Medium calculation difficulty but requires lot of data)
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	The L_{NIGHT} is an acoustic indicator for sound environment. L_{NIGHT} is expressed in dB(A) because it is based on a combination of equivalent sound pressure levels $L_{eq,T}$ (energetic summation through logarithmic law), calculated with the *A* ponderation on night, depending on the sound source emission (*i.e.* road traffic conditions). The L_{NIGHT} express the average sound pressure level over one night (Night period 22h-6h). This night can be chosen so that it is representative of a longer period — L_{NIGHT} also occurs in the END (Environmental Noise Directive). If used in that context, a yearly average night time level is intended. This is the night time indicator defined in EU-directive 2002/49 and used by WHO (EEA, 2010).
FOCUS/OBJECTIVES	

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Measured L_{NIGHT} (*in situ* measurements): acoustic acquisition (in dB(A)) on hourly periods (with typically 1 sec sampling rate), gathered on night period • Simulated L_{NIGHT} (numerical predictions): acoustic simulation (in dB(A)) on hourly periods (depending on input data, *e.g.* road traffic characterization, built-up implementation through GIS, etc.), gathered on night period.
INPUT TYPE (qualitative, quantitative, …)	• Measured L_{NIGHT} (*in situ* measurements): *quantitative* (L_{NIGHT} acquisition in dB(A) using sonometer) • Simulated L_{NIGHT} (numerical predictions): *quantitative* (georeferenced data, traffic counts, etc.) + *qualitative* (*e.g.* typology of NBS in urban medium)
DATA SOURCE	• Georeferenced data for built-up area: data from OPEN STREET MAP (OSM) • Road traffic counts: data from district, city or regional agencies • NBS data: qualitative information given by N4C consortium (when different scenarii will be available by other WPs and when additional functionalities will be integrated in numerical software)
FREQUENCY (how often to use this indicator?)	• Each time it is necessary, either for diagnosis (*in situ* measurement) or for scenario evaluation (numerical predictions) of sound environment
MEASUREMENT UNIT	• Decibels with A ponderation: "dB(A)"
REQUIRED TOOL	• Measured L_{NIGHT} (*in situ* measurements): integrating sonometer, either professional, low-cost or even smartphone http://noise-planet.org/noisecapture.html • Simulated L_{NIGHT} (numerical predictions): noise prediction software, e.g. open-source tool "NoiseModelling" http://noise-planet.org/noisemodelling.html
CALCULATION METHOD	• Measured L_{NIGHT} (*in situ* measurements): • Simulated L_{NIGHT} (numerical predictions): NMPB2008 or CNOSSOS-EU (see reference pdf document from UN/Ifsttar/LAE/BG)
OUTPUT TYPE	• ***L_{NIGHT}*** is an energetic indicator expressed in dB(A) because it is based on a combination of equivalent sound pressure levels $L_{eq,T}$ (energetic summation through logarithmic law), calculated with the *A* ponderation on night periods, depending on the sound source emission (*i.e.* road traffic conditions).
EXAMPLES	• WHO (2009): Night noise guidelines for europe • https://irstv.ec-nantes.fr/partenariats-et-projets • http://www.plante-et-cite.fr/n/vegdud-the-role-of-plants-in-sustainable-urban-development-impacts-on-climate-hy/n:76

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LINKS AND REFERENCES	
KEYWORDS	• Sound environment • Emission, propagation, reception and perception • Acoustic indicators, L_{DEN} • Road traffic noise • In situ measurements • Numerical predictions • Open-source software • NBS scenario evaluation
LINKS AND REFERENCES	• EEA (2010): Good practice guide on noise exposure and potential health effects. European Environmental Agency Technical Report, No 11/2010, Copenhagen. • Anderson, L.M., B.E. Mulligan, et L.S. Goodman. 1984. « Effects of vegetation on human response to sound ». *J. of Arboriculture* 10 (2): 45‑49. • Armon, R., et O. hanninen. 2015. *Environmental Indicators*. Springer. • Aumond, Pierre, Arnaud Can, Bert De Coensel, Dick Botteldooren, Carlos Ribeiro, et Catherine Lavandier. 2017. « Modeling Soundscape Pleasantness Using perceptual Assessments and Acoustic Measurements Along Paths in Urban Context ». *Acta Acustica united with Acustica* 103 (3): 430‑43. doi:10.3813/AAA.919073. • Axelsson, Östen, Mats E. Nilsson, et Birgitta Berglund. 2010. « A principal components model of soundscape perception ». *The Journal of the Acoustical Society of America* 128 (5): 2836‑46. doi:10.1121/1.3493436. • Bowles, A., et B. Schulte-Fortkamp. 2008. « Noise as an indicator of quality of life: advances in measurement of noise and noise effects on humans and animals in the environment ». *Acoustics Today* 4 (2): 35‑49 • Brambilla, G., L. Maffei, M. Di Gabriele, et V. Gallo. 2013. « Merging physical parameters and laboratory subjective ratings for the soundscape assessment of urban squares ». *J. Acoust. Soc. Amer.* 134 (1): 782‑90 • Brocolini, L., C. Lavandier, M. Quoy, et C. Ribeiro. 2013. « Measurement of acoustic environments for urban soundscapes: Choice of homogeneous periods, optimization of durations, and selection of indicators ». *J. Acoust. Soc. Amer.* 134 (1): 813‑21 • Brooks, B.M., B. Schulte-Fortkamp, K.S. Voigt, et A.U. Case. 2014. « Exploring our sonic environment through soundscape research and theory ». *Acoustics Today* 10 (1): 30‑40 • Brown, L. 2012. « A review of progress in soundscapes and an approach to soundscape planning ». *Int. J. of Acoustics and Vibration* 17 (2): 73‑81 • Can, A. 2015. « Noise pollution indicators ». In *Environmental indicators*, Springer, 501‑13. Dordrecht, The Netherlands • Can A. and Gauvreau B. 2015. « Describing and classifying urban sound environments with a relevant set of physical indicators ». *The Journal of the Acoustical*

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.1 | Acoustics

INDICATOR	
NAME	7.1.2 | L_{NIGHT} - Night noise level

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes: it is already widely used in impact studies by engineering tools and people, and urban planners.
R2: Policy support for policies:	Yes: although this indicator is not exhaustive to describe sound environments, its use is now stabilized and generalized because it has been defined several years ago by a European expert group, in order to compare different noise situations all over European cities (noise maps of people exposed to sound pollution) through the use of a single, common and harmonized indicator (see reference pdf document from UN/Ifsttar/LAE/BG).
R3: Comparability:	Yes: the methodology to provide data (either numerical predictions or *in situ* measurements) is now standardized (see reference pdf document from UN/Ifsttar/LAE/BG).

ACCEPTED	
A1: Policy makers:	Yes: it is already widely used in impact studies by engineering tools and people for the development or assessment of policies.
A2: Practitioners:	Yes: this operational indicator is widely used by urban planners (through numerical predictions or *in situ* measurements).
A3: Other stakeholders:	Yes, this indicator is well documented and now accepted by the community, although specialists (researchers and engineers) in environmental acoustics well know its limitations (see reference pdf document from UN/Ifsttar/LAE/BG).

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CREDIBLE	
C1: Unambiguous results:	Yes but with some limitations, for almost 3 reasons (see reference pdf document from UN/Ifsttar/LAE/BG): • The L_{NIGHT} indicator is an energetic indicator, which expressed an equivalent continuous sound pressure level, so it includes no dynamic such as time evolution, periodicity, impulsive sound events, etc. • The LNIGHT indicator is expressed in decibels (dB), which is not a easily understandable unit for a large audience Last but not least, the L_{DEN} indicator is expressed in dB(A), meaning that third octave bands are pondered by the "A" filter in order to be as close as possible to the human ear response. Thus there is no tonal information relative to frequencies (in octave or 1/3rd octave bands).
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes: by construction, the L_{NIGHT} indicator is uniformly applicable in all the European countries and cities.

EASY	
E1: Availability of data to calculate the indicator:	Yes, data is easily available for calculating the L_{DEN} indicator (from numerical predictions or *in situ* measurements) BUT it can be sometimes difficult to have representative measurements of L_D, L_E and L_N (*e.g.* only during 1 day or 1 week period regarding long-term periods such as 1 month or even 1 year).
E2: Technical feasibility:	Yes, the L_{NIGHT} indicator is simple to be carried out, without special calculation software or methodology BUT, since it is particularly dedicated to road traffic noise, numerical predictions are very dependent on traffic information (% of heavy trucks *vs* passenger cars, other silhouettes, flow, speed), which can be sometimes erroneous or outdated in some cases.
E3: Reproducibility:	Since the L_{NIGHT} indicator do NOT take into account all the physical sound phenomena involved *in situ* (see above remarks R1, E1, E2, C1 and A3), this indicator can vary significantly in different circumstances.

ROBUST	
R1: Data quality:	Yes: the L_{NIGHT} indicator can be considered as a robust indicator BUT only provided the representativeness of intermediate indicators L_D, L_E and L_N, either measured or calculated (see above remarks E1 and E2, respectively).
R2: Sensitiveness:	Uncertainty of the produced data is smoothed by construction (see above remark C1) BUT some influent parameters can lead to significant discrepancies, *e.g.* road traffic characterization, SIG accuracy, parasitic sound sources, etc.) (see above remarks E1 and E2) (see also reference pdf document from UN/Ifsttar/LAE/BG).
R3: Scale:	Yes: the L_{NIGHT} indicator can be used at different spatial scales, *i.e.* at street, district, city and regional scales (provided adapted resources, either numerical or experimental).

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7 | PUBLIC HEALTH AND WELL-BEING

7.1 | ACOUSTICS

7.1.3 | ENNH – EFFECTS OF NIGHT NOISE ON HEALTH

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.1 | Acoustics

INDICATOR	
NAME	**7.1.3 | ENNH – Effects of night noise on health**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The NNL describes the following health effects from the acoustic indicator L_{NIGHT} and thus the night noise level in urban areas (dB). The night-level indicator (L_{NIGHT}) is designed to assess sleep disturbance. The WHO-Night Noise Guidelines (2009) discusses in great detail the relations between, noise, sleep quality and health. The report states that sleep is an important biological function and impaired sleep — which is considered a health effect by itself — is related to a number of diseases. Although the function of sleep is still somewhat obscure, sleep deprivation is definitely a condition that deeply afflicts health. Animal experiments show that sleep deprived animals live less, and sleep deprived humans typically show dramatic function loss after a few days. As it can be demonstrated that noise disturbs sleep, the inference is that noise, via the sleep pathway, causes the same diseases. The recommendations are expressed in terms of L_{NIGHT} (the night time noise indicator from the END), and the report describes also a number of exposure-response relationships for instantaneous reactions. In part the relationships in the WHO-document are derived from the EU-position paper on night time noise. European threshold L_{NIGHT}: High Noise level: 50 decibels (dB) (EEA, 2010)

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Average night noise level over a year $L_{night,outside}$	Health effects observed in the population
Up to 30 dB	Although individual sensitivities and circumstances may differ, it appears that up to this level no substantial biological effects are observed. $L_{night,outside}$ of 30 dB is equivalent to the no observed effect level (NOEL) for night noise.
30 to 40 dB	A number of effects on sleep are observed from this range: body movements, awakening, self-reported sleep disturbance, arousals. The intensity of the effect depends on the nature of the source and the number of events. Vulnerable groups (for example children, the chronically ill and the elderly) are more susceptible. However, even in the worst cases the effects seem modest. $L_{night,outside}$ of 40 dB is equivalent to the lowest observed adverse effect level (LOAEL) for night noise.
40 to 55 dB	Adverse health effects are observed among the exposed population. Many people have to adapt their lives to cope with the noise at night. Vulnerable groups are more severely affected.
Above 55 dB	The situation is considered increasingly dangerous for public health. Adverse health effects occur frequently, a sizeable proportion of the population is highly annoyed and sleep-disturbed. There is evidence that the risk of cardiovascular disease increases.

Table 3
Effects of different levels of night noise on the population's health

Fig 2. Effects of different levels of night noise on the population's health (WHO, 2009).

FOCUS/ OBJECTIVES	• indicates the night noise levels of an area

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• L_{NIGHT} (Measurement or Simulation)
INPUT TYPE (qualitative, quantitative, …)	Quantitative: Average sound pressure level over one night, Noise classes
DATA SOURCE	Simulation • Digital model + noise simulation • Threshold levels/classes out of WHO Report. Measurement • L_{NIGHT}
FREQUENCY (how often to use this indicator?)	• One to several times in planning process
MEASUREMENT UNIT	• Night noise classes (dB) • %
REQUIRED TOOL	• Noise simulation software • Calculation tool
CALCULATION METHOD	• Threshold level and relative area ratio to other scenarios

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OUTPUT TYPE	● Area over threshold (m^2) ● Relative change (%)
EXAMPLES	European Environment Agency (2010): Good Practice guide on noise exposure and potential health effects. EEA Technical Report No. 11/2010. ISSN 1725-2237 https://www.eea.europa.eu/publications/good-practice-guide-on-noise/download WHO (2009): Night noise guidelines for Europe, http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

LINKS AND REFERENCES	
KEYWORDS	• Health • Well-being • Quality of life • World Health Organization • Noise • Night noise level • Sleep disturbance
LINKS AND REFERENCES	● European Environment Agency (2010): Good Practice guide on noise exposure and potential health effects. EEA Technical Report No. 11/2010. ISSN 1725-2237 https://www.eea.europa.eu/publications/good-practice-guide-on-noise/download ● WHO (2009): Night noise guidelines for Europe, http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	**7 | Public Health and Well-being**	**7.1 | Acoustics**

INDICATOR	
NAME	**7.1.3 | ENNH – Effect of night noise on health**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

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RELEVANT	
R1: Linkage to the project aim:	Yes, capable to describe initial planning problems like noise and health relation at night.
R2: Policy support for policies:	Yes, related to the WHO (2009): Night noise guidelines for Europe.
R3: Comparability:	Yes, standardized method and comparability.

ACCEPTED	
A1: Policy makers:	Yes, developed in the policy WHO (2009): Night noise guidelines for Europe
A2: Practitioners:	Basically a simplified indicator, but data generation requires expert knowledge.
A3: Other stakeholders:	Yes, several peer-reviewed publications in the recent years, but controversial because of abstract approach.

CREDIBLE	
C1: Unambiguous results:	Yes, indicator convey a clear message through noise classes including qualitative descriptions.
C2: Transparency:	Yes, indicator has a clear methodology.
C3: Documentation of assumptions and limitations:	Yes, methodology is fully disclosed, interpretable and reproducible.

EASY	
E1: Availability of data to calculate the indicator:	Some research data already existing but basically data has to be generated. In accordance with the Environmental Noise Directive (END) (Directive 2002/49/EC, 2002), the EU Member States have produced a large scale inventory of the noise situation in their area. The data were sent to the Commission and can be viewed on the Noise Observation and Information Service for Europe: http://noise.eionet.europa.eu/index.html.
E2: Technical feasibility:	Yes, simple usage but data generation needs expert knowledge.
E3: Reproducibility:	Yes, possible for numerous cases internationally.

ROBUST	
R1: Data quality:	Depending on the data input.
R2: Sensitiveness:	L_{Night} is based on A-Ponderation.
R3: Scale:	Yes, depending on the area. From city to object.

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7 | PUBLIC HEALTH AND WELL-BEING

7.1 | ACOUSTICS

7.1.4 | PAI – POPULATION ANNOYANCE INDEX

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.1 | Acoustics

INDICATOR	
NAME	**7.1.4 | PAI – Population Annoyance Index**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The PAI describes the following health effects from the acoustic indicator L_{DEN} and thus the night noise level in urban areas (dB). The day-evening-night–level indicator (L_{DEN}) designed to assess annoyance. L_{DEN} is the average sound pressure level over all days, evenings and nights in a year. In this compound indicator the evening value gets a penalty of 5 dB and the night value of 10 dB. This is the 'general purpose' indicator defined in EU-directive 2002/49. European threshold L_{DEN}: High Noise level: 55 decibels (dB) (EEA, 2014). PAI is a derived indicator regarding health effects of noise on exposed population and is linked to L_D, L_N and L_{DEN}.
FOCUS/OBJECTIVES	• indicates the day-evening-night noise levels of an area

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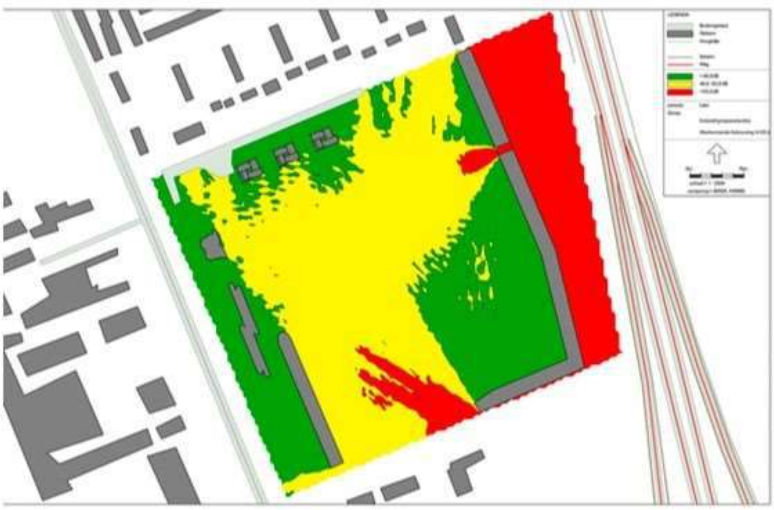
LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• LDEN (Measurement or Simulation)
INPUT TYPE (qualitative, quantitative, …)	Quantitative: Average sound pressure level over day-evening-night, Noise threshold
DATA SOURCE	Simulation • Digital model + noise simulation • Threshold levels/classes out of EEA/WHO Report. Measurement • LDEN
FREQUENCY (how often to use this indicator?)	• One to several times in planning process
MEASUREMENT UNIT	• noise classes (dB) • noise threshold • %
REQUIRED TOOL	• Noise simulation software • Calculation tool
CALCULATION METHOD	• Threshold level, classes and ratio as well as relative area ratio to other scenarios
OUTPUT TYPE	• Area over threshold (m^2) • Relative change (%)
EXAMPLES	 Fig 1: Example noise map with buildings and calculated noise contour areas.

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Contour area (dB)	Midvalue class (dB)	Resid-ences	Inhabit ants (*n*)	*p* (%)	*n.p*
45..50 dB	47,5	400	1000	0,98	9,8
50..55	52,5	250	625	3,56	22,3
55..60	57,5	150	375	7,76	29,1
60..65	62,5	100	250	13,57	33,9
65..70	67,5	6	15	21,00	3,2
				Sum:	**98**

Fig 2: Example PAI – Population Annoyance Index

- DERUITER, E. (nA): A tool for environmental noise control in urban planning: The Population Annoyance Index, http://www.peutz.nl/sites/default/files/publicaties/NAGDAGA-ER1.pdf
- European Environment Agency (2010): Good Practice guide on noise exposure and potential health effects. EEA Technical Report No. 11/2010. ISSN 1725-2237, https://www.eea.europa.eu/publications/good-practice-guide-on-noise/download
- European Environment Agency (2014): Noise in Europe. EEA Technical Report No. 10/2014. ISSN 1977-8449, https://www.eea.europa.eu/publications/noise-in-europe-2014/file

LINKS AND REFERENCES

KEYWORDS

- Health
- Well-being
- Quality of life
- World Health Organization
- Noise
- Day-evening-night noise level
- Annoyance
- Population Annoyance Index

LINKS AND REFERENCES

- DERUITER, E. (nA): A tool for environmental noise control in urban planning: The Population Annoyance Index, http://www.peutz.nl/sites/default/files/publicaties/NAGDAGA-ER1.pdf
- European Environment Agency (2010): Good Practice guide on noise exposure and potential health effects. EEA Technical Report No. 11/2010. ISSN 1725-2237, https://www.eea.europa.eu/publications/good-practice-guide-on-noise/download
- European Environment Agency (2014): Noise in Europe. EEA Technical Report No. 10/2014. ISSN 1977-8449, https://www.eea.europa.eu/publications/noise-in-europe-2014/file

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.1 | Acoustics

INDICATOR	
NAME	7.1.4 | PAI – Population Annoyance Index

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, capable to describe initial planning problems like population annoyance through noise over the overall day.
R2: Policy support for policies:	Yes, related to European Noise threshold levels.
R3: Comparability:	Yes, standardized method and comparability.

ACCEPTED	
A1: Policy makers:	Yes, L_{DEN}, but not the PAI so far.
A2: Practitioners:	Basically a simplified indicator, but data generation requires expert knowledge.
A3: Other stakeholders:	Yes, several peer-reviewed publications in the recent years, but controversial because of abstract approach.

CREDIBLE	
C1: Unambiguous results:	Yes, indicator convey a clear message through noise classes. Understandable for general public.
C2: Transparency:	Yes, indicator has a clear methodology.
C3: Documentation of assumptions and limitations:	Yes, methodology is fully disclosed, interpretable and reproducible.

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EASY	
E1: Availability of data to calculate the indicator:	Some research data already existing but basically data has to be generated (simulated). In accordance with the Environmental Noise Directive (END) (Directive 2002/49/EC, 2002), the EU Member States have produced a large scale inventory of the noise situation in their area. The data were sent to the Commission and can be viewed on the Noise Observation and Information Service for Europe: http://noise. eionet.europa.eu/index.html.
E2: Technical feasibility:	Yes, simple usage but data generation needs expert knowledge.
E3: Reproducibility:	Yes, possible for numerous cases international.

ROBUST	
R1: Data quality:	Depending on the data input.
R2: Sensitiveness:	L_{DEN} is based on Ponderation. But uncertainty sources in the quantification of this derived indicator: number of exposed persons from GIS analysis, dose-response relations from epidemiological studies, ...
R3: Scale:	Yes, depending on the area. From city to object.

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7 | PUBLIC HEALTH AND WELL-BEING

7.2 | QUALITY OF LIFE

Short description of USC: WHO defines Quality of Life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns. It is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment (WHOQOL, 1995; Parra et al., 2010; Muldoon et al. 1998).

7.2.1 | QOL – QUALITY OF LIFE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.2 | Quality of life

INDICATOR	
NAME	**7.2.1 | QOL – Quality of life**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	WHO defines Quality of Life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns. It is a broad ranging concept affected in a complex way by the person's physical health, psychological state, personal beliefs, social relationships and their relationship to salient features of their environment (WHO, 1995).
FOCUS/OBJECTIVES	• indicate the global level of perceived quality of Life

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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<table>
<tr><th colspan="2">DATA AND MEASUREMENT</th></tr>
<tr><td>REQUIRED DATA</td><td>• the participant response</td></tr>
<tr><td>INPUT TYPE (qualitative, quantitative, …)</td><td>Quantitative: The response of the participant on a lickert scale (a score from 1 to 5)
<table>
<tr><th></th><th></th><th>Very poor</th><th>Poor</th><th>Neither poor nor good</th><th>Good</th><th>Very good</th></tr>
<tr><td>1.</td><td>How would you rate your quality of life?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
</table>
Fig 1: Example out of the questionnaire (WHO 2004)</td></tr>
<tr><td>DATA SOURCE</td><td>• the response of the participant</td></tr>
<tr><td>FREQUENCY (how often to use this indicator?)</td><td>• One to several times in planning process</td></tr>
<tr><td>MEASUREMENT UNIT</td><td>• the response is rated on a 5-point scale from « 1 = very poor » to « 5 = very good »</td></tr>
<tr><td>REQUIRED TOOL</td><td>• the first item of the WHOQOL-BREF
General level of perceived quality of life measured through the first item of the WHOQOL-BREF scale that asks « How would you rate your quality of life? »</td></tr>
<tr><td>CALCULATION METHOD</td><td>• no calculation: it is an unidimensional score</td></tr>
<tr><td>OUTPUT TYPE</td><td>• numerical value (a score from 1 to 5)</td></tr>
<tr><td>EXAMPLES</td><td>• WHOQOL-BREF
http://www.who.int/mental_health/media/en/76.pdf
http://www.who.int/substance_abuse/research_tools/en/english_whoqol.pdf</td></tr>
</table>

<table>
<tr><th colspan="2">LINKS AND REFERENCES</th></tr>
<tr><td>KEYWORDS</td><td>• Health
• Well-being
• Quality of life
• World Health Organization
• Satisfaction</td></tr>
<tr><td>LINKS AND REFERENCES</td><td>• The World Health Organization Quality of Life assessment (WHOQOL): position paper from the World Health Organization. (1995). Soc Sci Med, 41(10), 1403-1409
• The World Health Organization Quality of Life (WHOQOL)-BREF © World Health Organization 1996, http://www.who.int/mental_health/media/en/76.pdf
• The World Health Organization Quality of Life (WHOQOL)-BREF © World Health Organization 2004, http://www.who.int/substance_abuse/research_tools/en/english_whoqol.pdf
http://www.who.int/substance_abuse/research_tools/whoqolbref/en/</td></tr>
</table>

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.2 | Quality of life

INDICATOR	
NAME	7.2.1 | QOL – Quality of life

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, capable to describe initial planning problems like perceived health in urban areas.
R2: Policy support for policies:	Yes, related to the World Health Organization Quality of Life (WHOQOL)-BREF © World Health Organization 2004
R3: Comparability:	Yes, standardized method and international comparability.

ACCEPTED	
A1: Policy makers:	Yes, developed and applied within WHOQOL-BREF. When health providers implement new policies it is important that the effect of policy changes on the quality of life of people in contact with health services is evaluated. The WHOQOL instruments allow such monitoring of policy changes.
A2: Practitioners:	Yes
A3: Other stakeholders:	Yes, several peer-reviewed publications in the recent years.

CREDIBLE	
C1: Unambiguous results:	Yes, indicator convey a clear message through being an overall Quality of Life indicator.
C2: Transparency:	Yes, based on a questionnaire.
C3: Documentation of assumptions and limitations:	Yes, worldwide application possible. There are existing app. 20 different language versions of the document.

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EASY	
E1: Availability of data to calculate the indicator:	Some research data already existing but basically data has to be generated by field surveys.
E2: Technical feasibility:	Yes, simple usage.
E3: Reproducibility:	Yes, possible for numerous cases internationally.

ROBUST	
R1: Data quality:	Data based on subjective answered survey.
R2: Sensitiveness:	Yes, uncertainty through subjective answer.
R3: Scale:	Yes, depending on the field survey respectively the field area. From city to object.

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7 | PUBLIC HEALTH AND WELL-BEING

7.3 | HEALTH

Short description of USC: Protecting and creating healthy environments is a critical component of sustainable development. NBS contribute to Environmental health in different ways, by reducing exposures to air pollution, improving water quality, reducing flood risk and the impact of heat waves. They also create environments that encourage biking and walking as alternatives for transportation and reduce greenhouse gas and toxic air pollution emissions and increases physical activity .

7.3.1 | PH – PERCEIVED HEALTH

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	**7.3.1 | PH – Perceived health**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Perceived health is a subjective measure of overall health status. Individuals' self-assessment of their health may include aspects that are difficult to capture clinically, such as incipient disease, disease severity, physiological and psychological reserves, and social function. Studies have demonstrated that this is a reliable and valid measure, associated with functional decline, morbidity and mortality.
FOCUS/OBJECTIVES	• indicate the global level of perceived health

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

<table>
<tr><th colspan="2">DATA AND MEASUREMENT</th></tr>
<tr><td>REQUIRED DATA</td><td>• the participant response</td></tr>
<tr><td>INPUT TYPE (qualitative, quantitative, …)</td><td>Quantitative: The response of the participant on a lickert scale (a score from 1 to 5)
<table>
<tr><th></th><th></th><th>Very dissatisfied</th><th>Dissatisfied</th><th>Neither satisfied nor dissatisfied</th><th>Satisfied</th><th>Very satisfied</th></tr>
<tr><td>2.</td><td>How satisfied are you with your health?</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
</table>
Fig 1: Example out of the questionnaire (WHO 2004)</td></tr>
<tr><td>DATA SOURCE</td><td>• the response of the participant</td></tr>
<tr><td>FREQUENCY (how often to use this indicator?)</td><td>• One to several times in planning process</td></tr>
<tr><td>MEASUREMENT UNIT</td><td>• the response is rated on a 5-point scale from « very dissatisfied » to « very satisfied» (WHO, 2004)</td></tr>
<tr><td>REQUIRED TOOL</td><td>• the second item of the WHOQOL-BREF
General level of perceived health measured through the second item of the WHOQOL-BREF scale that asks «“How satisfied are you with your health?”</td></tr>
<tr><td>CALCULATION METHOD</td><td>- no calculation: it is a unidimensional score</td></tr>
<tr><td>OUTPUT TYPE</td><td>• numerical value (a score from 1 to 5)</td></tr>
<tr><td>EXAMPLES</td><td>• WHOQOL-BREF
http://www.who.int/mental_health/media/en/76.pdf
http://www.who.int/substance_abuse/research_tools/en/english_whoqol.pdf</td></tr>
</table>

<table>
<tr><th colspan="2">LINKS AND REFERENCES</th></tr>
<tr><td>KEYWORDS</td><td>• Health
• World Health Organization
• Satisfaction</td></tr>
<tr><td>LINKS AND REFERENCES</td><td>• The World Health Organization Quality of Life (WHOQOL)-BREF © World Health Organization 1996, http://www.who.int/mental_health/media/en/76.pdf
• The World Health Organization Quality of Life (WHOQOL)-BREF © World Health Organization 2004, http://www.who.int/substance_abuse/research_tools/en/english_whoqol.pdf http://www.who.int/substance_abuse/research_tools/whoqolbref/en/</td></tr>
</table>

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	**7.3.1 | PHE – Perceived health**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, capable to describe initial planning problems like perceived health in urban areas.
R2: Policy support for policies:	Yes, related to the World Health Organization Quality of Life (WHOQOL)-BREF © World Health Organization 2004
R3: Comparability:	Yes, standardized method and international comparability.

ACCEPTED	
A1: Policy makers:	Yes, developed and applied within WHOQOL-BREF. When health providers implement new policies it is important that the effect of policy changes on the quality of life of people in contact with health services is evaluated. The WHOQOL instruments allow such monitoring of policy changes.
A2: Practitioners:	Yes
A3: Other stakeholders:	Yes, several peer-reviewed publications in the recent years.

CREDIBLE	
C1: Unambiguous results:	Yes, indicator convey a clear message through being an overall perceived health indicator.
C2: Transparency:	Yes, based on a questionnaire.
C3: Documentation of assumptions and limitations:	Yes, worldwide application possible. There are existing app. 20 different language versions of the document.

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EASY	
E1: Availability of data to calculate the indicator:	Some research data already existing but basically data has to be generated by field surveys.
E2: Technical feasibility:	Yes, simple usage.
E3: Reproducibility:	Yes, possible for numerous cases internationally.

ROBUST	
R1: Data quality:	Data based on subjective answered survey.
R2: Sensitiveness:	Yes, uncertainty through subjective answer.
R3: Scale:	Yes, depending on the field survey respectively the field area. From city to object.

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7 | PUBLIC HEALTH AND WELL-BEING

7.3 | HEALTH

7.3.2 | HIM – HEAT INDUCED MORTALITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	**7.3.2 | HIM – Heat induced mortality**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The HIM indicates the number of deaths associated with temperatures above the 75th percentile of daily mean temperature during summer months (Apr-Sep). Relative risks extracted from a European multi-city study (de' Donato et al. 2015) are used to describe the effect of high temperatures on mortality. **Derivation of risk estimates** Given the many studies showing a connection between high ambient temperatures and health, it is undisputable. However, scientific consensus as to the best climatological metric to describe or explain the connection between heat and health is missing. Studies use daily mean, maximum and minimum temperature (e.g. Medina-Ramon et al. 2006, de' Donato et al. 2015, Oudin et al. 2016) or a combination (Rocklov et al. 2011) to describe the temperature mortality relationship. Many combine temperature with humidity, given the human body's inability to cool in humid conditions but again the metrics differ (e.g. HUMIDEX, THOM index and apparent temperature). Although different temperature metrics are used to get the "best" predictor few evaluate the metric or the implications of the choice. Barnett et al. (2010) consider a range of metrics (mean, minimum and maximum temperature with and without humidity, apparent temperature and HUMIDEX) with mortality but found none to be consistently the best predictor. They conclude the modelling method can be of greater importance than the metric itself

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and therefore the choice should be based on practical constraints. Similarly, Foroni et al. (2007) found the choice of Thom index if based on the maximum temperature or mean and maximum Thom wasn't critical. Temperature mortality impact has been studied in a range of cities across Europe. However, Hajat and Kosatky's (2010) review found only Baccini et al. (2008) had multiple (15) European cities (e.g. Stockholm and Helsinki in the north and Athens and Valencia in the south). Baccini et al. (2008) established temperature thresholds for each city and a change in mortality for per degree increase above that threshold. These range from 1.84% K-1 (northcontinental) to 3.12% K-1 in the Mediterranean region. However, the temperature thresholds in each city have different percentiles making it hard to generalize or extrapolate from, so unsuitable for this project. Fortunately, newer studies have addressed multiple European cities. Guo et al. (2014) analysed 306 communities in 12 countries (e.g., Spain, Italy and United Kingdom). They conclude that Italy and Spain have higher temperature mortality risks than other countries based on accumulated risk over a 21-day lag of daily mean temperatures. Similarly, with Sweden (Stockholm) also included, an analysis of deaths attributable to the warm and cold season Gasparrini et al. (2015) found the lowest mortality was in the 80-90th percentile of annual mean temperatures for communities in a temperate region. The health effects from high temperatures in 9 European cities across a wide geographical distribution using daily mean temperature were considered using cumulative risk over 40 days (de' Donato et al. 2015). The risk ratio (RR) used was the difference in risk for days with temperatures at the 75th percentile of summer temperatures compared to the 99th percentile. This use of relative increases in temperature to estimate the health effects makes the results more comparable between cities and easier to extrapolate beyond the study cities. The study controlled for factors such as barometric pressure, wind speed and NO2 as confounders. The risks were estimated for two time periods to assess the possible effects of the 2003 heatwave. Here, the later period is used. de' Donato et al. (2015) risks range from an 11% increase in mortality in Paris to a 35% increase in Athens. As these are associated with a relative increase in mortality comparison with similar studies is hard. If a linear increase in mortality between the 75th and 99th percentile is assumed, the increase per 1 K is from 1.7% (Paris) to 7.9% (Barcelona (mean increase of 4.6% all cities) is similar to previous studies of European cities. If Europe is divided into two (North and South) a risk increase per 1 K above the 75th percentile based on the areal mean based on the similarity in estimated risks for the cities in the suggested regions (rather than geographical location per se). The suggested relative risks associated with 1 K increase above the 75th percentile are:

Region	RR	(range within region)
Europe	4,6%	(1.7%-7.9%)
Northern	2,5%	(1.7% – 3.5%)
Southern	6,2%	(4.7% – 7.9%)

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Using these RR for **the future scenario assumes no adaption**. Whereas, it is reasonable to expect individuals and populations will over time adapt to a changing climate. Temperature mortality relationships for a specific location change with adaptation, changes in population mortality rates or changing prevalence of chronic diseases, amongst other factors. Adaptation over time to regional temperatures has been observed using historical registers for the 20th century. For Europe, declining vulnerability to heat, and cold, are observed in Germany (Lerchl, 1998), London, UK (Carson et al. 2006), Zeeland, The Netherlands (Ekamper et al. 2009) and Stockholm, Sweden (Astrom et al. 2013). Contributing factors include: medical and technological advances, demographical and epidemiological changes, improvements in the public health and health care sectors, improvements in housing standards with increased use of air conditioners and central heating. Individual physiological adaptation to higher than normal temperatures may occur through increased sweating and improved cardiovascular capacity (Parsons 2002). Furthermore, behavioural changes among population may alter the temperature mortality relationship as people may actively take measures to avoiding the heat when extremes occur. These relationships can change within a summer, with the impact of heat being higher earlier in summer than later (Gasparrini et al. 2016). Impacts of heat and cold are regional, with heat-related mortality occurring at higher temperatures in warmer regions (Anderson and Bell 2009). Reduced vulnerability to heat before and after the 2003 heat wave was found in most cities but in northern cities (e.g. Stockholm, Helsinki) heat vulnerability increased (de'Donato et al. 2015). Demographic change can be a driver of changing impacts on population health (Huang et al. 2011). The expected increase in elderly and other potentially vulnerable groups could make temperature extremes impact on human health more severe (Sierra et al. 2009), as the elderly and chronically ill are more vulnerable to high temperature (Basu 2009, Oudin Åström et al. 2011, Åström et al. 2015). Changing prevalence of chronic diseases (e.g. diabetes and Chronic Obstructive Pulmonary Disease (COPD)) and (in and out) migration must be considered. For example, in Italy the region of birth has been associated with heat sensitivity in adulthood (Vigotti et al. 2006). Future winter mortality may modify the impacts on future summer mortality. High winter mortality reduces the effect of high temperatures the following summer in Stockholm (Rocklöv et al. 2009) and in warmer climates (Stafoggia et al. 2009). The mechanism may be that an increasing mortality during winter depletes the susceptible individuals pool who are most vulnerable to summer heat. Ebi and Mills (2013) suggest winter mortality rates are unlikely to decrease significantly. Future heat waves may also be more intense and have longer duration (Field 2012). There may be increasing risks for more extreme heat waves but no increase in cold spells (Barnett et al. 2012). Gasparrini and Armstrong (2011) separate the risk during elevated temperature into a main effect due to the daily high temperatures and the added effect of the duration of the heat wave. The latter, found to occur after 4-days, was rather small compared to the main effect (Gasparrini and Armstrong 2011). Todd and Valeron (2015) and Oudin Åström et al. (2016) reported that the minimum mortality temperatures were increasing over time in France and Sweden. This suggests that using a fixed percentile of current or future temperature distribution may be inappropriate. Observed changes over time of the temperature mortality relationship as well as changes in population demographics, prevalence of chronic disease with a changing climate

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	indicates estimating impacts of extreme temperatures on mortality is highly complex. Although it may be inappropriate to assume present relationships are representative of future responses at the European scale it may be necessary, as a limit to adaptation may exist among European countries that have recently experienced reduced risks and increased awareness in the northern regions, may reduce the risk in the future.
FOCUS/ OBJECTIVES	• indicate the global level of perceived health

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• climate data, population data and relative risk data
INPUT TYPE (qualitative, quantitative, …)	• Qualitative: relative risk climate data • Quantitative: climate data, population data
DATA SOURCE	• number of degree days above 75th percentile - air temperature (climate data Apr-Sep) • population data (baseline rate and number of exposed persons) • relative risk (RR)
FREQUENCY (how often to use this indicator?)	• every year
MEASUREMENT UNIT	• deaths/year or • deaths/year/100.000 inhabitants
REQUIRED TOOL	Calculation tool
CALCULATION METHOD	Temperature 75th percentile can be calculated (e.g. from Harmonie model output) at the location of an official weather station and then used in the evaluation of each grid cell. The determination of the temperature 75th percentile is made separately for the historical period and for the present window of the climate scenario (for the future window of the climate scenario, the same temperature 75th percentile as calculated in the present window is used). The evaluation period for health impacts of temperatures above the 75th percentile is the full year (this since for the future climate scenario there are temperatures above the thresholds also outside the period Apr-Sep). Relative risks (RR) are recalculated to represent the risk associated with a 1°C increase in daily mean temperature. These risk coefficients were aggregated to two regions (Southern and Northern Europe) as well as the mean for Europe. Thus, each city must be classified as belonging to one of these groups. Population data have been obtained for each city, region or country. For Stockholm national data for 2012, with a spatial resolution of 100×100 m2, have been obtained from Swedish statistics. For Bologna and Amsterdam/Rotterdam, a 1 * 1 km2 population grid disaggregated data has been applied (Gallego 2010). The estimated number of deaths are calculated as $\Delta Y = (Y0 * P) * (RR * Tdd)$ where Y0 is the baseline rate; P the number of exposed persons; RR the relative risk associated with a 1°C increase in temperature above the 75th percentile and Tdd is the number of degree days above the 75th percentile. The RR is scaled so that the total number of extra deaths for the entire city is equal to the number of deaths you would get if you used the daily temperatures from the location of the weather station for all the city population. This means that for present climate Urban SIS will just distribute spatially the impact to be stronger in more heated urban areas and lower in colder areas of the city. The scaling and the determination of the 75th percentile determined for the present climate is maintained for the future climate, thus allowing raising temperatures in the future to give a stronger health impact.
OUTPUT TYPE	• numerical value (number of annual heatrelated deaths)
EXAMPLES	• URBAN SIS: Climate Information for European Cities - CLIMATE COPERNICUS http://urbansis.climate.copernicus.eu/annual-heat-related-deaths/

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LINKS AND REFERENCES	
KEYWORDS	• HEALTH • HEAT • MORTALITY
LINKS AND REFERENCES	• Anderson BG & Bell ML 2009: Weather-related mortality: how heat, cold, and heat waves affect mortality in the United States. Epidemiology (Cambridge, Mass.), 20, 205. • Astrom DO, Forsberg B, Edvinsson S, Rocklov J 2013: Acute fatal effects of short-lasting extreme temperatures in Stockholm, Sweden: evidence across a century of change. Epidemiology, 24, 820-9. • Baccini M, Biggeri A, Accetta G, Kosatsky T, Katsouyanni K, Analitis A, . . . Michelozzi P 2008: Heat effects on mortality in 15 European cities. Epidemiology, 19:5, 711-719. doi:10.1097/EDE.0b013e318176bfcd • Barnett AG, Hajat S, Gasparrini A Rocklov J 2012: Cold and heat waves in the United States. Environ Res, 112, 218-24. • Barnett AG, Tong S, Clements AC 2010: What measure of temperature is the best predictor of mortality? Environ Res, 110:6, 604-611. doi:10.1016/j.envres.2010.05.006 • Basu R 2009: High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008. Environ Health, 8, 40. • Carson C, Hajat S, Armstrong B, Wilkinson P 2006. Declining vulnerability to temperature-related mortality in London over the 20th century. American Journal of Epidemiology, 164, 77-84. • de' Donato FK, Leone M, Scortichini M, De Sario M, Katsouyanni K, Lanki T, . . . Michelozzi P 2015: Changes in the Effect of Heat on Mortality in the Last 20 Years in Nine European Cities. Results from the PHASE Project. Int J Environ Res Public Health, 12:12, 15567-15583. doi:10.3390/ijerph121215006 • De'Donato FK, Leone M, Scortichini M, De Sario M, Katsouyanni K, Lanki T, Basagaña X, Ballester F, Åström C, Paldy A 2015: Changes in the effect of heat on mortality in the last 20 years in nine European cities. Results from the PHASE project. International journal of environmental research and public health, 12, 15567-15583. • Gallego FJ 2010: A population density grid of the European Union. Population and Environment. 31:6, 460-473. • Ebi KL, Mills D 2013: Winter mortality in a warming climate: a reassessment. Wiley Interdisciplinary Reviews: Climate Change, 4, 203-212. • Ekamper P, Van Poppel F, Van Duin C, Garssen J 2009: 150 Years of temperature-related excess mortality in the Netherlands. Demographic Research, 21, 385-426. • Field CB 2012: Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change, Cambridge University Press. • Foroni M, Salvioli G, Rielli R, Goldoni CA, Orlandi G, Zauli Sajani S, . . . Mussi C 2007: A retrospective study on heat-related mortality in an elderly population during the 2003 heat wave in Modena, Italy: the Argento Project. J Gerontol A Biol Sci Med Sci, 62(6), 647-651. • Gasparrini, A. & Armstrong, B. 2011. The impact of heat waves on mortality. Epidemiology (Cambridge, Mass.), 22, 68.

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- Gasparrini, A., Guo, Y., Hashizume, M., Lavigne, E., Zanobetti, A., Schwartz, J., . . . Armstrong, B. (2015). Mortality risk attributable to high and low ambient temperature: a multicountry observational study. Lancet, 386(9991), 369-375. doi:10.1016/S0140-6736(14)62114-0
- Guo Y, Gasparrini A, Armstrong B, Li S, Tawatsupa B, Tobias A, . . . Williams G 2014: Global variation in the effects of ambient temperature on mortality: a systematic evaluation. Epidemiology, 25:6, 781-789. doi:10.1097/EDE.0000000000000165
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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	7.3.2 | HIM – Heat induced mortality

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator describes initial planning problems like heat related health issues.
R2: Policy support for policies:	High score for policy support Europe-wide and international: - EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities - EU Strategy on Green Infrastructure - Intergovernmental Panel on Climate Change (IPCC) - Report on Climate Change Impacts, Adaptation and Vulnerability (2014) - Report on Mitigation of Climate Change (2014)
R3: Comparability:	Yes, methodology can be standardized.

ACCEPTED	
A1: Policy makers:	No.
A2: Practitioners:	Yes, because it’s a relative simple calculation. Can be done by Health authorities, environmental authorities and general public.
A3: Other stakeholders:	Yes, published validation paper in the framework of Urban Sis project.

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CREDIBLE	
C1: Unambiguous results:	Yes, there is a clear message with the statement for deaths/year.
C2: Transparency:	Yes, indicator has a clear and transparent method.
C3: Documentation of assumptions and limitations:	Yes, methods, assumptions and underlying data are fully disclosed and enables an European application.

EASY	
E1: Availability of data to calculate the indicator:	Partly already existing, but specific climate and person data needed. Easy to update and re-calculate.
E2: Technical feasibility	Yes, basically relatively simple and transparent calculation.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Partly depending on the input data.
R2: Sensitiveness:	No, the simulations made by HARMONIE-AROME in Urban SIS has been validated against observations in Urban SIS deliverable 5.1.
R3: Scale:	Yes, from city to grid.

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7 | PUBLIC HEALTH AND WELL-BEING

7.3 | HEALTH

7.3.3 | AQEshort – AIR QUALITY SHORT TERM HEALTH EFFECTS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	**7.3.3 | AQEshort – Air quality indicators: short term health effects**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The ASE estimates the number of preterm deaths due to ozone short-term exposure in urban areas (O_3). The WHO REVIHAAP project argues that despite the many respiratory outcomes associated with O3, mainly adverse health outcomes with known baseline rates are suited for health impact assessments. Evidence from time-series studies of short-term exposure to O3 suggest that health impact assessment calculations can be undertaken for a range of end-points, including all-age, all-cause mortality (WHO 2013a). There is still scientific debate whether the effects on mortality of long-term exposure to O3 are well enough documented to be included in health impact assessments. Multi-pollutant models in the largest European study of short-term exposure (APHEA2) reported short-term exposure increases of total mortality by approx. 0.3% per 10 µg m-3 using the daily 8-h or 1-h maximum, in a linear manner without a significant threshold (Gryparis et al. 2004). A WHO meta-analysis for the AQ guidelines (2003) reported a relative risk of 0.3% per 10 µg m-3 increase with the 95% (CI 0.1–0.4%) which we see as a robust exposure–response assumption to apply. WHO REVIHHAP conclude that the epidemiological evidence supports calculations that use all-year coefficients for daily maximum 8-h O3 (scaled from the 1-h measures reported in the literature), including adjustment for PM10. It is also recommended that health impact calculations for short-term exposures assume linear concentration–response relationships. Since the epidemiological evidence on linearity does not extend down to zero, appropriate cut-off points for health impact assessments are therefore recommended: at 10 ppb (20 µg m-3) for daily maximum 8-h O3 and at 35 ppb (70 µg m-3), for consistency with previous work using SOMO35 data (WHO

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	2013). Given the uncertainties in the effects of long-term exposure to O3 (see the REVIHAAP report) it was suggested that health impact assessments for long-term exposure and respiratory and cardiopulmonary mortality are undertaken as a sensitivity scenario. It is recommended the coefficients from single pollutant models from the American Cancer Society cohort study (Jerrett et al. 2009) are used, assuming an association exists within the range of O3concentrations studied. The WHO HRAPIE Project recommended use of a meta-coefficient from The APHENA Study (results from 32 European cities) of a 0.3% increase (95% CI 1.4 – 4.3) per 10 µg m-3 increase in daily maximum 8-h O3 (Katsouyanni et al. 2009) and cutoff at 35 ppb (SOMO35).
FOCUS/OBJECTIVES	• indicate the short-term health effects regarding air quality

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• climate data, population data and relative risk data
INPUT TYPE (qualitative, quantitative, …)	• Qualitative: relative risk • Quantitative: climate data, population data
DATA SOURCE	• population data (baseline rate and number of exposed persons) • exposure-response relationshiop (relative risk) • climate data (estimated mean exposure)
FREQUENCY (how often to use this indicator?)	• every year
MEASUREMENT UNIT	• deaths/year or • deaths/year/100.000 inhabitants
REQUIRED TOOL	• HIA tool AirQ or • Calculation tool

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Table 1. Air pollution health impact assessment tools

Tool	Developing institution	Geographical scope	Health endpoint addressed[1]
AirCounts	Abt Associates	Global (42 cities, additional 3000 under development)	Mortality
AirQ2.2 (update under development)	World Health Organization	Any population with specified size, mortality and morbidity characteristics	Mortality and morbidity
Aphekom	French Institute of Public Health Surveillance	Global (current version focuses on Europe)	Mortality and morbidity
Economic Valuation of Air Pollution (EVA)	Aarhus University	Northern hemisphere, continental (e.g. Europe), national, city	Mortality and morbidity
EcoSense	University of Stuttgart	Europe	Mortality and morbidity
Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE)	US Environmental Protection Agency	Continental USA and China pre-defined, any other as defined by user	Mortality and morbidity
Environmental Burden of Disease (EBD) Assessment tool for ambient air pollution	World Health Organization	Global	Mortality and morbidity
GMAPS[2]	World Bank	Global	Mortality and morbidity
IOMLIFET	Institute of Occupational Medicine	Can be used anywhere where there is background mortality data and measured or predicted pollutant concentrations	Mortality and morbidity
Rapid Co-benefits Calculator	US Environmental Protection Agency, Stockholm Environment Institute	Under development for all countries globally	Mortality
SIM-Air	Urban emissions	Asia, Africa, Latin America	Mortality
TM5-FASST	European Commission Joint Research Centre	Global (56 source regions)	Mortality and morbidity

1 Morbidity may include, for example: cardiovascular diseases, respiratory diseases, hospital admissions, emergency room admissions, days of restricted activity, and work loss days. Not all tools address all morbidity outcomes.
2 The model itself is no longer actively maintained and therefore no longer available for download.

Fig 1: Air pollution health impact assessment tools (WHO, 2016).

CALCULATION METHOD

Population data have been obtained for each city, region or country. For Stockholm national data for 2012, with a spatial resolution of 100×100 m2, have been obtained from Swedish statistics. For Bologna and Amsterdam/Rotterdam, a 1 * 1 km2 population grid disaggregated data has been applied (Gallego 2010). The data on baseline mortality are from national official sources, for Stockholm from Swedish statistics, for Bologna from the Bologna province statistics and for Amsterdam from Centraal Bureau voor de Statistiek. Baseline mortality for all ages for the city or region is used in combination with population exposure data for the city according to the HIA tool AirQ developed by WHO (2004), where the attributed mortality is calculated as

$\Delta Y = (Y0 * P) * (e^{\beta * X} - 1)$,

where Y0 is the baseline rate; P the number of exposed persons; β the exposure-response relationship (relative risk) and X the estimated mean exposure (with impact/above any assumed threshold).

Calculations will build on the WHO HRAPIE recommendation assuming a 0.3% increase (95% CI 1.4 – 4.3) per 10 µg m-3 increase in daily maximum 8-hour ozone and with a cutoff at 35 ppb (70 µg m-3) (SOMO35).

OUTPUT TYPE

- numerical value (number of preterm deaths to ozone short-term exposure)

EXAMPLES

- URBAN SIS: Climate Information for European Cities - CLIMATE COPERNICUS http://urbansis.climate.copernicus.eu/annual-deaths-due-to-ozone-short-term-exposure/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

LINKS AND REFERENCES	
KEYWORDS	• HEALTH • AIR QUALITY • O_3 • MORTALITY • AIR POLLUTION - adverse effects • AIR POLLUTION - analysis • RISK ASSESSMENT - methods • ENVIRONMENTAL MONITORING
LINKS AND REFERENCES	• Gallego FJ 2010: A population density grid of the European Union. Population and Environment. 31:6, 460-473. • Gryparis A et al. 2004: Acute effects of ozone on mortality from the 'air pollution and health: a European approach' project. American Journal of Respiratory and Critical Care Medicine, 170:10, 1080–1087. • Jerrett M et al. 2009: Long-term ozone exposure and mortality. The New England Journal of Medicine, 360:11, 1085–1095. • Katsouyanni K et al. 2009: Air pollution and health: a European and North American approach (APHENA). Boston, Health Effects Institute, Research Report 142. • WHO 2005: Air quality guidelines for Europe, Global Update 2005, Copenhagen. http://apps.who.int/iris/bitstream/10665/69477/1/WHO_SDE_PHE_OEH_06.02_eng.pdf • WHO 2004: Tools for health impact assessment of air quality: the AirQ 2.2 software. http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/tools-for-health-impactassessment-of-air-quality-the-airq-2.2-software • WHO 2013a: Review of evidence on health aspects of air pollution – REVIHAAP Project Technical Report. Copernicus Climate Change Service Urban SIS D4.3 Indicators for urban assessments, C3S_441 Lot3 Urban SIS, D4.3 22 Copenhagen. • WHO 2013b: Health risks of air pollution in Europe – HRAPIE. Recommendations for concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide. Copenhagen • WHO 2016. European Health For All Database. http://data.euro.who.int/hfadb/ • WHO 2016: Healt risk assessment of air pollution – general principles, Copenhagen. http://www.euro.who.int/__data/assets/pdf_file/0006/298482/Health-risk-assessment-air-pollution-General-principles-en.pdf?ua=1

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	**7.3.3 | AQEshort – Air quality indicators: short term health effects**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator describes initial planning problems like air quality related short-term health issues.
R2: Policy support for policies:	Yes, assessments are often used to answer the following policy questions (WHO Regional Office for Europe, 2014). 1. What is the public health burden associated with current levels of air pollution? 2. What are the human health benefits associated with changing an air quality policy or applying a more stringent air quality standard? 3. What are the human health impacts of emissions from specific sources or selected economic sectors, and what are the benefits of policies related to them? 4. What are the human health impacts of current policy or implemented action? 5. What are the policy implications of the uncertainties of the assessment? WHO 2005: Air quality guidelines for Europe, Global Update 2005, Copenhagen.
R3: Comparability:	Yes, methodology can be standardized.

ACCEPTED	
A1: Policy makers:	No.
A2: Practitioners:	Yes, because it's a relative simple calculation. Can be done by Health authorities, environmental authorities and general public.
A3: Other stakeholders:	Yes, published validation paper in the framework of Urban Sis project but controversial regarding NBS effects.

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CREDIBLE	
C1: Unambiguous results:	Yes, there is a clear message with the statement for deaths/year.
C2: Transparency:	Yes, indicator has a clear and transparent method.
C3: Documentation of assumptions and limitations:	Yes, methods, assumptions and underlying data are fully disclosed and enables an European application.

EASY	
E1: Availability of data to calculate the indicator:	Partly already existing, but specific climate and person data needed. Easy to update and re-calculate.
E2: Technical feasibility:	Yes, basically relatively simple and transparent calculation, but input data needed.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Partly depending on the input data.
R2: Sensitiveness:	No, the downscaling made by MATCH in Urban SIS has been validated against observations in Urban SIS deliverable 5.2
R3: Scale:	Yes, from city to grid.

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7 | PUBLIC HEALTH AND WELL-BEING

7.3 | HEALTH

7.3.4 | AQElong – AIR QUALITY LONG TERM HEALTH EFFECTS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	**7.3.4 | AQElong – Air quality indicators: long term health effects**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The ALE estimates the number of deaths in age group 30+ associated with long-term exposure to urban background levels of PM2.5 and NO2. Relative risks based on recommendations from WHO HRAPIE Project (WHO, 2013b) regarding PM2.5 and UK COMEAP (2015) regarding NO2. Estimates are presented both separately and combined for exposure to both pollutants.It has long been recognized that particle concentrations correlate with mortality, both temporally (short-term fluctuations) and spatially based on mortality and survival (WHO 2003, WHO 2006a). Short-term effects are usually assumed to be included in the long-term impacts on mortality. Particles in ambient air (indicated by PM2.5) are one of the major causes of preterm death in Europe, but also exposure to NO2 and ozone has been associated with mortality. The WHO Review of evidence on health aspects of air pollution (REVIHAAP, WHO 2013a), concludes that recent long-term studies are showing associations between PM and mortality at levels well below the current annual WHO air quality guideline level for PM2.5 (10 µg m-3). The WHO expert panel thus concluded that for Europe it is reasonable to use linear exposure-response functions, at least for particles and all-cause mortality, and to assume that any reduction in exposure will have benefits. The findings from REVIHAAP are used as a basis for the WHO Project Health risks of air pollution in Europe – HRAPIE (WHO 2013b). The conclusions from the HRAPIE project (Heroux et al. 2015) are implemented in costbenefit calculations done by EMRC/IAASA for the European Union. For the WHO HRAPIE impact assessment (WHO 2013b) for long-term exposure to PM2.5 and all cause (natural) mortality in ages 30+ recommended use of exposure-response function from a meta-

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	analysis of 13 cohort studies (Hoek et al. 2013). The RR for PM2.5from this meta-analysis was 1.062 (95% CI 1.040-1.083) per 10 µg m-3 is similar to the 1.06 per 10 µg m-3 increment of the annual average PM2.5 of the American Cancer Society Cohort Study (Pope et al. 1995). This assumption (6% per 10 µg m-3) has been used in many health impact assessments. Although, different types of particles and reasoning explain the impacts on mortality (WHO 2007, WHO 2013a), the WHO REVIHAAP panel of experts consider current knowledge does not allow precise quantification of the health effects of PM emissions from different sources. Current risk assessment should consider particles of different: sizes, sources and composition, as equally hazardous to health (WHO 2007). Practice has treated both PM10 and fine fraction PM2.5 (quite often considered to be more detrimental to health than the coarse fraction of PM10) as being equally toxic by mass, irrespective of the origin. Thus, commonly exposure-response functions obtained using urban background PM2.5 as the exposure indicator are converted to be used for PM10 through a factor based on their mass relation. In the new impact assessment HRAPIE no such conversion is recommended for PM10 and mortality. Different types of PM have been assumed to influence mortality differently; e.g., ExternE3 (2005) includes assumptions about the toxicity of other different types of PM. This reflects results that indicate a higher toxicity of combustion particles, especially from internal combustion engines. They treat nitrates as equivalent to half the toxicity of PM10, sulphates as equivalent to PM10, primary particles from power stations as equivalent to PM10, and primary particles from vehicles as equivalent to 1.5 the toxicity of PM2.5. Effects of combustion-related particles have been studied using black smoke, black carbon (BC) or elemental carbon (EC) as the exposure variable. REVIHAAP (WHO 2013a) recommended that BC should be used as exposure variable in more studies, but did not recommend it to be used for the HRAPIE impact calculations (WHO 2013b). A review of mortality and long-term exposure to the combustion-related particle indicators (Hoek et al. 2013) used different methods. Their relation and conversion factors have been described before (Janssen et al. 2011). All-cause mortality was significantly associated with EC, the meta-analysis resulted in a (relative risk) RR of 1.061 per 1 µg m-3 EC (95% CI 1.049-1.073), with highly non-significant heterogeneity of effect estimates. Most of studies assessed EC exposure without accounting for small-scale variation related to proximity to major roads. These results suggest that using the common RR for long-term exposure to PM2.5 and mortality, may lead to an underestimation of impacts of particle mass from motor vehicle exhaust.

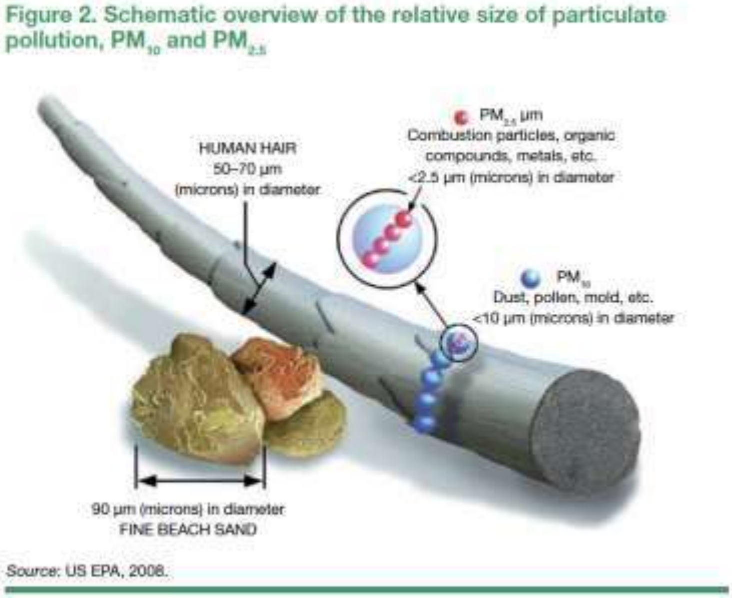

FIG 2: Schematic overview of the relative size of particulate pollution PM_{10} and $PM_{2.5}$ (WHO, 2016)

FOCUS/ OBJECTIVES	• indicate the long-term health effects regarding air quality

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• climate data, population data and relative risk data
INPUT TYPE (qualitative, quantitative, …)	• Qualitative: relative risk • Quantitative: climate data, population data
DATA SOURCE	• population data (baseline rate and number of exposed persons) • exposure-response relationshiop (relative risk) • climate data (estimated mean exposure)
FREQUENCY (how often to use this indicator?)	• every year
MEASUREMENT UNIT	• deaths/year or • deaths/year/100.000 inhabitants
REQUIRED TOOL	• HIA tool AirQ or • Calculation tool

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Table 1. Air pollution health impact assessment tools

Tool	Developing institution	Geographical scope	Health endpoint addressed[1]
AirCounts	Abt Associates	Global (42 cities, additional 3000 under development)	Mortality
AirQ2.2 (update under development)	World Health Organization	Any population with specified size, mortality and morbidity characteristics	Mortality and morbidity
Aphekom	French Institute of Public Health Surveillance	Global (current version focuses on Europe)	Mortality and morbidity
Economic Valuation of Air Pollution (EVA)	Aarhus University	Northern hemisphere, continental (e.g. Europe), national, city	Mortality and morbidity
EcoSense	University of Stuttgart	Europe	Mortality and morbidity
Environmental Benefits Mapping and Analysis Program – Community Edition (BenMAP-CE)	US Environmental Protection Agency	Continental USA and China pre-defined, any other as defined by user	Mortality and morbidity
Environmental Burden of Disease (EBD) Assessment tool for ambient air pollution	World Health Organization	Global	Mortality and morbidity
GMAPS[2]	World Bank	Global	Mortality and morbidity
IOMLIFET	Institute of Occupational Medicine	Can be used anywhere where there is background mortality data and measured or predicted pollutant concentrations	Mortality and morbidity
Rapid Co-benefits Calculator	US Environmental Protection Agency, Stockholm Environment Institute	Under development for all countries globally	Mortality
SIM-Air	Urban emissions	Asia, Africa, Latin America	Mortality
TM5-FASST	European Commission Joint Research Centre	Global (56 source regions)	Mortality and morbidity

1 Morbidity may include, for example: cardiovascular diseases, respiratory diseases, hospital admissions, emergency room admissions, days of restricted activity, and work loss days. Not all tools address all morbidity outcomes.
2 The model itself is no longer actively maintained and therefore no longer available for download.

Fig 1: Air pollution health impact assessment tools (WHO, 2016).

CALCULATION METHOD

Population data have been obtained for each city, region or country. For Stockholm national data for 2012, with a spatial resolution of 100×100 m2, have been obtained from Swedish statistics. For Bologna and Amsterdam/Rotterdam, a 1 * 1 km2 population grid disaggregated data has been applied (Gallego 2010). Baseline mortality in age group 30+ for the city or region is used in combination with population exposure data for the city according to the HIA tool AirQ developed by WHO (2004), where the attributed mortality is calculated as

$\Delta Y = (Y0 * P) * (e\beta*X – 1)$,
where Y0 is the baseline rate; P the number of exposed persons; β the exposure-response relationship (relative risk) and X the estimated mean exposure (with impact/above any assumed threshold).

The data on baseline mortality are from national official sources, for Stockholm from Swedish statistics, for Bologna from the Bologna province statistics and for Amsterdam from Centraal Bureau voor de Statistiek. The estimated mortality is presented both for a normalized population of 100 000 inhabitans on each grid (without using local population data from the city, the impact reflecting the concentrations only) and as mortality based on local population data.

OUTPUT TYPE

- numerical value (number of preterm deaths to ozone long-term exposure)

EXAMPLES

- URBAN SIS: Climate Information for European Cities - CLIMATE COPERNICUS http://urbansis.climate.copernicus.eu/annual-deaths-due-to-ozone-short-term-exposure/

LINKS AND REFERENCES

KEYWORDS

- HEALTH
- AIR QUALITY
- NO_2
- $PM_{2.5}$
- MORTALITY

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LINKS AND REFERENCES	• COMEAP 2015: Interim Statement on quantifying the association of long-term average concentrations of nitrogen dioxide and mortality. Public Health England, COMEAP: reports and statements. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485373/COMEAP_NO2_Mortality_Interim_Statement.pdf • EMRC/IIASA 2014: Implementation of the HRAPIE Recommendations for European Air Pollution CBA work. Mike Holland, EMRC. http://ec.europa.eu/environment/air/pdf/CBA%20HRAPIE%20implement.pdf • ExternE 1999: ExternE – Methodology 1998 update. European Comission. ISBN 92-828-7782-5 • ExternE 2005: Externalties of Energy – Methodology 2005 Update. Ed. P Bickel and R Friedrich, European Commission EUR 21951. • Faustini A, Rapp R, Forastiere F 2014: Nitrogen dioxide and mortality: review and meta-analysis of long-term studies. Eur Respir J. Eur Respir J. 44:3,744-53. • Gallego FJ 2010: A population density grid of the European Union. Population and Environment. 31:6, 460-473. • Héroux ME, Anderson HR, Atkinson R, Brunekreef B, Cohen A, Forastiere F, Hurley F, Katsouyanni K, Krewski D, Krzyzanowski M, Künzli N, Mills I, Querol X, Ostro B, Walton H 2015: Quantifying the health impacts of ambient air pollutants: recommendations of a WHO/Europe project. Int J Public Health.60:5, 619-27. • Hoek G, Krishnan RM, Beelen R, Peters A, Ostro B, Brunekreef B, Kaufman JD 2013: Long-term air pollution exposure and cardio-respiratory mortality: a review. Environmental Health 12:43. • Janssen NA, Hoek G, Simic-Lawson M, Fischer P, van Bree L, ten Brink H, Keuken M, Atkinson RW, Anderson HR, Brunekreef B, Cassee FR 2011: Black carbon as an additional indicator of the adverse health effects of airborne particles compared with PM10 and PM2.5. Environ Health Perspect. 119:12,1691-9. doi: 10.1289/ehp.1003369. • Jerrett M, Burnett RT, Ma R, Pope CA 3rd, Krewski D, Newbold KB, Thurston G, Shi Y, Finkelstein N, Calle EE, Thun MJ 2005: Spatial analysis of air pollution and mortality in Los Angeles. Epidemiology. 16:6, 727-36. • Pope CA, III, Thun MJ, Namboodiri MM, Dockery DW, Evans JS, Speizer FE, Heath CW Jr 1995: Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. Am. J. Respir. Crit. Care Med. 151: 669-674. • WHO 2003: Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide, World Health Organisation, Copenhagen. WHO 2004: Tools for health impact assessment of air quality: the AirQ 2.2 software. http://www.euro.who.int/en/healthtopics/environment-and-health/air-quality/activities/tools-for-health-impact-assessment-of-air-quality-the-airq-2.2- software • WHO 2005: Air quality guidelines for Europe, Global Update 2005, Copenhagen. WHO 2006a: Air Quality Guidelines Global Update 2005, Copenhagen. • WHO 2006b: Health risks of particulate matter from long-range transboundary air pollution. Copenhagen.

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- WHO 2007: Health relevance of particulate matter from various sources. Report on a WHO Workshop Bonn, Germany, 26- 27 March 2007.
- WHO 2013a: Review of evidence on health aspects of air pollution – REVIHAAP Project Technical Report. Copenhagen
- WHO 2013b: Health risks of air pollution in Europe – HRAPIE. Recommendations for concentration-response functions for cost-benefit analysis of particulate matter, ozone and nitrogen dioxide. Copenhagen WHO 2016. European Health For All. http://data.euro.who.int/hfadb/
- WHO 2016: Healt risk assessment of air pollution – general principles, Copenhagen. http://www.euro.who.int/__data/assets/pdf_file/0006/298482/Health-risk-assessment-air-pollution-General-principles-en.pdf?ua=1

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	7 | Public Health and Well-being	7.3 | Health

INDICATOR	
NAME	**7.3.4 | AQElong – Air quality indicators: long term health effects**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, indicator describes initial planning problems like air quality related long-term health issues.
R2: Policy support for policies:	Yes, assessments are often used to answer the following policy questions (WHO Regional Office for Europe, 2014). 1. What is the public health burden associated with current levels of air pollution? 2. What are the human health benefits associated with changing an air quality policy or applying a more stringent air quality standard? 3. What are the human health impacts of emissions from specific sources or selected economic sectors, and what are the benefits of policies related to them? 4. What are the human health impacts of current policy or implemented action? 5. What are the policy implications of the uncertainties of the assessment? WHO 2005: Air quality guidelines for Europe, Global Update 2005, Copenhagen.
R3: Comparability:	Yes, methodology can be standardized.

ACCEPTED	
A1: Policy makers:	No.
A2: Practitioners:	Yes, because it's a relative simple calculation. Can be done by Health authorities, environmental authorities and general public.
A3: Other stakeholders:	Yes, published validation paper in the framework of Urban Sis project but controversial regarding NBS effects.

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CREDIBLE	
C1: Unambiguous results:	Yes, there is a clear message with the statement for deaths/year.
C2: Transparency:	Yes, indicator has a clear and transparent method.
C3: Documentation of assumptions and limitations:	Yes, methods, assumptions and underlying data are fully disclosed and enables a European application.

EASY	
E1: Availability of data to calculate the indicator:	Partly already existing, but specific climate and person data needed. Easy to update and re-calculate.
E2: Technical feasibility:	Yes, basically relatively simple and transparent calculation, but input data needed.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Partly depending on the input data.
R2: Sensitiveness:	No, the downscaling made by MATCH in Urban SIS has been validated against observations in Urban SIS deliverable 5.2
R8: Scale:	Yes, from city to grid.

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8 | ENV. JUSTICE AND SOCIAL COHESION

Short description of UC: The environmental justice concepts allows to evaluate and assess **procedural** and **distributional** impacts of NBS-type of solutions in urban environments. It allows for addressing both the quality of the process and its outcomes (who benefits from the NBS). A pre-condition for procedural justice is the **recognition** of diverse needs and interests, but also attention to **capabilities** to participate and the room to assume (rather than be allocated) **responsibility**.

Since NBS are planned for and implemented in a specific local context, the extent to which these build on or improve the quality of existing local social networks is also important to consider. Addressing the social context through the concept of **social cohesion** allows to address, next to the justice elements which also bear on social cohesion, **social capital** is a main indicator, which refers to the value that social networks have (to those that are part and to those that are bystanders (Putnam in Jenson 2012:9).

8.1 | ENVIRONMENTAL JUSTICE

Short description of USC: Environmental justice is a concept that has evolved over the past years towards become increasingly suitable for evaluative purposes (Schlossberg 2004; Davoudi and Brooks 2014). The 5 main dimensions (mentioned above) of this concept will be analysed in relation to the process of realizing an NBS; in the assessment of the impact of an NBS; and in relation to the maintenance of an NBS.

8.1.1 | REC – RECOGNITION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.1 | REC – Recognition**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	*Recognition: how has attention been given to a diversity of voices and/or a diversity of participants in the process around this NBS? What can we know about the diversity of those affected by this particular NBS?* In the process from designing an intervention (NBS) until after its implementation and maintenance, questions about recognition of diversity refer to the acknowledgement of diverse needs and ambitions, with particular attention to vulnerable groups that are prone to exclusion (e.g. migrants, women, children, elderly, people with disabilities, people suffering from deprivation). Put the other way around, a lack of recognition of diverse needs undermines the quality of the participatory process and undermines possibilities for a fair distribution. Recognition of diversity also entails attention to different types of knowledge (scientific; local; tacit; experiential) For instance residents that know (his)stories about the neighbourhood may have a distinct perspective on the sort of NBS that 'fit' in that neighbourhood. Culture is also relevant here, as it colours how viable or valuable NBS are.
FOCUS/ OBJECTIVES	<u>In evaluating the process of realising an NBS:</u> address to what extent a diversity of voices, perspectives, needs and social groups that affect and/or are affected by this process and its outcome, have been involved. Particular attention to be paid to vulnerable groups (e.g. children, migrants, women, lowly educated groups, etc). <u>In assessing the impact of an NBS</u>, addressing how it affects (caters for the needs of) these diverse groups of stakeholders and social groups or individuals. <u>With regard to further maintenance of the NBS</u>: ensuring that diverse stakeholders' needs and interests are taken into account

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	- Data on diversity of backgrounds, needs, perspectives, types of knowledge and related understandings of NBS among all stakeholders (including citizens, local residents) - Cultural understandings affecting the valuation of NBS - Information about the process preceding the realisation of this NBS - Information on how this NBS can/does (cannot/does not) cater for various needs.
INPUT TYPE (qualitative, quantitative, …)	Quantified data on socio-economic demographics of stakeholder and target groups. Qualitative input – e.g. descriptions of the formal procedures
DATA SOURCE	- Socio-economic and demographic information (e.g. existing databases) - Reports written based data collected in interviews, surveys, storytelling, diaries, Q-sort, (participant) observation, workshops and/or other participatory methods to collect peoples' accounts.
FREQUENCY (how often to use this indicator?)	Depending on the specific situation and the exact question, it could address the process of the design phase of urban planning, decision-making, implementation, maintenance and evaluation.
MEASURMENT UNIT	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses;
REQUIRED TOOL	- Analytic tools to see how the diversity in the process matches the diversity identified based on socio-demographic data (e.g. using GIS and maps) - Data collecting and analysis procedures: interviews, surveys, storytelling, diaries, Q-sort, (participant) observation workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis.
CALCULATION METHOD	n/a
OUTPUT TYPE	- Become aware of the diversity of thoughts and feelings about a neighbourhood and the implications for NBS - Understand thoughts, imagery and feelings of people about their environment and the NBS - Assessment of inclusion of diversity in the process towards realising this NBS. - Assessment of how this NBS caters for diverse needs, wishes and ambitions and assessment of any mismatches (e.g. between intended benefit and experienced benefits to e.g. particular groups) - Potentially: ideas regarding the maintenance (and improvement) of this NBS in line with the identified diverse needs.
EXAMPLES	(Raymond et al 2017b:36);

LINKS AND REFERENCES	
Keywords	• Recognition of diversity • cultural understandings • tacit knowledge • local knowledge • experiential knowledge

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Links and references	• Raymond et al 2017a;b; Bell and Davoudi 2016;

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	8.1.1 | REC – Recognition

Remark:

- As I indicated in the indicator sheet, distinct descriptions of the indicators/dimensions that make up the concept of environmental justice does not mean that we think it is a good idea to fully decouple these indicators – as the aim is to evaluate a process and phenomenon (NBS intervention) within its real-life (social, institutional, physical, political) context.
- Furthermore, we pointed out that different approaches can be combined (e.g. analysis of interviews; surveys; statistical analysis; deskstudy) to achieve robust conclusions, which is why no decisive choice for one particular method is advisable
- And we pointed out that in the process of evaluation, it can be a good idea to involve stakeholders and end-users
- Therefore, in this evaluation factsheet we do not distinguish between the 5 main dimensions of environmental justice (recognition, procedural justice, distribution, capability and responsibility) but address the concept as a whole.

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, environmental justice is a very suitable concept to describe process-related problems in planning (e.g. related to recognition, procedural justice, capabilities and responsibilities)
R2: Policy support for policies:	Various policies address elements of environmental justice, but usually do not take the integral concept (except perhaps in the U.S. but then with slight differences in definition) *Examples needed*
R3: Comparability:	Depending on the specific context and question, it is possible to reach a level of standardisation, enabling cross-case comparisons as well. However, these comparisions, while addressing the same type of mechanisms, themes or topics, are qualitative in nature for the most part, because environmental justice cannot be grasped in quantitative terms.

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ACCEPTED	
A1: Policy makers:	Yes, policy makers do work with this or other definitions of the concepts. E.g. a Dutch social housing association used the 5 dimensions to evaluate its own policy approach towards a particular neighbourhood. *Need to search for more examples*
A2: Practitioners:	Yes, absolutely. In fact, DuneWorks has translated the concept of Environmental Justice that we use here into 5 sets of relevant questions to inform policy evaluation (at the outset, during and after an NBS intervention)
A3: Other stakeholders:	Yes, there is a whole body of literature that is still evolving.

CREDIBLE	
C1: Unambiguous results:	The results are rather pointing out ambiguities, room for further negotiation on trade-offs etc. The concept of environmental justice allows for a better articulation of the political nature of any intervention (also NBS).
C2: Transparency:	No, there are several approaches possible, depending on the context (availability of data and resources) and the exact question posed. For each situation, a tailored approach can be set up based on the indicator sheets.
C3: Documentation of assumptions and limitations:	Yes, underlying data can be disclosed although there are privacy issues involved (e.g. relating to interviews, stakeholder workshop reports etc) that need to be addressed. Uniform application across all context is not likely, as pointed out before, because different countries present different contexts (e.g. social norms, political institutions can differ a lot) and possibilities for inquiries on environmental justice.

EASY	
E1: Availability of data to calculate the indicator	In principle not, but in cases there may be data(sets) that can be used for a part of the assessment.
E2: Technical feasibility:	No, the use of software is not very likely in the first place. It is rather a set of questions and a qualitative approach that then needs to be carried out – but a training to that end can be provided as the concepts describing the dimensions of environmental justice can also be explained and operationalised in quite straightforward/common language.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases. (*what is meant with reasonable results)?*

ROBUST	
R1: Data quality:	n/a
R2: Sensitiveness:	n/a
R3: Scale:	Yes

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8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.1 | RECOGNITION

8.1.1.1 | PAT – PLACE ATTACHMENT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.1.1 | PAT – Place attachment**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Recognition furthermore includes **place attachment** which refers to the emotional and symbolic relationship that people have with a place. It addresses how people value particular places (and our interest would be how NBS interventions interfere with these valuations, e.g. in a positive or negative sense and with differences between groups in this). The focus can be on the level of the individual/personal or more on the social (community) level of place attachment. Yet another focus is on how a physical environment shapes place bonds (environmental identity and connectedness to nature). Meanings attributed can be gathered and analysed using e.g. storytelling, participatory methods, photo-based methods, psychometric scaling (Raymond 2017b). Learning about diverse place attachments is relevant to take into account when NBS interventions affect these places. Love for nature can be measured with the <u>Connectedness to Nature Scale</u> (Mayer et al., 2004).
FOCUS/ OBJECTIVES	• <u>In evaluating the process of realising an NBS:</u> attention to (diverse) meanings (and emotions) related to the place where this NBS has been realised • <u>In assessing the impact of an NBS</u>, addressing how it affects (improves, strengthens) the meaningfulness of this place for diverse groups in positive manners. • <u>With regard to further maintenance of the NBS</u>: ensuring that this is organised in line with identified meanings (which can result in e.g. letting local residents take up a role in this maintenance)

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	Data on diverse (symbolic) meaning and emotions people have in relation to this specific place. Information about the process preceding the realisation of this NBS Information on how this NBS can/does (cannot/does not) align with meanings and emotions people have**.**
INPUT TYPE (QUALITATIVE, QUANTITATIVE, …)	- Quantified data on socio-economic demographics of stakeholder and target groups; quantified data to reveal intensity of place bonds. - Information on the procedures - Qualitative information on the process in which place attachments evolve (acknowledging that these are not static)
DATA SOURCE	- Socio-economic and demographic information (e.g. existing databases) - Case-reports written based on data collected in interviews, surveys, storytelling, diaries, Q-sort, (participant) observation workshops and/or other participatory methods to collect peoples' accounts.
FREQUENCY (HOW OFTEN TO USE THIS INDICATOR?)	Depending on the specific situation and the exact question, it could address the process of the design phase of urban planning, decision-making, implementation, maintenance and evaluation.
MEASURMENT UNIT	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses. The particular focus will impact the methods adopted.
REQUIRED TOOL	*(For a discussion about methodological discussions and differences we refer to Brown et al 2015)*. - Analytic tools to see how the diversity in the process matches the diversity identified based on socio-demographic data (e.g. using GIS and maps); - Public participation GIS (PPGIS) methods - Data collecting and analysis procedures: interviews, surveys, storytelling, diaries, Q-sort, (participant) observation workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis. - Methods like Empathy Quotient (a self-report scale that looks at cognitive empathy, emotional reactivity and social skills). -Love for nature can be measured with the Connectedness to Nature Scale
CALCULATION METHOD	n/a

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OUTPUT TYPE	Assessment of inclusion of diversity in meanings attached to this place in the process towards realising this NBS. Assessment of how this NBS matches with these meanings, emotions. Potentially: ideas regarding the maintenance (and improvement) of this NBS in line with/to strengthen place attachment.
EXAMPLES	(Brown, Raymond and Corcoran 2015)

LINKS AND REFERENCES	
KEYWORDS	• Place • Meaning • Emotion • Identity • Community • Belongingness • empathy
LINKS AND REFERENCES	• Brown, Raymond and Corcoran 2015 • Hernández, B., Carmen Hidalgo, M., Salazar-Laplace, M. E., & Hess, S. (2007). Place attachment and place identity in natives and non-natives. Journal of Environmental Psychology, 27(4), 310-319. https://doi.org/10.1016/j.jenvp.2007.06.003 • Mayer, F.S., & Frantz, C.M. (2004). The connectedness to nature scale: a measure of individuals' feeling in community with nature. *Journal of Environmental Psychology, 24*, 503-515. Doi: 10.1016/j.jenvp.2004.10.001 • Raymond et al 2017b:36; • Williams, D. R., & Vaske, J. J. (2003). The measurement of place attachment : validity and generalizability of a psychometric approach. Forest Science, 49(6), 830-840

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8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.1 | RECOGNITION

8.1.1.2 | BIN – BODILY INTEGRITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.1.2 | BIN - Bodily integrity**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Attention for diversity and vulnerable groups furthermore points attention towards bodily integrity. The ability to move freely from place to place and to be secure against violent assault is something that can be affected both positively or negatively by NBS.
FOCUS/OBJECTIVES	• In evaluating the process of realising an NBS: attention that has been awarded to (perceived) levels of safety and potential influences of this NBS • In assessing the impact of an NBS, addressing how it affects (changes in) (perceived) levels of safety and ability to move around freely. • With regard to further maintenance of the NBS: ensuring that this is organised such that it contributes positively to perceptions and feelings of bodily integrity

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	Data on crime in relation to place and time of day. Data on diverse perceptions of safety among different groups (e.g. young; old; gender; different migrant backgrounds etc). Information about the process preceding the realisation of this NBS Information on how safety has been taken into account in the design and realisation.
INPUT TYPE (QUALITATIVE, QUANTITATIVE, …)	- Quantified data on crime and safety - Qualitative information on the process and outcome with attention to safety issues
DATA SOURCE	- Socio-economic and demographic information (e.g. existing databases) - Case-reports written based on data collection in interviews, surveys, storytelling, diaries, Q-sort, (participant) observation workshops and/or other participatory methods to collect peoples' accounts.
FREQUENCY (HOW OFTEN TO USE THIS INDICATOR?)	Depending on the specific situation and the exact question, it could address the process of the design phase of urban planning, decision-making, implementation, maintenance and evaluation.
MEASURMENT UNIT	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses.
REQUIRED TOOL	- Existing database that includes data on safety for geographic locations and which addresses time-of-day/night issues as well - Data collecting and analysis procedures: interviews, surveys, storytelling, diaries, Q-sort, (participant) observation workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis.
CALCULATION METHOD	n/a
OUTPUT TYPE	Assessment of attention to safety issues in the process towards realising this NBS. Assessment of how this NBS affects existing feelings of safety and how it invites more/less crime Potentially: ideas regarding the maintenance (and improvement) of this NBS to enhance its effect in terms of safety improvement
EXAMPLES	e.g. Case study Szeged for N4C – decisions to not use bushes because of safety issues

LINKS AND REFERENCES	
KEYWORDS	• Safety • bodily integrity • crime • assault
LINKS AND REFERENCES	• (Raymond et al 2017b)

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8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.1 | RECOGNITION

8.1.1.3 | AES – AVAILABILITY ES

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.1.3 | AES - Availability ES**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator addresses the cultural ecosystem services as cultural benefits that can be obtained from NBS interventions, e.g. recreational, spiritual, religious and other nonmaterial benefits. In relation to a specific NBS development, questions can be posed regarding benefits from enhanced opportunities for outdoor activities (e.g. walking, cycling); from access to knowledge about nature and environment; and benefits from access to recreational places that are in line with local needs (e.g. extent to which the NBS fits with local needs)
FOCUS/OBJECTIVES	• In evaluating the process of realising an NBS:, attention to diverse cultural ES that are implicated in the realisation of this NBS • In assessing the impact of an NBS, addressing how it affects enhanced availability of cultural ES for diverse users • With regard to further maintenance of the NBS: address how this affects ES availability

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASURMENT	
REQUIRED DATA	• Data on the type and quality (in terms of providing cultural ES) of green spaces • Diverse perspectives on the nonmaterial qualities of NBS for different groups • The diverse impacts this specific NBS has in terms of cultural ES
INPUT TYPE (QUALITATIVE, QUANTITATIVE, …)	• Quantitative • Qualitative data
DATA SOURCE	• E.g. Millennium Ecosystem Assessment (https://www.millenniumassessment.org/en/index.html • Public Participation Geographic Information Systems (PPGIS) (gathers data about the places people go to and their appreciation of these places) • Governmental statistics • GIS and maps with relevant data • Reports from surveys/interview; focus groups; workshops etc.
FREQUENCY (HOW OFTEN TO USE THIS INDICATOR?)	Depending on the specific situation, in the concept and detailed design phase of urban planning, as well as during implementation, maintenance and evaluation.
MEASURMENT UNIT	Individual as well as group level perspectives, opinions, understandings.
REQUIRED TOOL	• Deskstudy • GIS analysis • Data collecting and analysis procedures: interviews, surveys, storytelling, diaries, (participant) observation, workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis.
CALCULATION METHOD	n/a
OUTPUT TYPE	- Valuation of ES that the NBS provides - Maps showing distributional patterns of (access) to different types of cultural ES for diverse groups
EXAMPLES	Raymond et al 2017a; b

LINKS AND REFERENCES	
KEYWORDS	• Cultural ecosystem services • co-benefits • recreation • nonmaterial benefits
LINKS AND REFERENCES	• Raymond et al., 2017b

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8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.2 | PJU – PROCEDURAL JUSTICE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.2 | PJU - Procedural justice**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Procedural justice is about being able to participate effectively and meaningfully in political choices that govern one's life (and one's direct living and working environment). Procedural justice relates to the clarity and transparency of the rules that govern (participatory) processes and thus affects the extent to which a process in considered fair. Procedural justice refers to the quality of the participatory process, as it entails that the goal and the extent of the participation are made clear to all participants, and that clarity is provided about how diverse inputs from participants to process are going to be used. Attention is needed for: • The clarity and transparency of the procedures (rules of the game) and the extent to which stakeholders (including citizens) find these acceptable • The extent to which it is clear what the aim of the participation is (e.g. informing, consultation, co-production etc --- ladder of Arnstein (1968). • The extent to which it is clear to people how the input they provide during the participatory process will be used and that they will be provided with feedback on that. As an example, one may witness a rather limited participation (e.g. only consultation about a ready-made plan for an NBS) which is nevertheless considered fair because the above-mentioned criteria are met. The other way around, a very extensive participation trajectory can still be regarded as unfair due to a lack of clarity on the rules of the game – e.g. if the ideas provided by

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	participants are not used at all while the expectation was that these ideas were going to be used).
FOCUS/ OBJECTIVES	• In evaluating the process of realising an NBS:, assessing to what extent the procedures or rules of the game have been timely publicised, clarified to and shared with all stakeholders and (potential) participants to process. (with attention to whether this information was easily available and accessible) • In assessing the impact of a realised NBS, assessing to what extent the process towards realising this NBS has been considered as 'fair' by relevant stakeholders and how this NBS • With regard to further maintenance of the NBS: ensuring clarity and transparency with regard to the process of maintenance of the NBS Procedural justice can enhance acceptance and commitment to an NBS and it can help ensure future good relationships between all stakeholders involved (as a result of perception of fairness in the process); furthermore, it can contribute to outcomes (NBS) that reflect the inclusion of local and situated knowledge in the design of the (NBS) solution (hence contributing to NBS solutions that are better tailored to their context).

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	- Perceptions of fairness of process among participants and stakeholders - Data on the procedures and process history - Information on the transparency, quality and accessibility of the information about the planning and decision-making processes.
INPUT TYPE (qualitative, quantitative, …)	Quantitative (quantification of diverse types of perspectives) Qualitative input – e.g. descriptions of the formal procedures; informal process and stakeholder views
DATA SOURCE	- Writings on the formal and informal institutional setting (e.g. planning and decision-making procedures), e.g. (g.g. the OGP-reports (https://www.opengovpartnership.org/) in combination with local monitoring. (OGP provides an international platform striving at more open, accountable and responsive governments) - Socio-economic and demographic information (e.g. existing databases) - Reports written based on interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts.
FREQUENCY (how often to use this indicator?)	Depending on the specific situation, in the concept and detailed design phase of urban planning, as well as during implementation, maintenance and evaluation.
MEASURMENT UNIT	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses;

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REQUIRED TOOL	- Desk/document-study.; e.g. institutional analysis (formal and informal planning and decision making procedures in a given context) - Data collecting and analysis procedures like interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis.
CALCULATION METHOD	
OUTPUT TYPE	Overview of how the process/procedure around an NBS has been organised and how it is viewed by various stakeholders in terms of access to information, transparency, accountability and legitimacy of outcomes; perceived fairness of process (can be at different scale levels) Understanding of how the appreciation of the NBS relates to the appreciation of the process
EXAMPLES	Gross 2008;

LINKS AND REFERENCES	
KEYWORDS	• Procedural justice • Fairness • Legitimacy • Accountability • meaningful participation • transparency • access to information
LINKS AND REFERENCES	• Bell and Davoudi, 2016 • Gross, 2008 • Kabish et al 2016 • Raymond et al 2017a;b • Schlosbert 2004

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8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.3 | DJU – DISTRIBUTIONAL JUSTICE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	**8 | Environmental justice and social cohesion**	**8.1 | Environmental justice**

INDICATOR	
NAME	**8.1.3 | DJU - Distributional justice**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Distribution refers to the distribution of *environmental goods* and -*bads* across time, space and social groups.
FOCUS/OBJECTIVES	• <u>In evaluating the process of realising an NBS:</u> having ensured an equitable distribution of co-benefits and -costs, and ensuring that existing unequal distributions are not exacerbated. Particular attention is to be paid to already existing distributions and to known intended or unintended consequences of NBS interventions like e.g. gentrification • <u>In assessing the impact of a realised NBS:</u> assessing how this NBS and the (co-)benefits and costs that this NBS generates accrue to diverse (social) groups and stakeholders and assessing the impact in terms of changing existing unequal distributions (e.g. with attention well as gentrification) • <u>With regard to further maintenance of the NBS:</u> ensuring that distributional impacts are taken into account in and continue to be taken into account

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	Data on inequalities before, during and after the NBS intervention. Stakeholder perspectives on costs and benefits
INPUT TYPE (QUALITATIVE, QUANTITATIVE, …)	Quantitative Qualitative
DATA SOURCE	-Socio-economic and demographic information over time (e.g. existing databases) - Reports written based on interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts.
FREQUENCY (HOW OFTEN TO USE THIS INDICATOR?)	Depending on the specific situation, in the concept and detailed design phase of urban planning, as well as during implementation, maintenance and evaluation.
MEASURMENT UNIT	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses;
REQUIRED TOOL	- Desk/document-study - Data collecting and analysis procedures like interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis.
CALCULATION METHOD	n/a
FORMULA	n/a
OUTPUT TYPE	- Overview of how the process/procedure around an NBS has been organised and how it is viewed by various stakeholders in terms of (un)equal distribution of benefits and cost - Understanding how the planning, implementation and maintenance of this NBS affects inequalities and the possibilities to decrease these
EXAMPLES	Breukers et al 2017

LINKS AND REFERENCES	
KEYWORDS	• Distribution • Inequalities • co-benefits • costs • trade-off
LINKS AND REFERENCES	• Bell and Davoudi 2016 • Schlosberg 2004;

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8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.3 | DISTRIBUTIONAL JUSTICE

8.1.3.1 | GEN – GENTRIFICATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.3.1 | GEN - Gentrification**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Distribution refers to the distribution of *environmental goods* and - *bads* across time, space and social groups. When, as a result of NBS interventions, the distribution turns out unfavourable for those already vulnerable, to the extent of resulting in displacement, then a process of environmental gentrification is taking place. It is characterised by the coming together of several trends, policies and (market) mechanisms and may or may not be the intention of those that initiated the NBS. NBS interventions, while contributing to climate change adaptation or mitigation, the resulting increased attractiveness of the area can also lead to (or strengthen existing trends of) land price increase, increases in rent or an increase in private owned homes versus social housing. This can result in displacement, whereby those displaced also miss out on the benefits that the enhance natural solutions offer (Kabisch et al 2016). Gentrification has in fact been described as an unintended consequence of environmental justice activism, whereby the push for sustainability has been such that it has for instance benefited real estate developers trying to increase the value of their properties at the cost of low-income residents that have been displaced. As such, NBS can result in a more inequitable distribution of goods and bads (Checker 2011).
FOCUS/ OBJECTIVES	• <u>In evaluating the process of realising an NBS:</u> having ensured an equitable distribution of co-benefits and –costs on the short and longer term, and ensuring that existing unequal distributions are not exacerbated – esp. those relating to e.g. gentrification • <u>In assessing the impact of a realised NBS:</u> assessing how this NBS and the (co-)benefits and costs that this NBS generates has impacts in terms of increasing existing unequal distributions (risks on trade-offs)

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	• With regard to further maintenance of the NBS: ensuring that distributional impacts are taken into account in and continue to be taken into account in the maintenance

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	- Data on inequalities before, during and after the NBS intervention. - Longitudinal data on socio-demographic changes; economic and other trends (e.g. in real estate developments; land prices; housing developments) - Data on perceived changes in the neighbourhood(s); city etc.
INPUT TYPE (qualitative, quantitative, …)	Quantitative Qualitative
DATA SOURCE	-Socio-economic and demographic information over time (e.g. existing databases), e.g. in combination with GIS and maps - Reports written based on interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts.
FREQUENCY (how often to use this indicator?)	Depending on the specific situation, in the concept and detailed design phase of urban planning, as well as during implementation, maintenance and evaluation.
MEASURMENT UNIT	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses;
REQUIRED TOOL	- Desk/document-study - Data collecting and analysis procedures like interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis. - GIS and mapping
CALCULATION METHOD	n/a
OUTPUT TYPE	- Overview of how the process/procedure around an NBS has been organised and how it is viewed by various stakeholders in terms of causing/strengthening gentrification - Understand to what extent (potential) gentrification is intentional/desired and by which stakeholders (understand differences in interests, in power and the political nature of the process) - Understanding how the planning, implementation and maintenance of this NBS affects gentrification and possibilities to counter this
EXAMPLES	Checker 2011;

LINKS AND REFERENCES	
KEYWORDS	• Gentrification • Displacement • Inequality • distribution

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LINKS AND REFERENCES	• Checker 2011 • Kabish et al 2016 • Raymond et al 2017a & b

8.1.4 | CAP

8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.4 | CAP – CAPABILITIES

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.4 | CAP - CAPABILITIES**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator addresses the extent to which capabilities and resources are sufficiently present among stakeholders (including citizens; residents; end-users) to be able to voice concerns and/or to participate, and to shape their own lives in accordance to their needs and ambitions. Having access to resources (time, money, knowledge, means of transport, skills) and about knowing how to use these resources, which translates into certain abilities. These are the ability: • to voice concerns • to initiate actions • to collaborate • to participate in discussions/negotiations Being free of financial concerns (related to indebtedness), but also being able to access and understand the information provided (about the NBS, about the process), having/being able to acquire the skills to participate in discussion about the process or the NBS, distance to the venues where discussions take place (ability to travel), time and timing (e.g. not receiving information very late).It is also about being able to use the senses, to imagine, think, and reason about environmental qualities (in relation to local quality of place).
FOCUS/ OBJECTIVES	• In evaluating the process of realising an NBS: having ensured that all stakeholders and participants to the process have been enabled/empowered to fulfil this role (e.g. by providing understandable and accessible information in time; by ensuring that the discussions respect difference; by providing support, training and coaching if needed in order to enable those not used to these processes to participate; by using not only text and words, but also images and visualisations, stories etc; by choosing a venue that is inviting).

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	- <u>In assessing the impact of a realised NBS:</u> assessing to what extent this NBS has any impact on existing capabilities in its direct environment, i.e. how this NBS supports people and communities to shape their own lives and flourish - <u>With regard to further maintenance of the NBS:</u> ensuring that those interested in maintenance receive sufficient support and coaching to fulfil this role

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASURMENT	
REQUIRED DATA	Qualitative data that indicate how people are able to use resources at their disposal. Data on income, indebtedness and access to financial support; education levels; knowledge (incl. situated and experiential) and skills; time (or willingness to spend time)
INPUT TYPE (qualitative, quantitative, …)	-Socio-economic and demographic information over time (e.g. existing databases) - Reports written based on interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts.
DATA SOURCE	Depending on the specific situation, in the concept and detailed design phase of urban planning, as well as during implementation, maintenance and evaluation.
FREQUENCY (how often to use this indicator?)	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses;
MEASURMENT UNIT	
REQUIRED TOOL	- Desk/document-study - Data collecting and analysis procedures: procedures like interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis.
CALCULATION METHOD	n/a
OUTPUT TYPE	- Understanding how to empower people so that they are able to voice their concerns, to initiate action, to collaborate and to participate in discussions/negotiations - Understanding how NBS interventions can be used to enhance capabilities - Enable people to enjoy NBS (e.g. through training; education; engagement)
EXAMPLES	

LINKS AND REFERENCES	
KEYWORDS	- Capabilities - Empowerment - Knowledge - Skills

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	• training
LINKS AND REFERENCES	• Davoudi and Brooks, 2014

8.1.5 | RES

8 | ENV. JUSTICE AND SOCIAL COHESION

8.1 | ENVIRONMENTAL JUSTICE

8.1.5 | RES – RESPONSIBILITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.1 | Environmental justice

INDICATOR	
NAME	**8.1.5 | RES - Responsibility**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	**Responsibility** refers to the role stakeholders can and want to adopt at individual or collective levels, and this is affected by e.g. institutional context, physical and mental abilities, social norms and cultural values (Davoudi and Brooks 2014). In relation to the realisation and maintenance of NBS, we can ask how people have assumed responsibility and how they (and who) have allocated responsibilities to others. For instance, there can be expectations that people in a neighbourhood adopt responsibility to maintain an NBS, but this may not match with the ideas that those people have themselves (e.g. they may think that that is a task for the municipality).
FOCUS/OBJECTIVES	• In evaluating the process of realising an NBS: having ensured that in the process towards this NBS, people have had the choice to take the responsibility that they saw fit for themselves (enabling people to take responsibility rather than top-down allocation of responsibilities); having ensured that attention is paid to the different responsibilities people can and are willing to take involving NBS and green spaces; and having had room to discuss and negotiate the distribution of responsibilities • In assessing the impact of an NBS: assessing what responsibilities people have adopted and how. • With regard to further maintenance of the NBS: ensuring that those involved in the further maintenance of the NBS have chosen to be involved (rather than being allocated this responsibility).

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASURMENT	
REQUIRED DATA	Perceived constraints (e.g. lack in knowledge, experience, skills; or certain vulnerabilities or values that affect ability to adopt responsibility (Differences in) perspectives regarding who should do what and why
INPUT TYPE (QUALITATIVE, QUANTITATIVE, …)	• Reports written based interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts.
DATA SOURCE	Depending on the specific situation, in the concept and detailed design phase of urban planning, as well as during implementation, maintenance and evaluation.
FREQUENCY (HOW OFTEN TO USE THIS INDICATOR?)	Unit of analysis can be the individual and individual perspectives; or social groups; socially shared accounts/discourses;
MEASURMENT UNIT	
REQUIRED TOOL	- Data collecting and analysis procedures like interviews, surveys, focus groups or group discussion-reports; storytelling, diaries; (participant) observation; workshops and/or other participatory methods to collect peoples' accounts and corresponding methods of analysis.
CALCULATION METHOD	n/a
OUTPUT TYPE	- Understanding different perspectives on responsibility in relation to green spaces and NBS - Understanding how to enable the adoption of responsibilities (i.e. build capacities)
EXAMPLES	

LINKS AND REFERENCES	
KEYWORDS	Responsibility; choice; cultural values
LINKS AND REFERENCES	Davoudi and Brooks, 2014

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8 | ENV. JUSTICE AND SOCIAL COHESION

8.2 | SOCIAL COHESION

Short description of USC: The concept of social cohesion has no single straightforward definition and the ambiguity of the concept is widely acknowledged (see Jenson 2012 for a historical introduction to the concept). Social cohesion is a multiscalar concept (Jenson 2012) and indicators reflect local level rather than national level had been chosen.

8.2.1 | SCA – SOCIAL CAPITAL

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	8 | Environmental justice and social cohesion	8.2 | Social cohesion

INDICATOR	
NAME	**8.2.1 | SCA - SOCIAL CAPITAL**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	*Social capital: how has this NBS influenced peoples' social capital? But also: how does the existing social capital affect how well people have been able to (choose how to) participate/influence the process of implementing this NBS?* The concept of social cohesion has no single straightforward definition that is shared by all and the ambiguity of the concept is widely acknowledged (see Jenson 2012 for a historical introduction to the concept). It is good to keep in mind that in terms of definition and in terms of methodology suggested, other options are possible as well. Social cohesion is a multiscalar concept (Jenson 2012). NBS planning has a focus on local communities and cities. Therefore indicators that reflect local level rather than national level is chosen. In this context, Regina Berger-Schmitt (2002) decomposed the concept of social cohesion into two dimensions of inequality and social capital. As the issue of (environmental) justice is addressed already above the focus her will be on social capital dimension as the main indicator. Social capital refers to the value that social networks have (to those that are part and to those that are bystanders (Putnam in Jenson 2012:9). Empowerment, participation, associational activity and common purpose, supporting networks and reciprocity, collective norms and values, trust, safety and belonging are domains of social capital at the neighbourhood level (Forrest and Kearns 2001). These domains must be examined in order to understand the level of social cohesion at the local level.
FOCUS/ OBJECTIVES	• <u>In evaluating the process of realising an NBS:</u> having ensured that in the process towards this NBS, attention is paid to the various aspects/domains of social capital so that social cohesion improves in

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	the process of realising an NBS • In assessing the impact of an NBS: assessing how it further supports and improves social capital (e.g. consider collaboration; feelings of safety; feelings of belonging, an NBS as a local meeting point) • With regard to further maintenance of the NBS: ensuring that social cohesion is maintained of further strengthened in the maintenance of the NBS (e.g. NBS maintenance as empowerment; collective action; enhancing feelings of belonging and integration in the local community)

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASURMENT	
REQUIRED DATA	Empowerment: ● People in our neighbourhood (or city, NBS context) have a voice which is listened to. ● People in our neighbourhood (or city, NBS context) are involed in processes that affect them. ● People in our neighbourhood (or city, NBS context) can take action to initiate change. Participation ● People take part in social and community activities in our (or city, NBS context). ● In this neighbourhood (or city, NBS context) local events occur and are well attended. Associational activity and Common Purpose • In this neighbourhood (or city, NBS context), people co-operate with one another through the formation of formal and informal groups to further their interests. Supporting networks and reciprocity ● In this neighbourhood (or city, NBS context) individuals and organizations co-operate to support one another for either mutual or one-sided gain. ● In this neighbourhood (or city, NBS context), an expectation that help would be given to or received from others when needed. Collective norms and values ● In this neighbourhood (or city, NBS context), people share common values and norms of behaviour. Trust ● In this neighbourhood (or city, NBS context), people feel they can trust their co-residents ● In this neighbourhood (or city, NBS context), people feel they can trust local organizations responsible for governing or serving their area. Belonging ● In this neighbourhood (or city, NBS context), people feel connected to their co-residents. ● In this neighbourhood (or city, NBS context), people feel connected to their home area

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	• In this neighbourhood (or city, NBS context),people have a sense of belonging to the place and its people. Safety • In this neighbourhood (or city, NBS context), people feel safe • In this neighbourhood (or city, NBS context), I do not feel restricted in their use of public space by fear. Note: See Forrest and Kearns (2001) for the questionnaire
INPUT TYPE (qualitative, quantitative, …)	Quantitative
DATA SOURCE	Survey
FREQUENCY (how often to use this indicator?)	Annually
MEASURMENT UNIT	Likert Scale
REQUIRED TOOL	Questionnaire
CALCULATION METHOD	Average counts for different domains.
OUTPUT TYPE	Assessment of social cohesion in a neighbourhood
EXAMPLES	• Forrest and Kearns, 2001 • Jane, 2012 • Berger-Schmitt 2002

LINKS AND REFERENCES

KEYWORDS	• Social cohesion • social capital • empowerment • participation • associational activity and common purpose • supporting networks and reciprocity • collective norms and values, • trust • belonging • safety (indicator for safety is given under people's security section)
LINKS AND REFERENCES	• Forrest and Kearns, 2001 • Jane, 2012 • Berger-Schmitt 2002

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UC 9 | URBAN PLANNING AND GOVERNANCE

9.1.1 | AS

9 | URBAN PLANNING AND GOVERNANCE

Short description of UC: The challenge of urban planning is all about triggering new solutions for sustainable and liveable urban environment. Urban planning addresses several issues faced in the cities: environmental, societal and economic issues too.
The objective of the challenge Urban Planning and Governance is to evaluate the effectiveness of using nature-based solutions when tackling the challeges of Urban Planning and Governance.

9.1 | URBAN PLANNING AND FORM

Short description of USC: Urban planning addresses a lot of environmental issues: such as the quality of built environment, infrastructure needs, energy supply, food security, water and waste management. They are issues addressed in other urban challenges in this framework. In this UC, we focus on urban form as a result of urban planning. Urban form is defined as the physical characteristics that make up built-up areas, including the shape, size, density and configuration of settlements. However, this is a constantly developing circumstance.

9.1.1 | AS – AREAL SPRAWL

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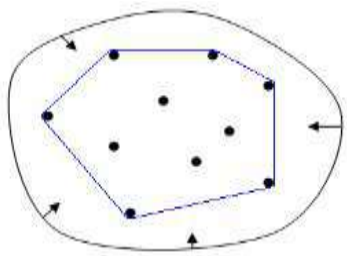
Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.1 | Urban planning and form

INDICATOR	
NAME	9.1.1 | AS - Areal Sprawl
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DESCRIPTION	Areal sprawl is the territorial aspect of several urban transitions. According to literature (Speck, 2013; Saelens et al. 2003.) the planning of city centres can avoid areal sprawl. If downtown is liveable, less people will tend to move to the outskirts of the city and undertake the burden of daily commute for the desired quality of their place of residence. Nature-based solutions are highly relevant from compact urban form point of view. Compactness can be also achieved with the balanced availability of green spaces and ecosystem services. In addition, unrestricted urban sprawl endangers natural environment around the city and the protective zones that mitigates the intensity of urban heat island. (See converting a forest into a parking lot of a shopping mall.) Areal sprawl indicator describes the level of compactness of a city, as the ratio between total building floor area to the area of the convex hull of the built space.  The convex hull of a set of points is the minimal convex envelope that contains those points. Computing this shape gives a fair ground to compare different cities or neighbourhoods, and a closer approximation to the actual built density.

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OBJECTIVES	• understand the severity of the sprawl of a city • assess the effect of different kinds of NBS within the city or around it on urban form. • to preserve the connectivity of green spaces around the city • protecting green belt around the city.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASURMENT	
REQUIRED DATA	• total floor area of buildings. If this is impossible to acquire directly it can be approximately calculated knowing the ground area of buildings and their heights. • To assess the impact of a future project, a tool that simulates urban evolution is needed.
TYPE OF DATA	• Geometric georeferenced data
SOURCE	• Municipality databases • Open sources like Open Street Map
FREQUENCY	Low frequency - yearly, in order to let slow sensible changes in the urban form happen
MEASURMENT UNIT	m^2 / m^2 (or m^3/m^2)
REQUIRED TOOL	• convex hull surface calculation software or library, like: Shapely, SciPy
CALCULATION METHOD	• computation of convex hull • collection or calculation of total floor area • ratio $\mathrm{Conv}(S) = \left\{ \sum_{i=1}^{\lvert S \rvert} \alpha_i x_i \,\middle\vert\, (\forall i : \alpha_i \geq 0) \wedge \sum_{i=1}^{\lvert S \rvert} \alpha_i = 1 \right\}.$ General formula for a convex hull $AS = A_{\text{convex hull}}/A_{\text{built space}}$
OUTPUT	• numerical value

LINKS AND REFERENCES	
KEYWORDS	• SPRAWL • CONVEX HULL • DENSITY • BUILT SPACE
LINKS AND REFERENCES	• Skiena, S. S. "Convex Hull." §8.6.2 in The Algorithm Design Manual. New York: Springer-Verlag, pp. 351-354, 1997. • http://mathworld.wolfram.com/ConvexHull.html • SPECK, Jeff (2013). Walkable City: How Downtown Can Save America, One Step at a Time. North Point Press • Saelens et al. 2003. Environmental Correlates of Walking and Cycling: Findings From the Transportation, Urban Design, and Planning Literatures"

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.1 | Urban planning and form

INDICATOR	
NAME	9.1.1 | AS - Areal Sprawl

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial conditions of the urban fabric.
R2: Policy support for policies:	No but the issue of urban sprawl has been tackled for example in Germany and UK with methodologies that implicitly follow the criterion. The use of 'green belts' regardless of administrative boundaries and the tendency to convert brownfields (disused industrial sites) aim to not cross the consolidated built city boundary
R3: Comparability:	Yes, it is possible and highly recommended to compare it to existing measures like population density and soil consumption.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	It can be used after minimal explanation. The concept of total floor area against the convex hull area of a city can be translated roughly as built "volume" against the city size. This can be related to popular concepts as demographic density.
A3: Other stakeholders:	No

CREDIBLE	
C1: Unambiguous results:	Yes it is unambiguous, and it relates to the decision of policy makers. Concepts like soil consumption and human density to which the areal sprawl relates are relatively known by the general public
C2: Transparency:	Yes, it has a clear mathematical methodology.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed Assessing future plans implies city evolution simulations that may rely on assumption that are more difficult to set.

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EASY	
E1: Availability of data to calculate the indicator:	Yes, for initial case virtually all municipalities have vector data of buildings. There are also open source datasets available, like Open Street Map Generally they are much quicker to register changes and updates since their crowd sourced nature, but they suffer from possible mismatches and empty areas where there is not an active user base. Municipalities often load their data (i.e., Liguria region in Italy has uploaded buildings shapes). To assess the impact of NBS such as green belt or large parks, the difficulty is to foresee attractiveness and it's impact on urban form.
E2: Technical feasibility:	No, but a simple software interface to calculation libraries could fill this gap.
R3: Reproducibility:	Yes. It can be used as a comparative indicator of different situation or solutions.

ROBUST	
R1: Data quality:	Yes.
R5: Sensitiveness:	No, to the best of our knowledge.
R8: Scale:	Yes, depending on the target of the calculation. It can be an entire city or sometimes a neighbourhood.

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9 | URBAN PLANNING AND GOVERNANCE

9.1 | URBAN PLANNING AND FORM

9.1.2 | BN – BETWEENNESS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.1 | Urban planning and form

INDICATOR	
NAME	**9.1.2 | BN – Betweenness**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DESCRIPTION	The computation of betweenness centrality in urban green networks needs a representation of the city street network as graph. The edges of a graph represent the streets, while the nodes represent the intersections and NBSs. The weight of an edge is the actual distance between two nodes. The graph can be *undirected* for the modelling of pedestrian fluxes, and *directed* in for vehicular traffic. The betweenness centrality is a mathematical concept of graph theory. It can be measured for a node or an edge, and quantifies the number of times a node or an edge acts as a link in the shortest path between two other green areas with certain size. This can be used to assess the importance of streets and connections in the urban green environment, and to detect missing links as well. It needs a representation of the urban green network as a graph, an abstract structure that sums up the relation between objects disregarding their actual physical appearance. An NBS that actively changes the physical communication network would affect the pedestrian flows, with repercussions or benefits to economic activities in the area nearby, and conversely on a social level. Dismissed tramway tracks converted in a walkway would radically change the connectivity of an area, turning from a barrier with some chokepoints to a connective space with green areas.
OBJECTIVES	• Understand and take into consideration the spatial organization of at least neighbourhood scale NBSs in urban fabric. • Highlight the weak and strong points of the urban green network.

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LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASURMENT	
REQUIRED DATA	• Urban graph: an abstract representation of the street networks of a city or neighbourhood, where the links between green spaces and NBSs with certain minimum area represented by streets and nodes
TYPE OF DATA	• Topological georeferenced data
SOURCE	• Municipality databases • Open sources like Open Street Map • Proprietary sources like Google, TomTom etc.
FREQUENCY	Low frequency - yearly, in order to let slow sensible changes in the urban form happen. For
MEASURMENT UNIT	dimensionless
REQUIRED TOOL	• Graph representation and centrality computation software or library, like: Osmnx, NetworkX, GraphTool, BoostGraph.
CALCULATION METHOD	• representation of urban fabric as a weighted graph • computation of betweenness centrality The betweenness centrality of a node *v* is the sum, on every couple of nodes (*s*,*t*), of the ratios between the number of shortest paths, between those two nodes *s* and *t*, passing through the node *v* and the total number of shortest paths between *s* and *t*. $C_b(v) = \sum_{s \neq t \neq v \in V} \frac{\sigma_{st}(v)}{\sigma_{st}} (1)$ where $C_b(v)$ is the betweenness centrality for the v node $\sigma_{st}(v)$ is the sum of shortest paths between two nodes s and t passing through v σ_{st} is the total number of shortest paths in the graph between s and t. This can be calculated for edges (i.e. streets) too. $C_b(a)$ is the betweenness of an edge. The formula is virtually the same, but the path has to pass through the entire edge and not just through a node. $C_b(a) = \sum_{(s,t) \neq a} \frac{\sigma_{st}(v)}{\sigma_{st}}$ In graphs representing urban networks, it could be more convenient to use a special case of the betweenness centrality, called stress centrality $C_s(v)$, which does not account for equivalent shortest paths since in most urban context given two nodes there is only one.

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	$C_s(v) = \sum_{s \neq t \neq v \in V} \sigma_{st}(v)$ (2)
OUTPUT	• numerical value

LINKS AND REFERENCES	
KEYWORDS	• GRAPH • CENTRALITY • BETWEENNESS • SPACIAL ORGANIZATION
LINKS AND REFERENCES	• Freeman, Linton (1977). "A set of measures of centrality based on betweenness". *Sociometry*.**40**: 35–41. doi:10.2307/3033543. • BARABÁSI, Albert-László. Network science book. Boston, MA: Center for Complex Network, Northeastern University. Available online at: http://barabasi. com/networksciencebook, 2014. • Swyngedouw, E. and Kaika, M. (2003) The Environment of the City… or the Urbanization of Nature, in A Companion to the City (eds G. Bridge and S. Watson), Blackwell Publishing Ltd, Oxford, UK. doi: 10.1002/9780470693414.ch47 • Jeff Speck: Walkable City, North Point Press, 2013. • Andrés Duany, Jeff Speck, Mike Lydon: The Smart Growth Manual, McGraw-Hill Education, 2009.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.1 | Urban planning and form

INDICATOR	
NAME	9.1.2 | BN - Betweenness

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe the current conditions of the urban connectivity, possibly on pedestrian and vehicular scopes.
R2: Policy support for policies:	No
R3: Comparability:	Not directly, but it can be correlated to traffic intensity data, or to identify both central and disconnected areas. It is a measure that strongly depends on the observed context.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	It requires some kind of training but it can be related to generally known concept such as congestion.
A3: Other stakeholders:	Yes, applied to urban environments, social networks and web analysis.

CREDIBLE	
C1: Unambiguous results:	Not generally. The measure has to be used within a specific context, since it carries a relative value. Comparing two values makes sense only within the same computation batch.
C2: Transparency:	Yes, it has a clear mathematical methodology.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

EASY	
E1: Availability of data to calculate the indicator:	Yes, virtually all municipalities have vector data of the street networks. Open sources like Open street Map are excellent on both pedestrian and vehicular networks. Proprietary sources like TomTom and Google are available too.
E2: Technical feasibility:	No, but a simple software interface could fill this gap. Computational burden is relevant.
R3: Reproducibility:	Yes. It can be used as a comparative indicator of different situation or solutions.

ROBUST	
R1: Data quality:	Yes.
R5: Sensitiveness:	No, this is an exact method
R8: Scale:	Yes

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9 | URBAN PLANNING AND GOVERNANCE

9.1 | URBAN PLANNING AND FORM

9.1.3 | ACC – ACCESSIBILITY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.1 | Urban planning and form

INDICATOR	
NAME	**9.1.3 | ACC - Accessibility**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☐ Object
DESCRIPTION	Accessibility is an indicator describing the quality of a particular entity of being reached. In this case accessibility is measured referring to green spaces and their walking distance from residential areas. Concluding this indicator is measuring the walking distance between a certain point (residential building) and the nearest green space. However, Accessibility gives information on the residential a building itself, and thus the spatial distribution of green spaces in the city. Accessibility can be measured in several ways. We can distinguish different methodologies based on what types of NBS are taken into account: only green spaces above a certain area or we can also consider linear and spot-like NBSs too. On the other hand, we can also calculate accessibility based on the radius of certain NBSs or based on the walking distance between two points. The following Figure 1 and 2 show the case when spot-like, linear and areal NBSs are also taken into account and the base of calculation is the radius of the NBS elements.

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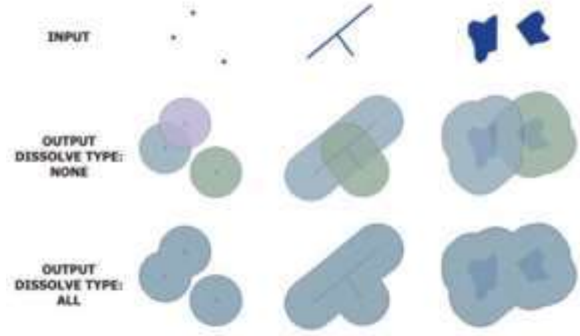

Figure 1. Inputs for calculating accessibility in GIS based softwares.
Source: Shuk Wai So: Urban Green Space Accessibility and Environmental Justice: A GIS-Based Analysis in the City of Phoenix, Arizona. Master Thesis, University of Southern California, august 2016.

This method does not consider the road-network which can sometimes leads to approximate results, however, it gives a clear view on the spatial network of green spaces within the city.

The next figure shows a real life example of the 8th District of Capital Budapest, measuring the geometric radius from green spaces within the residential area of the district.

Figure 2. Accessibility in Budapest, Józsefváros.
Source: *Alföldi, György and Kovács, Zoltán (ed.): Városi zöld könyv, Kulcs a fenntartható városhoz ; Budapest: ÉTK ; MTA FKI; Rév8 Zrt, 2007. 195 p.; ISBN:978-963-513-207-2;*

OBJECTIVES	• evaluating quality of life by describing the accessibility to green spaces for recreation • considering the spatial organization of NBSs in the urban fabric • Highlight the weak and strong points of the urban green network.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data

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5	High calculation difficulty and requires lot of data

DATA AND MEASURMENT	
REQUIRED DATA	• Topographic base and vectoral database of the analysed area (including green spaces / NBSs) • Optional: walking distance based on road network.
TYPE OF DATA	• Topological georeferenced data with attribute table
SOURCE	• Municipality databases • Open sources like Open Street Map • Proprietary sources like Google, TomTom etc.
FREQUENCY	Low frequency - yearly, in order to let slow sensible changes in the urban form happen.
MEASURMENT UNIT	m / minutes
REQUIRED TOOL	• Graph representation and centrality computation software or library, like: Osmnx, NetworkX, GraphTool, BoostGraph.
CALCULATION METHOD	The travel distance model measures the minimum travel distance between each location of origin and the nearest destination, and can be expressed as (Talen and Anselin 1998): $A_i^E = min\|d_{ij}\|$ where A_i^E is the index for minimum distance from zone “i” to the nearest facility (Talen and Anselin 1998), and the lower the value of the index, the higher the accessibility.
OUTPUT	map representing either distance or walking distance in time.
EXAMPLES	

LINKS AND REFERENCES	
KEYWORDS	• ACCESSIBILITY • CENTRALITY • BETWEENNESS • SPATIAL ORGANIZATION
LINKS AND REFERENCES	• Freeman, Linton (1977). "A set of measures of centrality based on betweenness". *Sociometry*.**40**: 35–41. doi:10.2307/3033543. • BARABÁSI, Albert-László. Network science book. Boston, MA: Center for Complex Network, Northeastern University. Available online at: http://barabasi. com/networksciencebook, 2014. • Swyngedouw, E. and Kaika, M. (2003) The Environment of the City… or the Urbanization of Nature, in A Companion to the City (eds G. Bridge and S. Watson), Blackwell Publishing Ltd, Oxford, UK. doi: 10.1002/9780470693414.ch47 • Andrés Duany, Elizabeth Plater-Zyberk, and Jeff Speck: Suburban Nation: The Rise of Sprawl and the Decline of the American Dream, Farrar, Straus and Giroux, 2010 • E Talen, L Anselin (1998): Assessing Spatial Equity: An Evaluation of Measures of Accessibility to Public Playgrounds: https://doi.org/10.1068/a300595

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.1 | Urban planning and form

INDICATOR	
NAME	9.1.3 | ACC - Accessibility

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe the current conditions of the urban connectivity, possibly on pedestrian and vehicular scopes.
R2: Policy support for policies:	No
R3: Comparability:	Not directly, but it can be correlated to traffic intensity data, or to identify both central and disconnected areas. It is a measure that strongly depends on the observed context.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	It requires some kind of training but it can be related to generally known concept such as congestion.
A3: Other stakeholders:	Yes, applied to urban environments, social networks and web analysis.

CREDIBLE	
C1: Unambiguous results:	Not generally. The measure has to be used within a specific context, since it carries a relative value. Comparing two values makes sense only within the same computation batch.
C2: Transparency:	Yes, it has a clear mathematical methodology.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed

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EASY	
E1: Availability of data to calculate the indicator:	Yes, virtually all municipalities have vector data of the street networks. Open sources like Open street Map are excellent on both pedestrian and vehicular networks. Proprietary sources like TomTom and Google are available too.
E2: Technical feasibility:	No, but a simple software interface could fill this gap. Computational burden is relevant.
E3: Reproducibility:	Yes, virtually all municipalities have vector data of the street networks. Open sources like Open street Map are excellent on both pedestrian and vehicular networks. Proprietary sources like TomTom and Google are available too.

ROBUST	
R1: Data quality:	Yes.
R2: Sensitiveness:	No, this is an exact method
R3: Scale:	Yes

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9 | URBAN PLANNING AND GOVERNANCE

9.2 | GOVERNANCE IN PLANNING

Short description of USC: Governance has the power to manifest society's values and needs through urban planning, and for sure it is securing the framework of planning. One can easily realize the importance of urban planning and design, a tool of implementing decisions of the governance.
Urban planning and governance is a rather complex process therefore the evaluation also needs a compound method. As the planning and governance system varies in European countries, the methodology of evaluations should also differ, which wouldn't make a harmonized system.

9.2.1 | ABNA – BUDGET NATURAL ASSETS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.2 | Governance in planning

INDICATOR	
NAME	**9.2.1 | ABNA - annual budget of natural assets management**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DESCRIPTION	NBS presumes a conscious planning and management of the nature in a city. The annual budget spent on natural assets management relative to the annual budget of a city reflects to importance of this asset. Due to the very "nature" of this infrastructure, it is a long-term investment that requires a persistent effort. For this reason, if we aspire to define an indicator to measure it, we need to consider at least a 10 years long period.
OBJECTIVES	• clarify the fiscal limits for a sustainable planning and management of natural assets • enhance the level consciousness in the planning and management of natural assets • foster a long term thinking in natural assets management

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• annual budget of a city in the past ten years • annual budget of natural assets management

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TYPE OF DATA	• budget figures
SOURCE	• annual budget of a municipality • annual budget of the public and private actors involved in natural assets management
FREQUENCY	• annual
MEASUREMENT UNIT	Percentage
REQUIRED TOOL	• no required tool
CALCULATION METHOD	• no calculation method required
FORMULA	$ABNA = \frac{A}{B}$ where A is the total budget of a city in the past 10 years; B is the total budget spent on the management of natural assets in the past 10 years
OUTPUT	numerical value

LINKS AND REFERENCES	
KEYWORDS	• BLUE INFRASTRUCTURE • GREEN INFRASTRUCTURE
LINKS AND REFERENCES	• Brueckner, J. K. (2000). Urban sprawl: diagnosis and remedies. *International regional science review*, *23*(2), 160-171. • Frey, H. (2003). *Designing the city: towards a more sustainable urban form*. Taylor & Francis.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.1 | Urban form

INDICATOR	
NAME	**9.2.1 | ABNA - annual budget of urban** natural assets **management**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like e.g. the financial resources available for managing natural assets.
R2: Policy support for policies:	High score for policy support Europe-wide and international: • EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities • EU Strategy on Green Infrastructure • Intergovernmental Panel on Climate Change (IPCC) • Report on Climate Change Impacts, Adaptation and Vulnerability (2014) • Report on Mitigation of Climate Change (2014)
R3: Comparability:	Yes, it is possible to standardise the methodology, in order to provide fully comparable results.

ACCEPTED	
A1: Policy makers:	No, not so far, but expected to be in the near feature.
A2: Practitioners:	Yes, it defines the limits for the fiscally sustainable planning of natural assets.
A3: Other stakeholders:	Not in the ones I know.

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CREDIBLE	
C1: Unambiguous results:	It is built on very simple – and we believe telling - facts and for this reason it is very easy to interpret for the decision makers and the wider public.
C2: Transparency:	It is built on a simple mathematical calculation.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be apply in all EU member states.

EASY	
E1: Availability of data to calculate the indicator:	Municipal budgets are by law open to the public, as well as the fiscal figures of municipally owned companies, or any contracts that are financed by any of them.
E2: Technical feasibility:	No, special expertise, instruments or skills are needed.
E3: Reproducibility:	Budgetary regulations are considerably homogeneous, thus it is reliably reproducible over time and space.

ROBUST	
R1: Data quality:	Input data for simulation model are real data. Climate data input can be based on real data as well on declared assumptions (scientifically based – e.g. full forcing method).
R2: Sensitiveness:	This indicator does not involve this risk.
R3: Scale:	Yes, depending on the project scale. (sub city, city, district)

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9.2.2 | SI

9 | URBAN PLANNING AND GOVERNANCE

9.2 | GOVERNANCE IN PLANNING

9.2.2 | SI – SEGREGATION INDEX

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.2 | Governance in planning

INDICATOR	
NAME	**9.2.2 | SI - Segregation index**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DESCRIPTION	One of most important social transitions is the process of segregation. Segregation shows the spatial separation of different social strata in a given spatial area. Various indices have been developed to measure segregation that differ in complexity and explanatory power. Here a rather simple but widely used one suffices. Duncan and Duncan index of dissimilarity delineates the segregation of a neighbourhood or a district, in per cent. It shows the ratio of the population having to move to have an equal distribution. It calculates the segregation of a select stratum that is to be selected according to the nature of the study, that is, in this case, the upper strata. As educational level is the best proxy to social status, we suggest it as the variable and the university degree as the value to be assessed. Segregation index is related to the development of NBS in the following ways: - Inhabitants of lower social status can be characterized with poor life qualities, which also mean less or no access to good quality green spaces. - This also works the other way around. Areas where good quality green spaces are accessible in 5-10 minutes of walking distance are usually the areas with higher real-estate prices. This also means segregation. It is easily seen that the accessibility of green spaces and social segregation within the city are strongly interconnected. The social impact of NBS projects can be traced by the spatial or temporal alterations of the segregation index. Correlation can be proved between segregation and the development of green infrastructure, if the implementation of a large scale and complex NBS project has measurable social effect. (Irvine et al. 2013, Haffner 2015, Dooling 2009, Checker 2011)

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OBJECTIVES	• reduce the social exclusion of different social groups, especially the disadvantageous ones. • measure the change of the ratio of segregation, before and after the application of an NBS.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASURMENT	
REQUIRED DATA	• data, which shows the status of social groups, like ratio of graduated people or income in each spatial unit within the whole city • when correlation analysis is carried out there are 2 ways to analyse connection segregation and NBS. 1.) If spatial comparison is done as input data simply the existence of NBS (green areas, larger than 1000 m^2) is taken into account. 2.) If correlation carried out on a temporal basis the status and quality of NBS is taken into account. Such indicators can be considered such as accessibility.
TYPE OF DATA	• statistical
SOURCE	• Surveys, • Data of Central Bureau for Statistics, • Data of electoral districts (municipalities own them) • Growth of green areas. [m^2]
FREQUENCY	At the beginning and 5 years after the end of an NBS project
MEASUREMENT UNIT	%
REQUIRED TOOL	• Excel or SPSS
CALCULATION METHOD	Duncan and Duncan index of dissimilarity, calculation of existing data on neighbourhood (election district) levels. Further a correlation analysis is required to trace the impacts of NBS implementation on a timely or spatial basis.
FORMULA	$\sum_{i=1}^{n} \frac{\lvert a_i - b_i \rvert}{2}$, where *a* is the ratio of a given group in a sub-territory and *b* is the ratio of the rest, n is the total number of subterritories and i is the actual sub-territory. We suggest it be calculated with *a* as the ratio of population with university degree. The impact of an NBS project can be proved in two ways. As mentioned, it is possible to track the effect on a timely basis, thus measuring segregation at the beginning of an NBS project and 5 years after its end, the changes in segregation level can be measured. On the other hand, the impact of an NBS implementation can be also proved with spatial comparison of the measured neighbourhood (where NBS has been implemented) and another one that has similar features, but no actions has been done. This allows to prove the effectiveness of NBS projects on segregation if there are no timely data available. It is also important to mention that there might be other dependent variables that cannot be influenced by the implementation of NBS projects. These variables need to be normalized before carrying out the correlation analysis.

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OUTPUT	● numerical value ● map showing numerical value for different cities and towns / or neighbourhoods
EXAMPLES	● "In addition, indicators addressing social and environmental justice issues such as measurements of green space availability through the number or share of residents affected by displacement or increasing segregation. The installation of new or restoration of existing green spaces might be beneficiary as an NbS for climate change adaptation or mitigation, but may simultaneously lead to increases in land prices and rent because of increased attractiveness of the area. In turn, those residents for which the green spaces would be most beneficial sometimes cannot profit from the natural area because of displacement processes. Such effects are called the "green paradox" (Wolch et al. 2014), eco-gentrification (Irvine et al. 2013, Haffner 2015), ecological gentrification (Dooling 2009), or environmental gentrification (Checker 2011)." Source of citation: https://www.ecologyandsociety.org/vol21/iss2/art39/ ● "Last but not least, for scaling nature-based solutions to contribute to accelerating sustainability transitions in cities, social and environmental agendas in cities need to connect or exploit synergies more strategically. Nature-based solutions require a social process to be spatially integrated in a city, and produce social benefits in the form of sense of place, empowering communities and establishing ties between social groups. As such, even though on the outset nature-based solutions are 'environmental solutions', they produce multiple benefits and with our cases we show that they produce social benefits, addressing social challenges such as segregation and inclusion. Hence, it may be worth noticing that an urban agenda for nature-based solutions is intrinsically an integrated agenda for social and environmental issues." https://link.springer.com/chapter/10.1007/978-3-319-56091-5_5 ● Watson-Puskás, N. (2017), A case study on Budapest: Lessons on urban resilience. Plea 2017 Edinburgh – Conference Paper https://www.researchgate.net/profile/Nikolett_Watson-Puskas/publication/318324312_A_case_study_on_Budapest_Lessons_on_urban_resilience/links/5963b519aca2728c112739ca/A-case-study-on-Budapest-Lessons-on-urban-resilience.pdf

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	9 | Urban planning and governance	9.2 | Governance in planning

INDICATOR	
NAME	9.2.2 | SI - Segregation index

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Indicator is capable to describe initial planning problems, like problems with social cohesion and integration.
R2: Policy support for policies:	High score for policy support Europe-wide and international: ● Social inclusion ● Equal opportunities ● Liveable cities
R3: Comparability:	Yes, as a well-documented indicator the Segregation index has a well elaborated methodology. The indicator is used for more the 5 decades for measuring segregation and it can be easily calculated from data that are accessible without any difficulties.

ACCEPTED	
A1: Policy makers:	In myriad cases it is one of the basic tools of spatial sociology. Although more elaborate measuring techniques exist, Duncan and Duncan index of dissimilarity is still the most accepted method.
A2: Practitioners:	It is often used but mostly by social scientists.
A3: Other stakeholders:	Yes, a lot, see e.g. Indicator sheet.

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CREDIBLE	
C1: Unambiguous results:	The interpretation of the result often needs clarification for the lay users.
C2: Transparency:	Yes, it has.
C3: Documentation of assumptions and limitations:	Yes, underlying data, calculation method and assumptions are fully disclosed, interpretable and reproducible and can be applicate in all (most) EU member states.

EASY	
E1: Availability of data to calculate the indicator:	It needs data available in all EU member states.
E2: Technical feasibility:	It is a standard procedure in spatial social sciences.
R3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes.
R2: Sensitiveness:	The results are sensible to the size and the number of the units an area is broken into.
R3: Scale:	Partially and indirectly as a measure of social cohesion and segregation of an area.

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UC 10 | PEOPLE SECURITY

10.1.1 | CC

10 | PEOPLE SECURITY

Short description of UC: This challenge mainly focuses on safety of the people in NBS contexts. **Two threats, manmade events or crime and extraordinary events (such as natural disasters), are considered in this challenge**. In 1990s UNDP and Canadian Government introduced the notion of human security as an important challenge of our times. Human security contains multiple elements like economic security, food security, health security, environmental security, personal security, community security, and political security. NBS contexts which are managed at material, infrastructural, and social levels are micro-localities in a neighbourhood controlled from insecurities. This leads to sustainability to NBS and control of crime in neighborhoods.

10.1 | CONTROL OF CRIME

Short description of USC: Man-made events or crime occurring in NBS contexts create threats to personal security which refers to an individual's freedom from crime and violence (Bajpai 2000). We can think of different forms of crime in NBS contexts such as murder, rape, assault, and robbery. Crime counts in different categories of crime (Bella 2015) and percentage of victimization are important measures of crime. Even if crime does not exist, if people perceive the environment as unsafe then they prefer not to be there.

10.1.1 | CC – CRIME COUNTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	10.1.1 | CC - CRIME COUNTS
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	Crime counts are statistical records collected mostly by the government bodies at the street, neighbourhood, or city levels. These are straightforward indicators of crime and useful to localize the events and categories of events. Practitioners governing or designing NBS may use this indicator in making tactical decisions (Bella et al 2015). For each crime category (rape, assault, theft, robbery etc), total number of incidents at a specific NBS, street, neighbourhood, or city can be collected, Average number of events per locality can be calculated as well.
FOCUS/OBJECTIVES	• Identify different types of manmade events so as to control the occurrences of these events. • Throughout time information can be used to monitor the changes in the number and types of events occurring at the NBS context. This information can feed into the decision making process of the NBS governors.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• total number of incidents at a specific NBS, street, neighbourhood, or city • Average number of events per locality
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Statistical Records from Governmental Bodies
FREQUENCY (how often to use this indicator?)	• Monthly • At the design stage
MEASUREMENT UNIT	• Number of events
REQUIRED TOOL	• Police or Government records
CALCULATION METHOD	• Frequency counts
OUTPUT TYPE	• Numerical value • Graphics
EXAMPLES	• Ambrey, Christopher L et al (2014) "Perception or Reality, What Matters Most when it comes to crime in your neighbourhood?" Social Indicators Research, 119, 877-896. • Bella, Enrico di, Matteo Corsi and Lucia Leporatti (2015) "A Multi-indicator Approach for Smart Security Policy Making," *Social Indicator Research*, 122, 653-675.

LINKS AND REFERENCES	
KEYWORDS	• Crime statistics, Crime counts,
LINKS AND REFERENCES	• Ambrey, Christopher L et al (2014) "Perception or Reality, What Matters Most when it comes to crime in your neighbourhood?" Social Indicators Research, 119, 877-896. • Bella, Enrico di, Matteo Corsi and Lucia Leporatti (2015) "A Multi-indicator Approach for Smart Security Policy Making," *Social Indicator Research*, 122, 653-675.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	10.1.1 | CC - CRIME COUNTS

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Measuring the amount of crime and crime categories. Therefore partially indicates the impact on people's security.
R2: Policy support for policies:	Actively used by public administrators and governors (see Bella 2015)
R3: Comparability:	It is a descriptive statistic which provides frequency counts, percentages, averages. Yes, they can be used to compare.

ACCEPTED	
A1: Policy makers:	Secucities project of European Forum for Urban Safety (2004) suggests that local safety policies must be based on up-to-date and comprehensive crime statistics. http://efus.eu/files/fileadmin/efus/pdf/gb_pub_justy.pdf
A2: Practitioners:	Yes. Safecity frameworks aim to decrease the crime rates as an indicator of safer cities. (see UN-Habitat Program Report 2007) http://mirror.unhabitat.org/downloads/docs/GRHS2007.pdf
A3: Other stakeholders:	Yes, governors at different has been utilizing it (Bella et al 2015).

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CREDIBLE	
C1: Unambiguous results:	Yes, it is very simple and clear to understand. Just frequency counts.
C2: Transparency:	Crimes reported to the authorities are only counted in the data.
C3: Documentation of assumptions and limitations:	Eurostat provides these records for most of the member states. Most of the countries possess these statistics at the city level.

EASY	
E1: Availability of data to calculate the indicator	A straight forward measure which can be accessed from national or police statistics. It can be updated from the government records.
E2: Technical feasibility:	Yes, very simple.
R3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Unrecorded incidences must be checked. People may not inform authorities on certain types of crimes.
R2: Sensitiveness:	No error estimation in government records. Uncertainty may be described in general terms.
R3: Scale:	No, it is not.

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10.1.2 | PC

10 | PEOPLE SECURITY

10.1 | CONTROL OF CRIME

10.1.2 | PC – PERCEIVED CRIME

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	**10.1.2 | PC – Perceived Crime**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	Perceived crime is an indicator of people security that identifies the quality of life of the NBS users. If higher crime rates are perceived, people experience anxiety or fear of crime, decrease in the motivation to consume the NBS or participate the communal activities. So, high levels of perceived crime hinders benefits of the NBS such as personal health or social cohesion. Literature identifies that women, old, less educated people develop higher levels of fear of crime (Sulemana 2015).
FOCUS/OBJECTIVES	• Decreased levels of perceived crime leads to frequent usage of NBS • Decreased levels of perceived crime for women results in distributional justice of the benefits and harms of NBS • Decreased levels of perceived crime, increases the usage of the NBS and create benefits for personal health. • Decreased levels of perceived crime results in the increase in social cohesion in the NBS context.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Perceived Crime 'How common are "……" (types of events such as assault, theft,…) in your local "…." (neighbourhood, street etc)?' The perception variable is ordinal and rated: 1 (never happens); 2 (very rare); 3 (not common); 4 (fairly common); or 5 (very common). (Ambrey et al 2014)
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Questionnaire
FREQUENCY (how often to use this indicator?)	- Annual
MEASUREMENT UNIT	• Perceived frequency of occurrence
REQUIRED TOOL	• Survey
CALCULATION METHOD	• Average "perception of crime types" •
OUTPUT TYPE	• Numerical value • Graphics
EXAMPLES	• Ambrey, Christopher L et al (2014) "Perception or Reality, What Matters Most when it comes to crime in your neighbourhood?" *Social Indicators Research*, 119, 877-896. • Bella, Enrico di, Matteo Corsi and Lucia Leporatti (2015) "A Multi-indicator Approach for Smart Security Policy Making," *Social Indicators Research*, 122, 653-675. • Sulemana, Iddisah (2015) "Fear of Crime and Crime Victimization on Subjective Well-being in Africa," *Social Indicators Research*, 121, 849-872.

LINKS AND REFERENCES	
KEYWORDS	• Crime statistics • Crime counts,
LINKS AND REFERENCES	• Ambrey, Christopher L et al (2014) "Perception or Reality, What Matters Most when it comes to crime in your neighbourhood?" Social Indicators Research, 119, 877-896. • Bella, Enrico di, Matteo Corsi and Lucia Leporatti (2015) "A Multi-indicator Approach for Smart Security Policy Making," *Social Indicator Research*, 122, 653-675.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	10.1.2 | PCR – Perceived Crime

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator shows the levels of perception of crime (an subjective assessment of the individual). There are always differences between the real and the perceived levels. If the perceived levels of crime decrease, NBS engagement will increase.
R2: Policy support for policies:	Used by policy makers. (please see: https://www.justice.govt.nz/assets/Documents/Publications/Public-perceptions-of-crime-and-the-criminal-justice-system-survey-2014-results.pdf)
R3: Comparability:	It is a descriptive statistic providing average perception. Yes, they can be used to compare.

ACCEPTED	
A1: Policy makers:	Yes. E.g. https://www.justice.govt.nz/assets/Documents/Publications/Public-perceptions-of-crime-and-the-criminal-justice-system-survey-2014-results.pdf
A2: Practitioners:	It has potential
A3: Other stakeholders:	Yes, municipalities can use the information.

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CREDIBLE	
C1: Unambiguous results:	Yes, it is very simple and clear to understand. Just average value.
C2: Transparency:	Very clear question. Answers are measured with ordinal scaleç Average value for the sample is calculated.
C3: Documentation of assumptions and limitations:	Yes they are.

EASY	
E1: Availability of data to calculate the indicator:	It has to be generated.
E2: Technical feasibility:	Yes, very simple.
E3: Reproducibility:	Yes. Can be applied to different cities, neighborhoods etc.

ROBUST	
R1: Data quality:	Yes, it uses real data.
R2: Sensitiveness:	No error estimation in government records. Uncertainty may be described in general terms.
R3: Scale:	No, it is not.

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10.1.3 | PCFS

10 | PEOPLE SECURITY

10.1 | CONTROL OF CRIME

10.1.3 | PCFS – % CITIZENS FEELING SAFE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	**10.1.3 – PCFS - Percentage of citizens feeling safe**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	This indicator measures the percentage of citizens feeling safe or very safe.
FOCUS/OBJECTIVES	To assess the perception of citizens' safetY

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Number of people answering that feel safe or very safe in the query. • Total number of answers to the query.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Surveys.
FREQUENCY (how often to use this indicator?)	- Annually.

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MEASUREMENT UNIT	• Percentage
REQUIRED TOOL	• The indicator is rather simple to calculate (it is a split). No tool will be required
CALCULATION METHOD	• Simple equation $\frac{Number\ of\ people\ feeling\ safe\ or\ very\ safe}{Number\ of\ answers\ to\ the\ query}$
OUTPUT TYPE	• Percentage
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Crime • Safety feeling
LINKS AND REFERENCES	• UN Indicators of Sustainable Development: Guidelines and Methodologies. http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf • Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. https://publications.iadb.org/bitstream/handle/11319/8132/Guia-Metodologica-Programa-de-Ciudades-Emergentes-y-Sostenibles-Tercera-edicion-Anexo-de-indicadores.pdf?sequence=1

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	**10.1.3 – PCFS - Percentage of citizens feeling safe**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is able to describe the perception of the citizens about security in the city. Therefore, able to partially inform about the impact on people's security.
R2: Policy support for policies:	The indicator is used in UN Indicators of Sustainable Development and Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development
R3: Comparability:	The indicator depends on survey data. Therefore, it would be possible to compare this percentage with other complementary or opposite percentages.

ACCEPTED	
A1: Policy makers:	The indicator is used in UN Indicators of Sustainable Development and Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development
A2: Practitioners:	The indicator could be possible to move forward its use at municipality level in the EU. In that case it could inform urban planners. Especially if information can be gathered also until neighbourhood level. It could help to re-think urban design.
A3: Other stakeholders:	The indicator is used in UN Indicators of Sustainable Development and Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development

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CREDIBLE	
C1: Unambiguous results:	Yes, the indicator is able to describe the perception of the citizens about security in the city. The indicator would be quite simple to understand by the general public.
C2: Transparency:	Yes, the data will be gathered with surveys. Therefore, it should be defined the amount of people considered as representative for the survey.
C3: Documentation of assumptions and limitations:	Surveys and percentage calculation is a universal method.

EASY	
E1: Availability of data to calculate the indicator:	As it is the result of a survey, it is as easy as doing the survey to the amount of people considered representative and to calculate the percentages of positive answers.
E2: Technical feasibility:	The indicator is simple to calculate. Probably no tools are needs to calculate. However, percentage is a data format that is not leading to ambiguity.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	There is no possibility of uncertainty in the data if the survey is carried out with the due guarantees.
R3: Scale:	No, the indicator is not valuing NBS impacts on more scales.

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10 | PEOPLE SECURITY

10.1 | CONTROL OF CRIME

10.1.4 | PGV – % OF GENDER VIOLENCE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	**10.1.4 | PGV - Percentage of gender violence**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☒ Object
DEFINITION	This indicator measures the percentage of women between 15 and 49 years who have ever had a relationship and have suffered physical violence from their actual couple or their previous one during the last 12 months.
FOCUS/OBJECTIVES	To assess the reduction (or not) on gender violence.
NOTES	Based on the definition of violence of the Centres for Disease Control and Prevention (CDC) and of the World Health Organization (WHO).

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Number of women between 15 and 49 years who have ever had a relationship and have suffered physical violence from their actual couple or their previous one during the last 12 months. • Total number of women between 15 and 49 years who have ever had a relationship expressed in percentage.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Police data, Institutes of statistics data or by doing surveys.
FREQUENCY (how often to use this indicator?)	- Annually.
MEASUREMENT UNIT	• Percentage
REQUIRED TOOL	• The indicator is rather simple to calculate (it is a split). No tool will be required
CALCULATION METHOD	• Simple equation $\frac{\textit{Number of women who have suffered violence in the last 12 mont}}{\textit{Percentage of women who have ever had a relationship}}$
OUTPUT TYPE	• Percentage
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Gender violence • Women
LINKS AND REFERENCES	• Centres for Disease Control and Prevention. https://www.cdc.gov/ • World Health Organization. http://www.who.int/en/ • UN organization dedicated to gender equality and the empowerment of women http://www.unwomen.org/en • Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. https://publications.iadb.org/bitstream/handle/11319/8132/Guia-Metodologica-Programa-de-Ciudades-Emergentes-y-Sostenibles-Tercera-edicion-Anexo-de-indicadores.pdf?sequence=1

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	**10.1.4 | PGV - Percentage of gender violence**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	This indicator measures the percentage of women between 15 and 49 years who have ever had a relationship and have suffered physical violence from their actual couple or their previous one during the last 12 months. Therefore, able to partially inform about the impact on people's security.
R2: Policy support for policies:	The indicator is used in Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. The Centres for Disease Control and Prevention, World Health Organization and UN organization dedicated to gender equality and the empowerment of women also use it.
R3: Comparability:	The indicator depends on survey data or police's data. Therefore, it would be possible to compare this percentage with other complementary or opposite percentages.

ACCEPTED	
A1: Policy makers:	The indicator is used in Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. The Centres for Disease Control and Prevention, World Health Organization and UN organization dedicated to gender equality and the empowerment of women also use it.
A2: Practitioners:	The indicator could be possible to move forward its use at municipality level in the EU. In that case it could inform urban planners. Especially if information can be gathered also until neighbourhood level.

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A3: Other stakeholders:	The indicator is used in Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. The Centres for Disease Control and Prevention, World Health Organization and UN organization dedicated to gender equality and the empowerment of women also use it.

CREDIBLE	
C1: Unambiguous results:	Yes, this indicator measures the percentage of women between 15 and 49 years who have ever had a relationship and have suffered physical violence from their actual couple or their previous one during the last 12 months. The indicator would be quite simple to understand by the general public.
C2: Transparency:	Yes, the data will be gathered with surveys or with police data. Therefore, it should be defined the amount of people considered as representative for the survey.
C3: Documentation of assumptions and limitations:	Surveys or gathering police's data and percentage calculation is a universal method.

EASY	
E1: Availability of data to calculate the indicator	As it is the result of a survey, it is as easy as doing the survey to the amount of people considered representative and to calculate the percentages of positive answers. Gather police's data is also an easy way.
E2: Technical feasibility:	The indicator is simple to calculate. Probably no tools are needed to calculate. However, percentage is a data format that is not leading to ambiguity.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	There is no possibility of uncertainty in the data if the survey is carried out with the due guarantees. Though, this data will be more reliable than police's because there are a certain percentage of crimes that are not denounced.
R3: Scale:	No, the indicator is not valuing NBS impacts on more scales.

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10 | PEOPLE SECURITY

10.1 | CONTROL OF CRIME

10.1.5 | PV – % OF VICTIMIZATION

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	**10.1.5 | PC - Percentage of victimization**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☐ No
TYPE (☐ | ☒)	☒ Descriptive ☐ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	This indicator measures the percentage of citizens that have been victim of a crime in the last 12 months.
FOCUS/OBJECTIVES	To assess the presence of crimes.
NOTES	This has to be measured by surveys because sometimes crimes are not denounced.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Number of people answering that have been victim of a crime in the last 12 months. • Total number of answers to the query.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Surveys. This has to be measured by surveys because sometimes crimes are not denounced.
FREQUENCY (how often to use this indicator?)	• Annually.
MEASUREMENT UNIT	• Percentage
REQUIRED TOOL	• The indicator is rather simple to calculate (it is a split). No tool will be required
CALCULATION METHOD	• Simple equation $\frac{Number\ of\ people\ that\ has\ been\ victim\ of\ a\ crime}{Number\ of\ answers\ to\ the\ query}$
OUTPUT TYPE	• Percentage
EXAMPLES	•

LINKS AND REFERENCES	
KEYWORDS	• Crime • Victimization
LINKS AND REFERENCES	• UN Indicators of Sustainable Development: Guidelines and Methodologies. http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf • Hemispheric Security Observatory http://www.oas.org/dsp/english/cpo_observatorio_estadisticas.asp • National Crime Victimization Survey of USA http://www.icpsr.umich.edu/icpsrweb/ICPSR/series/95 • Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. https://publications.iadb.org/bitstream/handle/11319/8132/Guia-Metodologica-Programa-de-Ciudades-Emergentes-y-Sostenibles-Tercera-edicion-Anexo-de-indicadores.pdf?sequence=1

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.1 | Control of crime

INDICATOR	
NAME	10.1.5 | PV - Percentage of victimization

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is able to describe the number of citizens that suffered some kind of crime in the last 12 months. Therefore, able to partially inform about the impact on people's security.
R2: Policy support for policies:	The indicator is used in UN Indicators of Sustainable Development and Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. The Hemispheric Security Observatory and National Crime Victimization Survey of USA also use it.
R3: Comparability:	The indicator depends on survey data. Therefore, it would be possible to compare this percentage with other complementary or opposite percentages.

ACCEPTED	
A1: Policy makers:	The indicator is used in UN Indicators of Sustainable Development and Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. The Hemispheric Security Observatory and National Crime Victimization Survey of USA also use it.
A2: Practitioners:	The indicator could be possible to move forward its use at municipality level in the EU. In that case it could inform urban planners. Especially if information can be gathered also until neighbourhood level. It could help to re-think urban design.

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A3: Other stakeholders:	The indicator is used in UN Indicators of Sustainable Development and Indicators of the Sustainable and Emergent Cities Initiative of the Inter-American Bank of Development. The Hemispheric Security Observatory and National Crime Victimization Survey of USA also use it.

CREDIBLE	
C1: Unambiguous results:	Yes, the indicator is able to describe the number of citizens that suffered some kind of crime in the last 12 months. The indicator would be quite simple to understand by the general public.
C2: Transparency:	Yes, the data will be gathered with surveys. Therefore, it should be defined the amount of people considered as representative for the survey.
C3: Documentation of assumptions and limitations:	Surveys and percentage calculation is a universal method.

EASY	
E1: Availability of data to calculate the indicator:	As it is the result of a survey, it is as easy as doing the survey to the amount of people considered representative and to calculate the percentages of positive answers.
E2: Technical feasibility:	The indicator is simple to calculate. Probably no tools are needs to calculate. However, percentage is a data format that is not leading to ambiguity.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	There is no possibility of uncertainty in the data if the survey is carried out with the due guarantees. Though, this data will be more reliable than police's because there are a certain percentage of crimes that are not denounced.
R3: Scale:	No, the indicator is not valuing NBS impacts on more scales.

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10 | PEOPLE SECURITY

10.2 | CONTROL OF EXTRAORDINARY EVENTS

10.2.1 | DPIC – DOMESTIC PROPERTY INSURANCE CLAIMS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.2 | Control of extraordinary events

INDICATOR	
NAME	**10.2.1 | DPIC - Domestic Property Insurance Claims**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	This indicator measures value of insurance claims for property due to major weather events
FOCUS/OBJECTIVES	To assess the reduction (or not) on residential building assets affected by extreme events.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Insurance companies' data on insurance claims related to damage on properties due to weather events inside the city (neighbourhood) boundaries. Note: There might be an issue with private data. In this case or a confidential agreement is done or the insurance company should aggregate the data to street or neighbourhood level.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Insurance companies or their local headquarters
FREQUENCY (how often to use this indicator?)	• Anually. Flooding events are not that frequent and usually related to specific periods of the year.
MEASUREMENT UNIT	• Euros/ha
REQUIRED TOOL	• The indicator is rather simple to calculate. No tool will be required
CALCULATION METHOD	• Simple equation ((Total value of insurance claims)/area of scope))
OUTPUT TYPE	• Simple quantitative value
EXAMPLES	

LINKS AND REFERENCES	
KEYWORDS	• Domestic property • Insurance • Economic Value
LINKS AND REFERENCES	• Donnelly, A., Jones, M. B., & Sweeney, J. 2004. A review of indicators of climate change for use in Ireland. *International Journal of Biometeorology*, *49*(1), 1-12. • Cannell, M., Brown, T., Sparks, T., Marsh, T., Parr, T., George, G., ... & Leaper, R. 2004. Review of UK climate change indicators.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.2 | Control of extraordinary events

INDICATOR	
NAME	10.2.1 | PIC - Domestic Property Insurance Claims

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is able to describe the economic lost of residential properties due to extreme events. Therefore, able to partially inform about the impact on people's security due to extreme event
R2: Policy support for policies:	The indicator was considered as part of the initial group of UK Climate Change indicators of 1999. The indicator was considered as a potential indicator of climate change for use in Ireland.
R3: Comparability:	Yes, The indicator depends on data from insurance companies. Therefore, it would be possible to harmonise the datasets from different companies before the calculation of the indicator. It also would be possible to differentiate between weather or disaster events.

ACCEPTED	
A1: Policy makers:	It is part of the UK Indicators of Climate Change (last information from 2003). Therefore, It informed UK policies.
A2: Practitioners:	No. The indicator has been applied at national level. But it could be possible to move forward its use at municipality level in the EU. In that case it could inform urban planners. Especially if information can be gathered also until neighbourhood level or linked with specific weather events or disasters.
A3: Other stakeholders:	Yes, the indicator is considered by policy makers.

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CREDIBLE	
C1: Unambiguous results:	Yes, the indicator inform about part of the economic losses of residents and therefore the impact in their well-being security. The indicator would be quite simple to understand by the general public. It is unknown if the general public would accept it.
C2: Transparency:	No, the data needs to come from insurance companies. Therefore, it is not easy to know how they treated the information, unless work is developed with the insurance companies to harmonise calculations.
C3: Documentation of assumptions and limitations:	No, but a collaboration between public agencies and insurance companies could resolve this.

EASY	
E1: Availability of data to calculate the indicator:	The indicator needs data already collected. The issue is that the data is private, belonging to insurance companies. The data will need to be collected from them and harmonised.
E2: Technical feasibility:	The indicator is simple to calculate. The provision of geographic data associated to the information of insurance companies could need of GIS software. However, open versions of this software exist and the demanding capabilities are already part of most urban planners skills.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	No, there is no assessment of the uncertainty. For example, it would not acknowledge the damage on residential properties without an insurance.
R3: Scale:	Yes, the indicator is originally proposed for national scales. But, due to the current quality of data in EU, we consider that it is feasible to transpose the indicator to local level.

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10 | PEOPLE SECURITY

10.2 | CONTROL OF EXTRAORDINARY EVENTS

Short description of USC: In NBS contexts, in addition to man-made events or crime, extraordinary events can happen and influence the security of people. Natural disasters such as fire, earthquakes, floods constitute examples of such extraordinary events. In order to control this subchallenge, people who died, relocated, evacuated, or injured must be identified. Also value of insurance claims provide an economic measure for the effect of these events on the citizens' properties.

10.2.2 | NDMP – NO. DEATHS AND MISSING PEOPLE

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.2 | Control of extraordinary events

INDICATOR	
NAME	**10.2.2 | NDMP - Number of deaths and missing people**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	This indicator measures the number of deaths and missing people due to disasters (flooding disasters) per 10.000 population.
FOCUS/OBJECTIVES	To assess the reduction (or not) on deaths and missing people due to the implementation of NBS for storm water management and flooding alleviation. This will inform the improvement on people security.
NOTES	We modified the original indicator to focus only on flooding events and in relation to the impact of some NBS on storm water management and flooding alleviation. We also substituted the division by 100.000 people by 10.000 to adapt the metric to local contexts. If the information on people and the flooding event is accurate enough it could inform people security at neighbourhood (district) level. This indicator is usually related or integrated with the indicator: *number of people injured, relocated and evacuated.* This indicator measures irreparable damage (critical impact). Meanwhile, number of people injured measures reparable or economic damage (low/medium/severe impact).

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data

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5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• The number of people who died during the flooding event or after it as a direct result of the disaster. • The number of people whose whereabouts is unknown since the disaster event.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Summation of data deaths and missing people from local disaster databases or national disaster databases that indicate municipalities.
FREQUENCY (how often to use this indicator?)	• The frequency will be dependent on the frequency of update of the database. However, since flooding events are not that frequent and usually related to specific periods of the year, our assumption is that the frequency should be each year or similar.
MEASUREMENT UNIT	• N° of people
REQUIRED TOOL	• The indicator is rather simple to calculate. No tool will be required
CALCULATION METHOD	• Simple equation ((No. of deaths + No. of missing people)/10.000 population))
OUTPUT TYPE	• Simple quantitative value
EXAMPLES	• OIEWG. 2016. The results of a feasibility exercise conducted among Member States on the indicators for the global targets of the Sendai Framework. Note: The example is at national level. It does not analyse the validity of the indicator. It assess the feasibility of recording it. For EU countries is considered that this type of information could be gathered also at local level.

LINKS AND REFERENCES	
KEYWORDS	• Deaths • missing people
LINKS AND REFERENCES	• UNSTAT. 2017. Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (E/CN.3/2017/2), Annex III • UNISDR, FAO, GFDRR, IOM, UNCCD, UNDP,UNESCAP, UNESCO, UNFPA, UNHCR, UNOCHA, UNOOSA, UNOPS, UNU, UNWOMEN, WHO and WMO. 2015. Proposal on Disaster-Related Indicators to Sustainable Development Goals.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	**10 | People security**	**10.2 | Control of extraordinary events**

INDICATOR	
NAME	**10.2.2 | NDMP - Number of deaths and missing people**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is able to describe critical impacts on the security of people (deaths or missing).
R2: Policy support for policies:	Integrated with the indicator *number of people injured and relocated* it is integrated in the Sustainable Development Goal Indicators of UNSTAT to inform national policies on sustainability. It appears related to the goal 13 (Urgent action to combat climate change and its impacts). The indicator itself appears in a proposal on Disaster-related indicators.
R3: Comparability:	Yes, The indicator depends on data from public agencies. Therefore, the criteria to identify someone as dead or missing can be harmonised to ensure comparability.

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ACCEPTED	
A1: Policy makers:	The feasibility of the indicator is being considered by national governments together with other SDG indicators. In any case, this type of data is usually used to inform the impact of natural disaster events.
A2: Practitioners:	Yes, if disaggregated until neighbourhood level and related with other information regarding risks (e.g. Flood Risk Areas).
A3: Other stakeholders:	Yes, the indicator is considered by policy makers at international and national level.

CREDIBLE	
C1: Unambiguous results:	Not completely. A reduction of the flooding risk in an area due to the impact of NBS implementation does not always need to be associated with a reduction of deaths. This depends on the severity of the events of the specific year considered and also the behaviour of people.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes

EASY	
E1: Availability of data to calculate the indicator	The indicator needs data already collected. The issue is to obtain inventories of the data at local level
E2: Technical feasibility:	The indicator is very simple to calculate.
E3: Reproducibility:	Yes, it's possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	No, there is no assessment of the uncertainty.
R3: Scale:	Yes, the indicator is originally proposed for national scales. But, due to the current quality of data in EU, we consider that it is feasible to transpose the indicator to local level.

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10.2.3 | NPIRE

10 | PEOPLE SECURITY

10.2 | CONTROL OF EXTRAORDINARY EVENTS

10.2.3 | NPIRE – NO. PEOPLE INJURED, RELOCATED AND EVACUATED

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.2 | Control of extraordinary events

INDICATOR	
NAME	**10.2.3 | NPIRE - Number of people injured, relocated and evacuated**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	This indicator measures the number of people injured, relocated and evacuated per 10.000 population.
FOCUS/OBJECTIVES	To assess the reduction (or not) on people affected by flood events due to the implementation of NBS for storm water management and flooding alleviation. This will inform the improvement on people security.
NOTES	We modified the original indicator to focus only on flooding events an in relation to the impact of some NBS on storm water management and flooding alleviation. We also substituted the division by 100.000 people by 10.000 to adapt the metric to local contexts. If the information on people and the flooding event is accurate enough it could inform people security at neighbourhood (district) level. This indicator is usually related or integrated with the indicator: *number of deaths and missing people.* This indicator measures reparable or economic damage (low/medium/severe impact) and complements the indicator on death that measures irreparable damage (critical impact).

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data

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5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• The number of people who was injured during the flooding event or after it as a direct result of the disaster. • The number of people was evacuated or relocated during the flooding event or after it as a direct result of the disaster
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Summation of injured, evacuated and relocated people from local disaster databases or national disaster databases that indicate municipalities.
FREQUENCY (how often to use this indicator?)	• The frequency will be dependent on the frequency of update of the database. However, since flooding events are not that frequent and usually related to specific periods of the year, our assumption is that the frequency should be each year or similar.
MEASUREMENT UNIT	• N° of people
REQUIRED TOOL	• The indicator is rather simple to calculate. No tool will be required
CALCULATION METHOD	• Simple equation ((No. of deaths + No. of missing people)/10.000 population))
OUTPUT TYPE	• Simple quantitative value
EXAMPLES	• OIEWG. 2016. The results of a feasibility exercise conducted among Member States on the indicators for the global targets of the Sendai Framework. Note: The example is at national level. It does not analyse the validity of the indicator. It assess the feasibility of recording it. For EU countries we consider that this type of information could be gathered also at local level.

LINKS AND REFERENCES	
KEYWORDS	• Deaths • missing people
LINKS AND REFERENCES	• UNSTAT. 2017. Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (E/CN.3/2017/2), Annex III • UNISDR, FAO, GFDRR, IOM, UNCCD, UNDP,UNESCAP, UNESCO, UNFPA, UNHCR, UNOCHA, UNOOSA, UNOPS, UNU, UNWOMEN, WHO and WMO. 2015. Proposal on Disaster-Related Indicators to Sustainable Development Goals.

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
SOCIAL	10 | People security	10.2 | Control of extraordinary events

INDICATOR	
NAME	**10.2.3 | NPIRE - Number of people injured, relocated and evacuated**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is able to describe low, medium to several impacts on the security of people (injured, relocation or evacuation).
R2: Policy support for policies:	Integrated with the indicator *number of people death and missing* is integrated in the Sustainable Development Goal Indicators of UNSTAT to inform national policies on sustainability. It appears related to the goal 13 (Urgent action to combat climate change and its impacts). The indicator itself appears in a proposal on Disaster-related indicators.
R3: Comparability:	Yes, The indicator depends on data from public agencies. Therefore, the criteria to identify someone as injured, relocated or evacuated can be harmonised to ensure comparability.

ACCEPTED	
A1: Policy makers:	The feasibility of the indicator is being considered by national governments together with other SDG indicators. In any case, this type of data is usually used to inform the impact of natural disaster events.
A2: Practitioners:	Yes, if disaggregated until neighbourhood level and related with other information regarding risks (e.g. Flood Risk Areas).
A3: Other stakeholders:	Yes, the indicator is considered by policy makers at international and national level.

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CREDIBLE	
C1: Unambiguous results:	Not completely. A reduction of the flooding risk in an area due to the impact of NBS implementation does not always need to be associated with a reduction of injured people or evacuated. This depends on the severity of the events of the specific year considered and also the behaviour of people. Also, as it is presented does not differentiate between types of injuries or periods of evacuation. Perhaps there is a reduction in the people injured but they injuries are more severe than in previous situation due to a reduction of the area of the impact of the natural disaster, but an increase in its intensity.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes

EASY	
E1: Availability of data to calculate the indicator:	The indicator needs data already collected. The issue is to obtain inventories of the data at local level
E2: Technical feasibility:	The indicator is very simple to calculate.
E3: Reproducibility:	Yes, it is possible to apply the indicator in numerous cases.

ROBUST	
R1: Data quality:	Yes, the indicator uses real data
R2: Sensitiveness:	No, there is no assessment of the uncertainty.
R3: Scale:	Yes, the indicator is originally proposed for national scales. But, due to the current quality of data in EU, we consider that it is feasible to transpose the indicator to local level.

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11 | GREEN ECONOMY

Short description of UC: The European Environment Agency (2017) defines Green Economy as one that generates increasing welfare while maintaining the environment that supports us. From a practical point of view, UNEP (2017) considers that a green economy is one whose *growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services.*

11.1 | CIRCULAR ECONOMY

Short description of USC: The circular economy goes beyond the traditional extractive industrial model and it aims to gradually decouple economic activity from the consumption of finite resources in order to reduce negative impacts. According to the Ellen Macarthur Foundation it is based on three principles: design out waste and pollution, keep products and materials in use and regenerate natural systems.

11.1.1 | C&DW – CONSTRUCTION AND DEMOLITION WASTE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.1 | Circular economy**

INDICATOR	
NAME	**11.1.1 | C&DW - Construction and demolition waste**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☐ City ☒ Neighbourhood ☒ Object
DEFINITION	Reporting is based on the output flows from relevant on site and off site processes. These output flows are split into the different waste fractions, so as to aid an understanding of the material flow as a whole and how much is reused and recycled.
FOCUS/OBJECTIVES	The focus of indicator is on waste that may arise at a number of specific, defined points in the life cycle of a building/project.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• kg of waste and materials generated • m^2 of useful floor area
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Practitioners

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FREQUENCY (how often to use this indicator?)	• Once for each life cycle stage and project
MEASUREMENT UNIT	• kg of waste and materials generated per 1 m2 of useful floor area demolished or constructed (kg/m2/life cycle stage reported on).
REQUIRED TOOL	• No specific tool required.
CALCULATION METHOD	The common performance assessment focuses on gathering data to report on the total waste disposed of and waste diverted. This requires confirmation of the waste types and whether the data is estimated or from a site. The reporting is at a basic level, making a distinction between waste disposed of and waste diverted For each of the stages in the life cycle (design stage, construction stage and completion stage) , and as relevant to the nature of the project being reported on, the following categories of output flows shall be reported on, with the option to disaggregate each flow by material stream: • Waste disposed of: hazardous and non-hazardous waste streams. This shall include waste disposed of to landfill and by incineration. • Components for re-use: This shall include all materials recovered for re-use either on or off site, with a focus on encouraging the reuse of structural elements. • Materials for recycling: This shall include all materials recovered for recycling either on or off site. Waste materials used in backfilling operations on or off site are excluded. • Materials for other material recovery operations: This shall include backfilling and processes that meet the EU definition of energy recovery. Waste generated during the prefabrication or assembly of parts or elements off site that would otherwise take place on site shall be included within reporting on waste disposed of. This is to ensure that any burden shifting in order to reduce on-site waste is accounted for. The flows reported on under the scope of this indicator reflect those defined 'indicators describing additional environmental information' in the reference standards EN 15978.
OUTPUT TYPE	• Quantitative
EXAMPLES	

LINKS AND REFERENCES	
KEYWORDS	• Life cycle assessment • Waste • Recycling
LINKS AND REFERENCES	• Nicholas Dodd, Mauro Cordella, Marzia Traverso, Shane Donatello, “Level(s) – A common EU framework of core sustainability indicators for office and residential buildings” European Commission Joint Research Centre, August 2017

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TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	11 | Green economy	11.1 | Circular economy

INDICATOR	
NAME	11.1.1 | C&DW - Construction and demolition waste

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	This indicator is designed to monitor the development of the recycling rate.
R2: Policy support for policies:	For most European countries an improvement in the national recycling rate is a political goal. Directive 2008/98/EC on waste established the following target in Article 11(2): "for the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight". Therefore the intended trend in recycling rate is upwards (although for economic and technical reasons the long term goal might be below 100%).19 The indicator is a Resource Efficiency Indicator (t2020_rt120). It has been included in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.
R3: Comparability:	The Eurostat quality grading system considers that the comparability of this indicator (geographical and over time) is high.

[19] http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/resource-efficiency-indicators/resource-efficiency-scoreboard/thematic-indicators/transforming-the-economy/turning-waste-into-resource

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ACCEPTED	
A1: Policy makers:	Considered within "Urban indicators for sustainable cities" by European Commission as part of the best currently available indicator tools for sustainable cities. [20]
A2: Practitioners:	Yes.
A3: Other stakeholders:	The indicator is accepted by academics and related working in sustainable economy.

CREDIBLE	
C1: Unambiguous results:	Yes.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes. The issue is to ensure the collection of information at municipal level.

EASY	
E1: Availability of data to calculate the indicator:	Yes.
E2: Technical feasibility:	The calculation of the indicator is easy.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	It is used at country and European level but this indicator will not be adequate for the neighbourhood or object level

[20] Science for Environment Policy (2015) Indicators for sustainable cities. In-depth Report 12. Produced for the European Commission DG Environment by the Science Communication

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11 | GREEN ECONOMY

11.1 | CIRCULAR ECONOMY

11.1.2 | MCI – MATERIAL CIRCULATORY INDIC

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.1 | Circular economy**

INDICATOR	
NAME	**11.1.2 | MCI - Material Circulatory Indicator**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐☐No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	Material circularity indicator (MCI) measures how circular a production system and how long and intensely the product in question is being used. It is comprised of the amount of virgin materials used during production stage, amount of unrecoverable waste generated at the end of product life cycle and utility factor.
FOCUS/OBJECTIVES	The objective of the indicator is to give a value in terms of circularity as a result of strategic implementation of NBS.
NOTES	According to the type of the NBS implemented, the priority of this indicator may change.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	● V: Mass of virgin feedstock used in a product ● M: Mass of a product ● F_R: Fraction of mass of a product's feedstock from recycled sources ● F_U: Fraction of mass of a product's feedstock from reused sources ● W: Mass of unrecoverable waste ● W_0: Mass of unrecoverable waste through a product's material going into landfill, waste to energy and any other type of process where the materials are no longer recoverable ● W_F: Mass of unrecoverable waste generated when producing recycled feedstock for a product ● W_C: Mass of unrecoverable waste generated in the process of recycling parts of a product ● L: lifetime of the product ● L_{av}: average lifetime of the similar products on the market ● U: number of times function served over the lifetime ● U_{av}: average number of times function is served over the lifetime by similar products on the market
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	● Public Administration
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	● N/A
REQUIRED TOOL	● There is no specific software required. But in order to collect the information extensive databases and software such as Excel or Access to manage them will be required.
CALCULATION METHOD	• Evaluate the virgin feedstock consumption • Calculate the mass of unrecoverable waste • Evaluate the utility factor F(X) • Evaluate linear flow index (LFI) • Calculate MCI
OUTPUT TYPE	● Quantitative value
EXAMPLES	● An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005 (Haas et al, 2015).

LINKS AND REFERENCES	
KEYWORDS	● Material Circularity Indicator ● Circular economy
LINKS AND REFERENCES	● Ellen McArthur Foundation & Granta, 2015. Circularity Indicators An Approach to Measuring Circularity Methodology. URL: https://www.ellenmacarthurfoundation.org/assets/downloads/insight/CircularityIndicators_Methodology_May2015.pdf Date of Access: July 2016. ● Haas, W., Krausmann, F., Wiedenhofer, D., & Heinz, M, 2015, How Circular is the Global Economy?: An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005. *Journal of Industrial Ecology, 19*(5), 765-777.

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TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.1 | Circular economy**

INDICATOR	
NAME	**11.1.2 | MCI - Material Circulatory Indicator**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, as the project aims to introduce NBS as mainstream solutions for re-naturing cities, this indicator is crucial as it gives a broader insight of the material life cycle. Therefore, it enables to engage urban stakeholders in a collective-learning process about re-naturing cities.
R2: Policy support for policies:	Yes. Material Circularity indicator is related to the EU priority *"Towards a Circular Economy"* and to specific policies such as: "*Closing the loop - An EU action plan for the Circular Economy Brussels, European Commission, 2015*".
R3: Comparability:	Yes. As long as the data is available and open source (by public administrations). It is designed for use with product data representative of what actually happens in the marketplace. The Material Circularity Indicator is constructed by first computing virgin feedstock and unrecoverable waste, then building in the utility factor. The Material Circularity Indicator of a product can then be defined by an equation and it is quantitative, so the comparability is guaranteed.

ACCEPTED	
A1: Policy makers:	No
A2: Practitioners:	Yes, it could help to engage urban planners improve the city waste treatment system and procedures.
A3: Other stakeholders:	Yes. Analysed in "An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005 (Haas et al, 2015)". And developed in "Circularity Indicators – An approach to measuring circularity" (LIFE project).

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CREDIBLE	
C1: Unambiguous results:	Yes, the indicator measures how circular a production system and how long and intensely the product in question is being used. It is an indicator that gives a clear value in terms of circularity as a result of strategic implementation of NBS.
C2: Transparency:	Yes. It is provided by an equation.
C3: Documentation of assumptions and limitations:	Yes

EASY	
E1: Availability of data to calculate the indicator:	Yes, the data that it requires is usually from open sources and given by Public Administrations.
E2: Technical feasibility:	Yes, the indicator is rather easy to calculate by an/several equations.
E3: Reproducibility:	Yes, it is possible to use the indicator in numerous case studies.

ROBUST	
R1: Data quality:	Yes.
R2: Sensitiveness:	No. There is no equation or any other method to calculate the error or uncertainty.
R3: Scale:	Yes, the indicator can be applied at metropolitan level, city scale, district scales, or scales below city level.

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11 | GREEN ECONOMY

11.1 | CIRCULAR ECONOMY

11.1.3 | RRMW – RECYCLING MUNICIPAL WASTE

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.1 | Circular economy**

INDICATOR	
NAME	**11.1.3 | RRMW - Recycling rate of municipal waste**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☐ Yes ☒ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	Recycling of waste is defined as any recovery operation by which waste materials are reprocessed into products, materials or substances, whether for the original or other purposes. It includes the reprocessing of organic material (e.g. by composting or digesting) but does not include energy recovery and reprocessing into materials that are to be used as fuels or for backfilling operations (Eurostat, 2015).
FOCUS/OBJECTIVES	The objective is to measure the increase or not of recycling rates in urban areas after the implementation of NBS.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Tonnage recycled from municipal waste per year (includes material recycling, composting and anaerobic digestion) • Total municipal waste generated per year
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Public Administration
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• % from municipal waste per year
REQUIRED TOOL	• There is no specific software required.
CALCULATION METHOD	For the calculation of the indicator the annual amount of waste generated in 1000 tonnes is divided by the amount of material recycling + composting and digestion for the relevant year.
OUTPUT TYPE	• Quantitative
EXAMPLES	• A.W. Larsen, H. Merrild, J. Møller, T.H. Christensen, Waste collection systems for recyclables: An environmental and economic assessment for the municipality of Aarhus (Denmark), In Waste Management, Volume 30, Issue 5, 2010, Pages 744-754, ISSN 0956-053X,

LINKS AND REFERENCES	
KEYWORDS	• Waste • Recycling
LINKS AND REFERENCES	• EUROSTAT: TURNING WASTE INTO A RESOURCE http://ec.europa.eu/eurostat/web/environmental-data-centre-on-natural-resources/resource-efficiency-indicators/resource-efficiency-scoreboard/thematic-indicators/transforming-the-economy/turning-waste-into-resource#recycling-rate • Eurostat: Environmental Data Centre on Waste: Municipal waste • Mudgal, S., Tan, A., Lockwood, S., Eisenmenger, N., Fischer-Kowalski, M., Giljum, S., Brucker, M., 2012. Assessment of Resource Efficiency Indicators and Targets – Annex Report URL: http://ec.europa.eu/environment/enveco/resource_efficiency/pdf/annex_report.pdf Date of access: October 2017 • Science for Environment Policy (2015) Indicators for sustainable cities. In-depth Report 12. Produced for the European Commission DG Environment by the Science Communication

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.1 | Circular economy**

INDICATOR	
NAME	**11.1.3 | RRMW - Recycling rate of municipal waste**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	As complementary to waste generation indicator, recycling rates reveal the efficiency of waste management activities, which is important for urban ecosystems. The indicator is able to describe increase or decrease in the recycling in cities (including material recycling, composting and anaerobic digestion)
R2: Policy support for policies:	For most European countries an improvement in the national recycling rate is a political goal. Directive 2008/98/EC on waste established the following target in Article 11(2): "for the preparing for re-use and the recycling of waste materials such as at least paper, metal, plastic and glass from households and possibly from other origins as far as these waste streams are similar to waste from households, shall be increased to a minimum of overall 50 % by weight". Therefore the intended trend in recycling rate is upwards (although for economic and technical reasons the long term goal might be below 100%)
R3: Comparability:	The Eurostat quality grading system considers that the comparability of this indicator (geographical and over time) is high.

ACCEPTED	
A1: Policy makers:	Considered within “Urban indicators for sustainable cities” by European Commission as part of the best currently available indicator tools for sustainable cities.
A2: Practitioners:	

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A3: Other stakeholders:	Recycling is an issue that first gained importance on the industry (micro) level. Thus, the acceptance of recycling rates and the value of monitoring can be considered as important on the industry level. The importance is even increasing with rising global market prices for metals and minerals. Recycling is a field of interest for academia, in particular research groups focussing on substance flows. However, a standardization of indicators has not yet been achieved which can be applied across substances and address different research questions in a comparable way. Recycling can be easily understood by the general public and is accepted by the civil society as an indicator of importance. However, the lack of transparency in what exactly is measured has not yet lead to a deep understanding of recycling.

CREDIBLE	
C1: Unambiguous results:	Higher recycling rates do show that more resources are used in a closed circle. However, without an additional measure of total amounts of secondary (or alternatively primary) raw materials used by societies the indicator cannot show if more or less of a particular resource is used.
C2: Transparency:	Recycling can be easily understood by the general public and is accepted by the civil society as an indicator of importance. However, the lack of transparency in what exactly is measured has not yet lead to a deep understanding of recycling. At the moment, different definitions of recycling rates are available. More transparency and a harmonization of terms and methods are urgently needed.
C3: Documentation of assumptions and limitations:	More transparency and a harmonization of terms and methods are urgently needed.

EASY	
E1: Availability of data to calculate the indicator:	No consistent data on recycling rates for metals or non-metallic minerals are available across substances and sectors. The underlying data (consistent with macro material flow data or also waste statistics) lack consistency.
E2: Technical feasibility:	If the underlying data were available, the indicator could be calculated most easily.
E3: Reproducibility:	Currently, several definitions of and measures for recycling are available and the indication on what exactly is measured in not always clear. This makes it very difficult to understand and reproduce results.

ROBUST	
R1: Data quality:	No consistent data on recycling rates for metals or non-metallic minerals are available across substances and sectors. The underlying data (consistent with macro material flow data or also waste statistics) lack consistency.
R2: Sensitiveness:	The indicator has the potential to capture short-term effects. However, the sensitiveness to policy changes depends on whether there are incentives for change as well as on the development of new technologies that enable the practical implementation of theoretical recycling options.

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R3: Scale:	Yes.

11.2.1 | GVAEGS

11 | GREEN ECONOMY

11.2 | BIOECONOMY ACTIVITIES

Short description of USC: Bioeconomy covers all the economic sectors and industries, including their service areas, that produce manage or use biological resources. As part of the green economy challenge, the bioeconomy sub-challenge is focused on assessing how NBS and their implementation could contribute to the empowerment of these economic sectors in the urban areas, by increasing the local production of biological resources or making a more efficient use of biowastes.

11.2.1 | GVAEGS – GROSS VALUE ADDED ENVIRONMENTAL GOOD & SERVICES

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	11 | Green economy	11.2 | Bioeconomy activities

INDICATOR	
NAME	**11.2.1 | GVAEGS - Gross Value Added in the local Environmental Good & Services sector**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	This indicator measures the value added by the Environmental Good & Services (EGS) sector to the total economy with respect the total value of the other activities. The value added reflects the contribution of labour and capital to production.
FOCUS/ OBJECTIVES	The objective of the indicator is to give an overall value in monetary units of the increase or decrease of the EGS sector due to strategic implementation of NBS.
NOTES	If the NBS implementation is not strategic or it is not developed with a focus on enhancing the economy of the area (e.g. provision of new jobs, enhancement of bioproducts market) this indicator would be irrelevant. But also other indicators of bioeconomy.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Information on the value added of the different products and economic activities related to the EGS sector (see Appendix I and II of Eurostat 2016) in the city.

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	• Value added is the value of the gross output of producers less the value of intermediate goods and services consumed in production, before accounting for consumption of fixed capital in production. It is calculated at either basic prices (excluding net taxes on products) or producer prices (including net taxes on products paid by producers but excluding sales or value added taxes). Both valuations exclude transport charges that are invoiced separately by producers. Total GDP is measured at purchaser prices. Value added by industry is normally measured at basic prices. Therefore, to apply this indicator the city council needs to monitor its GDP and the value added of the different economic sectors.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Public Administration
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• % of the city GDP/year
REQUIRED TOOL	• There is no specific software required. But in order to collect the information extensive databases and software such as Excel or Access to manage them will be required.
CALCULATION METHOD	• Sum up of the added values of Environmental Goods & Services sector divided by the GDP of the city. • In order to obtain the added value the EGS sector output from activities and products will need to be calculated first. • The calculation procedure can be found in the chapter 3 and 5 of Eurostat 2016. Due to the extension of it will not be included in the fact sheet
OUTPUT TYPE	• Aggregated quantitative value
EXAMPLES	Low Carbon Leicester and Leicestershire research Study (Dalgleish et al, 2014). Note: This example uses information on the EGS sector (employment and GVA) to inform about the increase of the green economy. However, the example does not relate to NBS.

LINKS AND REFERENCES	
KEYWORDS	• Output • Gross Value Added • GDP
LINKS AND REFERENCES	• Eurostat. 2016. Environmental goods and services sector accounts: practical guide. 2016 Edition. [Link]: http://webcache.googleusercontent.com/search?q=cache:8qVPUrr3_2kJ:ec.europa.eu/eurostat/documents/3859598/7741794/KS-GQ-16-011-EN-N.pdf/3196a7bc-c269-40ab-b48a-73465e3edd89+&cd=3&hl=en&ct=clnk&gl=fr] [Last Access]: 30th September 2017 • Eurostat. 2009. The Environmental Goods & Services Sector – A Data Collection Handbook. Namur, Eurostat. • Green Growth Knowledge Platform. 2013. Moving towards a common approach on green growth indicators. • OECD. 2011. Towards Green Growth: Monitoring Progress - OECD Indicators. OECD, Paris.

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- UNEP. 2012. Measuring Progress towards an Inclusive Green Economy. UNEP, Nairobi.
- K. Dalgleish, W. Eadson, M. Foden, Gore. 2014. Low Carbon Leicester and Leicestershire Research Study, Centre for Regional Economic and Social Research. Sheffield, Sheffield Hallam University.

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.2 | Bioeconomy activities**

INDICATOR	
NAME	**11.2.1 | GVAEGS - Gross Value Added in the local Environmental Good & Services sector**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is able to describe increase or decrease in the gross value added of the environmental good and services sector (EGSS) as a proxy of enhance of a green economy. In the case, of cities related to the bioeconomy sector.
R2: Policy support for policies:	Not related to specific policies. However, the indicator is included in the Green Economy Growth indicators list of the OECD and recommended by EUROSTAT at national level. Therefore, we consider that contributes to the objective of monitor the enchancement of national green economies.
R3: Comparability:	The methodology is already applied in countries. The indicator has been already used for Leicester City and Leicestershire. We assumed that for other cities pushing green economy. EUROSTAT includes a standardized procedure to select the activities and products part of EGSS, which could be applied for cities too. The main limitation is that municipalities need to compile the information required for the calculation. It is not common right now. However, it might be possible in the case of EU.

ACCEPTED	
A1: Policy makers:	No, that we know. But please see R2

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A2: Practitioners:	Yes, once the economic information is collected this could inform metropolitan or city level strategies regarding green economy or sustainability.
A3: Other stakeholders:	The indicator is accepted by economic academics and related working in sustainable economy. Also, it is accepted by institutions such as World Economic Forum (integrates the indicator in Inclusive Development Index), EUROSTAT and OECD.

CREDIBLE	
C1: Unambiguous results:	The indicator is complicated and depends on several economic factors that are not well understood by the general public. The indicator could be affected by other interventions not related to NBS or their implementation. Therefore, its change in values cannot be strictly linked to NBS, unless there is no policy change or other type of intervention affecting the EGSS.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes. The issue as stated above is to ensure the collection of information at municipal level.

EASY	
E1: Availability of data to calculate the indicator:	No, usually cities do not collect all the data required. But many cities might have already part of the data required.
E2: Technical feasibility:	The calculation of the indicator is not excessively complicated once the database is available. However, the collection of the data and its aggregation require economy expertise. We consider that municipalities and related agencies have economist in their group of employees. Therefore, if the access to the data is possible at local level it should be technically feasible to do the calculation.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	No. It would be difficult to go beyond the city or metropolitan level. This indicator will not be adequate for the neighbourhood or object level

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11 | GREEN ECONOMY

11.2 | BIOECONOMY ACTIVITIES

11.2.2 | LPB – LABOUR PRODUCTIVITY BIO

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.2 | Bioeconomy activities**

INDICATOR	
NAME	**11.2.2 | LPB - Labour productivity of bioeconomy**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	The average amount of turnover generated by a person employed in the bioeconomy
FOCUS/OBJECTIVES	A decreasing number of persons employed and an increasing turnover results in labour productivity gains. Generally, the focus is on sectoral efficiency.
NOTES	This would only be relevant if the NBS is implemented to support policy/strategically enhance the bioeconomy and this would be an indicator of the status of the sector.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• Number of people employed and turnover – for the manufacturing sectors as defined below: • Number of persons employed: The number of persons employed is defined as the total number of persons who work in the observation unit (inclusive of working proprietors, partners working regularly in the unit and unpaid family workers working regularly in the unit), as well as persons

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	who work outside the unit who belong to it and are paid by it (e.g. sales representatives, delivery personnel, repair and maintenance teams). It includes persons absent for a short period (e.g. sick leave, paid leave or special leave), and also those on strike, but not those absent for an indefinite period. It also includes part-time workers who are regarded as such under the laws of the country concerned and who are on the pay-roll, as well as seasonal workers, apprentices and home workers on the pay-roll. • Location quotient (LQ) = employment share in the bioeconomy of a Member State total divided by the employment share in the EU bioeconomy of the EU total (or studied domain). LQ is a way of quantifying how "concentrated" the bioeconomy is in a Member State compared to the European Union. • Turnover (Million euros): Turnover comprises the totals invoiced by the observation unit during the reference period, and this corresponds to market sales of goods or services supplied to third parties.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Public statistics entitry (Ie. Eurostat) • Bioeconomy specific data extracted from EUROSTAT and STECF is available at "Jobs and Turnover in the European Union Bioeconomy" https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html • In this research: Employment data are retrieved from Eurostat's Labour Force Surveys (lfsa_egan22d for the agricultural sector and for_emp_lfs for the forestry sector) and Economic Accounts (aact_eaa01 for the agricultural sector and for_eco_cp for the forestry sector). Fishing data is from Scientific, Technical and Economic Committee for Fisheries (STECF) in two different documents: (i) aquaculture data are compiled in the report on 'the economic performance of the EU Aquaculture Sector' (STECF, 2014) while (ii) landings data are released in the 'Annual Economic Report on the EU Fishing Fleet' (STECF, 2016).
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• € turnover/persons employed
REQUIRED TOOL	• There is no specific software required. But in order to collect and process software such as Excel or Access to manage them will be required.
CALCULATION METHOD	• A simple division of turnover/persons employed
OUTPUT TYPE	• Aggregated quantitative value
EXAMPLES	Bioeconomy turnover values for EU countries can be found at "Jobs and Turnover in the European Union Bioeconomy" https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html.

LINKS AND REFERENCES	
KEYWORDS	• Productivity • Labour • Turnover • Employment

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LINKS AND REFERENCES	• EC 2014. Jobs and Turnover in the European Union Bioeconomy [Link]: https://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html [Last Access]: 4 October 2017 • Ronzon, Tevecia; Pietrowski, Stephan; M'Barek, Robert; Carus, Michael. 2017. A systematic approach to understanding and quantifying the EU's bioeconomy.

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.2 | Bioeconomy activities**

INDICATOR	
NAME	**11.2.2 | LPB - Labour productivity of bioeconomy**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, The indicator is able to describe labour productivity in the bioeconomy sector, which is related to planning but not a primary problem in planning. It may be an indirect result of a planning decision and an indirect problem.
R2: Policy support for policies:	No.
R3: Comparability:	It is possible to standardise the methodology as it is a simple calculation that is more dependent on data source than the tool of calculation. Existing databases can be used and compared.

ACCEPTED	
A1: Policy makers:	Not of our knowledge, though it can be integrated.
A2: Practitioners:	It can be observed and taken into consideration for policy planning and urban strategic planning but not directly an input for plans.
A3: Other stakeholders:	Not in the context of NBS.

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CREDIBLE	
C1: Unambiguous results:	Yes, as it is a simple calculation that delivers a clear numeric output, it is very easy to comprehend and utilize.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes.

EASY	
E1: Availability of data to calculate the indicator:	Yes, the data should have been already collected by public agencies.
E2: Technical feasibility:	Yes, the indicator is rather easy to calculate.
E3: Reproducibility:	Yes, it is possible to use the indicator in numerous case studies.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	No, the indicator should be applied at city and metropolitan level, but is not meaningful at object level.

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11 | GREEN ECONOMY

11.2 | BIOECONOMY ACTIVITIES

11.2.3 | NVATRBB – NO. VAT REGISTERED BIOECONOMY BUSINESS

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.2 | Bioeconomy activities**

INDICATOR	
NAME	**11.2.3 | NVATRBB - N° of VAT registered bioeconomy business**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☒ 1st ☐ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	This indicator measures the increase or decrease in the bioeconomy business in the area after implementation of NBS in a strategic level
FOCUS/OBJECTIVES	To assess the increase of new companies related to bioeconomy after strategic implementation of NBS in an urban area. It will measure the economic impact of strategic implementation models of NBS that take into account economic aspects.
NOTES	If the NBS implementation is not strategic or it is not developed with a focus on enhancing the economy of the area (e.g. provision of new jobs, enhancement of bioproducts market) this indicator would be irrelevant. But also other indicators of bioeconomy.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

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DATA AND MEASUREMENT	
REQUIRED DATA	• Information on VAT registered companies in the city obtained from the public administration classified by economic sectors. • Later an aggregation of all the sectors related to bioeconomy will be necessary. Note: In many cases this information is controlled by national or regional authorities. Therefore, it would be necessary to contact them and ask for the information of a certain municipality or groups of them.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Public Administration
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• Number of business/ha
REQUIRED TOOL	• The indicator is rather simple to calculate. No tool will be required
CALCULATION METHOD	• Simple equation (Number of business/administrative area of the city)
OUTPUT TYPE	• Simple quantitative value
EXAMPLES	

LINKS AND REFERENCES	
KEYWORDS	• VAT • Registered companies
LINKS AND REFERENCES	• World Bank's Entrepreneurship Survey and database. 2017. [Link]: http://econ.worldbank.org/research/entrepreneurship). [Last Access]: 29/09/2017 • Indicators – Defra Science. 2017 [Link]: http://randd.defra.gov.uk/Document.aspx?Document=NR0119_8756_FRA.pdf. [Last Access]: 29/09/2017

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.2 | Bioeconomy activities**

INDICATOR	
NAME	**11.2.3 | NVATRBB - N° of VAT registered bioeconomy business**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, the indicator is able to describe increase in business in the bioeconomy sector. Therefore, the increase of employment and contribution to wealth coming from this sector.
R2: Policy support for policies:	No.
R3: Comparability:	The methodology is rather simple. It only needs to account for increase of business in the bioeconomy sector divided by the total area of the city. The data regarding VAT business should be obtained from public agencies (e.g. HM Revenue & Customs). Therefore, the procedure it should be similar in different countries, already quite standardised.

ACCEPTED	
A1: Policy makers:	No.
A2: Practitioners:	Yes, it could help urban planners for plans and strategy at city and metropolitan level. It could provide a better understanding of the effect of NBS implementation at those levels.
A3: Other stakeholders:	No.

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CREDIBLE	
C1: Unambiguous results:	Yes, the indicator informs about the increase or decrease of businesses related to the bioeconomy. Therefore, gives unbiased information about the contribution to wealth of this sector. It is an indicator easy to explain to the general public. Therefore, it is expected to be understood by the general public.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes.

EASY	
E1: Availability of data to calculate the indicator	Yes, the data should have been already collected by public agencies.
E2: Technical feasibility:	Yes, the indicator is rather easy to calculate.
E3: Reproducibility:	Yes, it is possible to use the indicator in numerous case studies.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	No, the indicator should be applied at city and metropolitan level, but not below city level.

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11 | GREEN ECONOMY

11.3 | DIRECT ECONOMIC VALUE OF NBS

Short description of USC: Nature-based solutions need to demonstrate their value as economic input in cities to facilitate its mainstreaming in cities. As part of the green economy challenge, the Direct Economic Value of NBS assess the contribution of suppliec ecosystem services into the economy of cities by reducing costs or avoiding them, demonstration their insurance value (to mitigate economic impacts of extreme natural events) and increasing the value of private and public built assets, such as private residential properties.

11.3.1 | ANS – ADJUSTED NET SAVING

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730468

Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.3 | Direct economic value of NBS**

INDICATOR	
NAME	**11.3.1 | ANS - Adjusted Net Saving (or Genuine Saving)**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	Adjusted net savings are equal to net municipal savings plus education expenditure and minus energy depletion, mineral depletion, net forest depletion, and carbon dioxide and particulate emissions damage.
FOCUS/OBJECTIVES	The objective is to measure the reduction or not of natural capital depletion and damage from carbon dioxide and particulate emissions produced by (and in) urban areas after the implementation of NBS.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	• The contribution of the municipality to gross national income and the expenses of the total consumption. • Current public expenditure on education • Contribution of the municipality to energy, mineral and forest depletion (depletion of Natural Capital).

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	• Data on CO_2 emissions and sequestration • Data on Air Pollution emissions and deposition.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Public Administration • Monitoring stations of pollutants • Remote Sensing
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• % of the city GNI
REQUIRED TOOL	• There is no specific software required. But in order to collect the information extensive databases and software such as Excel or Access to manage them will be required.
CALCULATION METHOD	Adjusted net savings are derived from standard city accounting measures of gross savings by making four adjustments: • First, estimates of fixed capital consumption of produced assets are deducted to obtain net savings. • Second, current public expenditures on education are added to net savings (in standard national accounting these expenditures are treated as consumption). • Third, estimates of the depletion of a variety of natural resources are deducted to reflect the decline in asset values associated with their extraction and harvest. • And fourth, deductions are made for damages from carbon dioxide emissions and local pollution Note: the fourth calculation uses experimental estimates. Waves 2014 is recommended as a reference.
OUTPUT TYPE	• Aggregated quantitative value
EXAMPLES	- Wen, Z.G. et al. 2005.

LINKS AND REFERENCES	
KEYWORDS	• Natural Capital • Depletion • Emissions • Gross National Income
LINKS AND REFERENCES	• World Bank. 2006. *Where is the Wealth of Nations? Measuring Capital for the 21st Century.* Washington, DC: The World Bank. • World Bank. 2011. *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millenium.* Washington, DC: The World Bank. • Waves. 2015. Constructing Adjusted Net Saving: Presentation. [Link]:https://webcache.googleusercontent.com/search?q=cache:eYFzXaCbbEUJ:https://www.wavespartnership.org/sites/waves/files/images/Constructing%2520Adjusted%2520Net%2520Saving.pdf+&cd=1&hl=en&ct=clnk&gl=fr [Last Access]: 29/09/2017 • World Bank Data 2017. [Link]: https://data.worldbank.org/indicator/NY.ADJ.SVNG.GN.ZS?view=chart [Last Access]: 29/09/2017

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	• Wen, Z.G., et al., 2005. Genuine saving rate: an integrated indicator to measure sustainable development towards ecocity. International Journal of Sustainable Development and World Ecology 12 (2), 184–196.

Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.3 | Direct economic value of NBS**

INDICATOR	
NAME	**11.3.1 | ANS - Adjusted Net Saving (or Genuine Saving)**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	The indicator is able to describe increase or decrease in the depletion of resources and pollutants in cities or by city contribution
R2: Policy support for policies:	No
R3: Comparability:	The methodology is already applied in countries and in some cases for counties. We also found application of the indicator to calculate sustainable development of ecocities in China. The methodology is standardised by the World Bank and WAVES includes a short presentation on how to calculate the different factors. However, municipalities need to compile the information required for the calculation. It is not common right now. However, it might be possible in the case of EU.

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ACCEPTED	
A1: Policy makers:	No, that we know. But it is used by World Bank to assess sustainable performance of countries.
A2: Practitioners:	Yes, once the economic information is collected this could inform metropolitan or city level strategies regarding green economy or sustainability.
A3: Other stakeholders:	The indicator is accepted by economic academics and related working in sustainable economy. Also, it is accepted by institutions such as World Economic Forum (integrates the indicator in Inclusive Development Index) and World Bank.

CREDIBLE	
C1: Unambiguous results:	The indicator is complicated and depends on several economic factors that are not well understood by the general public. Also, the value of the indicators could be affected by many other interventions that reduce the depletion of natural capital .Therefore, it is not strictly linked to NBS.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes. The issue as stated above is to ensure the collection of information at municipal level.

EASY	
E1: Availability of data to calculate the indicator:	No, usually cities do not collect all the data required. But many cities might have already part of the data required.
E2: Technical feasibility:	The calculation of the indicator is not excessively complicated once the database is available. However, the collection of the data and its aggregation require economy expertise. We consider that municipalities and related agencies have economist in their group of employees. Therefore, if the access to the data is possible at local level it should be technically feasible to do the calculation.
E3: Reproducibility:	Yes

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	No. It would be difficult to go beyond the city or metropolitan level. This indicator will not be adequate for the neighbourhood or object level

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11 | GREEN ECONOMY

11.3 | DIRECT ECONOMIC VALUE OF NBS

11.3.2 | HPI – HOUSE PRICING INDEX

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.3 | Direct economic value of NBS**

INDICATOR	
NAME	**11.3.2 | HPI - House Pricing Index**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☒ 2nd ☐ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☒ Assessment ☐ Monitoring
SCALE (☐ | ☒)	☒ City ☒ Neighbourhood ☐ Object
DEFINITION	The indicator measures the price of residential building's value in an area or group of areas. In this case, the value of housing act as a component of wealth in an area.
FOCUS/OBJECTIVES	To calculate the housing pricing index before NBS implementation and to monitor its change after the implementation would permit to understand if the NBS has enhanced the value of housing, and wealth in general.
NOTES	This indicator or similar could be used also to understand if gentrification might be occurring in a neighbourhood.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	Data in the following housing characteristics for a statistically relevant number of observations inside the area of interest: • The area of the structure of the house • The area of the land that the structure sits on

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	• The location • The age of the structure • The type of structure (apartment, detached dwelling, etc) • The materials used in the construction • The number of bedrooms, bathrooms, garage, and other facilities • Urban green areas characteristics: distance to houses, size, spatial configuration, species composition. Note: Usually information on urban green areas is not considered in detail. But in our case we want to understand the influence of green areas (NBS) in the housing price. Authors such as Cho et al (2008), Saphores & Li (2012), and Luttik (2000). In our case, we want to understand the relevance of green areas and distances of housing to them on the housing price index. So, we can better value their contribution to wealth. So, during the application of the time dummy variable method we will focus on the effect of urban green areas characteristics and their changes in the housing price index.
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Information from the real estate market in the area of interest. This should include the characteristics of the houses.
FREQUENCY (how often to use this indicator?)	• Annually
MEASUREMENT UNIT	• Euros/m2
REQUIRED TOOL	• No specific tool is required, but statistical treatment of the information is necessary. Therefore, software such as excel or specific statistical software (R, SPSS, Past) will be required.
CALCULATION METHOD	Extracted from Eurostat (2013) a calculation methods is proposed: hedonic regression method (time dummy variable method). • Definition of hedonic modelling (EUROSTAT, 2013, p.26). "Hedonic modelling assumes that information on the characteristics of the properties sold is known, the samples can be stratified and, if a sufficient number of observations is available, separate indices can be estimated for the strata. In other words, hedonic regression methods can provide a set of constant quality price indices for various types of property" • Calculation (EUROSTAT, 2013, p.50). In order to be able to estimate the marginal contributions of the characteristics using standard regression techniques, equation (5.1) has to be specified as a parametric model. The two best-known hedonic specifications are the fully linear model. $p_n^t = \beta_0^t + \sum_{k=1}^{K} \beta_k^t z_{nk}^t + \varepsilon_n^t$ and the logarithmic-linear model $\ln p_n^t = \beta_0^t + \sum_{k=1}^{K} \beta_k^t z_{nk}^t + \varepsilon_n^t$

	where *t*0 β and *tk* β are the intercept term and the characteristics parameters to be estimated. In practice, many explanatory variables will be categorical rather than continuous and represented by a set of dummy variables which take the value of 1 if a property belongs to the category in question and the value of 0 otherwise. Specificities of the Time Dummy Variable method to better account for changes on the quantities of the characteristics and their affection on the house price change can be found from page 51 of EUROSTAT (2013). Also a case study showing how to perform the calculation is found in page 57 of the same report (with information of the case study on page 42). .
OUTPUT TYPE	• A quantitative value
EXAMPLES	• Cho et al. 2008. Spatial analysis of the amenity value of green open space in Jinan City, China. • Saphores and Li. 2012. Estimating the value of urban green areas in Los Angeles. • Luttik, J., 2000. The value of trees, water and open space as reflected by house prices in the Netherlands.

LINKS AND REFERENCES

KEYWORDS	• Housing • Prices • Stratification of transactions • Hedonic Modeling
LINKS AND REFERENCES	• EUROSTAT. 2013. Handbook on residential property indices. EUROSTAT, Belgium. • EUROSTAT. 2017. Housing Price Statistics. [Link]: http://ec.europa.eu/eurostat/web/housing-price-statistics [Last Access]: 01/10/2017 • Cho, S.H., Poudyal, N.C. and Roberts, R.K. 2008. Spatial analysis of the amenity value of green open space. *Ecological Economics*, *66*(2), pp.403-416. • Luttik, J., 2000. The value of trees, water and open space as reflected by house prices in the Netherlands. *Landscape and urban planning*, *48*(3), pp.161-167. • Saphores, J.D. and Li, W. 2012. Estimating the value of urban green areas: A hedonic pricing analysis of the single family housing market in Los Angeles, CA. *Landscape and Urban Planning*, *104*(3), pp.373-38

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.3 | Direct economic value of NBS**

INDICATOR	
NAME	**11.3.2 | HPI - House Pricing Index**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	Yes, the indicator is able to describe changes in the values of residential buildings along the time due to changes in defined attributes of the houses and context. In our case green spaces is the main attribute of interest.
R2: Policy support for policies:	It is used for monetary policy and inflation targeting at a national level (EUROSTAT, 2013).
R3: Comparability:	The methodology is standardised. We selected the hedonic regression method, but other methods are possible. A specific emphasis on targeting attributes of urban green areas to include in the hedonic regression method is possible and already applied by several authors (e.g. Cho et al 2008). Although a specific group of attributes it is not agreed yet.

ACCEPTED	
A1: Policy makers:	Yes, at a national level. Please see R2
A2: Practitioners:	Yes, it could be useful for neighbourhood and metropolitan level. The first case could inform on the impact of specific interventions. The second case could inform on the impact of several or strategic interventions.
A3: Other stakeholders:	Yes, the indicator is used by economist, but also by the real estate sector.

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CREDIBLE	
C1: Unambiguous results:	The indicator depends on several attributes of the houses and context. In a ceteris paribus situation, where the main changes in the sample of observation is attributed to the implementation of NBS the indicator will provide unambiguous results. The sampling can be controlled to minimise the inclusion of properties too old (effect of depreciation value) or with refurbishments or extensions applied during the monitoring. In any case, the time dummy variable method stated as preferred should be able to inform about the impact of the specific attributes on the house pricing index.
C2: Transparency:	Yes
C3: Documentation of assumptions and limitations:	Yes. The issue is the collection of data, which could be time demanding.

EASY	
E1: Availability of data to calculate the indicator:	No, the data should be collected or obtained from sources that collect this data. We assume that real estate companies, insurance companies and in some cases public agencies (e.g. Treasury Chambers, HM Revenue & Customs) collect this data. It should be easy to update, but time demanding
E2: Technical feasibility:	The calculation of the indicator is not excessively complicated once the information is collected. We consider that municipalities and related agencies have economist or real estate professionals in their group of employees able to perform the calculations and statistical analysis.
E3: Reproducibility:	Yes. Also, it has been used in different case studies.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	The indicator could track impacts in neighbourhood and city scale.

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11 | GREEN ECONOMY

11.3 | DIRECT ECONOMIC VALUE OF NBS

11.3.3 | DIPSB – DIRECT AND INDIRECT PUBLIC SPENDING ON BIOECONOMY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.3 | Direct economic value of NBS**

INDICATOR	
NAME	**11.3.3 | DIPSB - Direct and indirect public spending on bioeconomy**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ ☒ 3 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☒ City ☐ Neighbourhood ☐ Object
DEFINITION	Direct public spending under grants, loans and incentives as well as indirect spendings under promotion, procurement, R&D education for bioeconomy
FOCUS/OBJECTIVES	To determine the amount of public spending on the bioeconomy, indicating policy level priority and potential of the sector
NOTES	●If the NBS implementation is not strategic or it is not developed with a focus on enhancing the bioeconomy, or if this investment does not support the development of NBS, this indicator would be irrelevant. But also other indicators of bioeconomy. ●The majority of the public sector's contribution to investment in the bioeconomy is found in research and innovation spending (though some also goes on capital expenditure such as buildings or equipment. ●This is part of EU's action plan for the bioeconomy as to " Ensure substantial EU and national funding as well as private investment and partnering for bioeconomy research and innovation. Develop further JPI and ERA-Net activities in order to strengthen coherence and synergies between public programmes.".

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data

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4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data
5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT	
REQUIRED DATA	Gross fixed capital formation data is needed from the relevant statistical authority of the public body of the studied domain. Some institutions that work with relevant data are: Bio Based Industries Consortium http://biconsortium.eu/ European Investment Bank http://www.eib.org Bio Based Industries Public Private Partnership https://bbi-europe.eu/
INPUT TYPE (qualitative, quantitative, …)	• Quantitative
DATA SOURCE	• Public Administration, statistics entity (depends on country) • Ie. US Data: Consolidated Federal Funds Report (CFFR)
FREQUENCY (how often to use this indicator?)	• Annually (can be done for any interval that is useful for the research, though budgets are annual)
MEASUREMENT UNIT	• €
REQUIRED TOOL	• The information will be retrieved as a cumulative number. Data processing tools such as Excel can be used to store and process the data.
CALCULATION METHOD	• Overall investment is defined as gross fixed capital formation which is probably the most regularly cited measure of investment from national accounts. It refers to the net increase (i.e. investment minus disposals) in physical (i.e. non-financial) assets within the measurement period. It does not account for the consumption (depreciation) of fixed capital, and also does not include land purchases. • Calculation is a simple sum of the statistical data mentioned above.
OUTPUT TYPE	• Aggregated quantitative value
EXAMPLES	• " Capital Economics Limited. 2016. Evidencing the Bioeconomy: An assessment of evidence on the contribution of, and growth opportunities in, the bioeconomy in the United Kingdom" provides an

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assessment of investments and sectoral examples but does not relate to NBS.

Investments	Indicators and Examples
Direct Public Spending	Direct payments to individuals (USDA Bioenergy Program)
	Grants (DOE Regional Biomass Energy Program, DOE Alternative Fuel Transportation Program)
	Loans and loan guarantees
	Infrastructure to new plants (roads, pipeines, other)
	Other incentives (federal, state, local)
	Other direct spending
Indirect Public Spending	Bioeconomy promotion
	Bioproduct procurement (FB4P)
	Research and development
	Workforce development/education systems (agricultural and science degree programs)
	Transportation infrastructure (highways, locks and dams, multimodal transportation)
Tax Policy	Production tax credits, tax rebates, depreciation allowances
Trade Policy	Tariffs and quotas

Figure 10 USDA. 2011. Biobased Economy Indicators

LINKS AND REFERENCES

KEYWORDS

- Public
- Subsidies
- Funding

LINKS AND REFERENCES

- USDA. 2011. Biobased Economy Indicators.
- Cambridge Econometrics. 2014. Criteria and Indicators describing the regional bioeconomy
- Capital Economics Limited. 2016. Evidencing the Bioeconomy: An assessment of evidence on the contribution of, and growth opportunities in, the bioeconomy in the United Kingdom
- EU. 2012. Innovating for Sustainable Growth: A Bioeconomy for Europe
- European Investment Bank. 2017. Access-to-finance conditions for Investments in Bio-Based Industries and the Blue Economy
- European Investment Bank. 2017. Agriculture and bioeconomy Unlocking production potential in a sustainable and resource-efficient way

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	11 | Green economy	11.3 | Direct economic value of NBS

INDICATOR	
NAME	**11.3.3 | DIPSB - Direct and indirect public spending on bioeconomy**

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	This is indirectly relevant as this indicator states "sectoral readiness" through its capacity to draw private investment and grow and bioeconomy is a sector that can support/be supported by NBS:
R2: Policy support for policies:	It is related to EU's Bioeconomy Policy, however not in relation to NBS.
R3: Comparability:	The results are in a simple total Euro amount which can be integrated into any calculation and compared.

ACCEPTED	
A1: Policy makers:	No.
A2: Practitioners:	It can be taken as a readiness level indicator for policy/strategic plans.
A3: Other stakeholders:	No.

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CREDIBLE	
C1: Unambiguous results:	This is a total amount expressed in the desired currency, which is very easy to communicate. What has been included and excluded in the calculation can easily be noted to compare values.
C2: Transparency:	Yes, though depending on the transparency of the data sources.
C3: Documentation of assumptions and limitations:	This is highly dependent on the privacy and data collection policies of the data sources, which can be multiple sources for the private sector.

EASY	
E1: Availability of data to calculate the indicator:	Data should be already collected as it is a numeric value expressing economic activity, however, it may be dispersed and not made available to the researcher as it comes from private sources to public statistical bodies. Entities such as the Bio Based Industries Consortium demonstrate progress in this regard.
E2: Technical feasibility:	Yes, it is a statistical value that is easy to calculate given data is available.
E3: Reproducibility:	Yes, it is possible to use the indicator in numerous case studies.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	No, the indicator should be applied at city and metropolitan level, but would not be useful in neighbourhood and object levels.

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11.3.4 | PIB

11 | GREEN ECONOMY

11.3 | DIRECT ECONOMIC VALUE OF NBS

11.3.4 | PIB – PRIVAT INVEST BIOECONOMY

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Factsheet URBAN PERFORMANCE INDICATOR

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	**11 | Green economy**	**11.3 | Direct economic value of NBS**

INDICATOR	
NAME	**11.3.4 | PIB - Private investment on bioeconomy**
COMPLEXITY LEVEL (☐ | ☒) see legend below	☐ 1 ☐ 2 ☐ ☒ 3 4 ☐ 5
INDICATOR LEVEL (☐ | ☒)	☐ 1st ☐ 2nd ☒ 3rd
AGGREGATION (☐ | ☒)	☒ Yes ☐ No
TYPE (☐ | ☒)	☐ Descriptive ☐ Assessment ☒ Monitoring
SCALE (☐ | ☒)	☐ City ☐ Neighbourhood ☒ Object
DEFINITION	Private capital investment (plant and equipment, storage and distribution infrastructure), private R&D investment, and other investments
FOCUS/ OBJECTIVES	To determine the amount and trends of private investment in the bioeconomy as it is a "readiness indicator" that allows the industry to grow.
NOTES	If the NBS implementation is not strategic or it is not developed with a focus on enhancing the bioeconomy, or if this investment does not support the development of NBS, this indicator would be irrelevant. But also other indicators of bioeconomy. Bioeconomy investments are seen as a way of enhancing economy and employment while contributing to matters such as food security by the EU and private investment is part of the bioeconomy strategy as: " Ensure substantial EU and national funding as well as private investment and partnering for bioeconomy research and innovation... Support bioclusters and KICs under the EIT for partnering with the private sector." Private investment is directly linked to public investment. Mitigating risk, providing subsidies to adopt new technologies and providing a knowledge base are mentioned among public activities that can improve this indicator.

LEGEND COMPLEXITY LEVEL	
1	Easy to calculate and requires few data
2	Easy to calculate but requires data
3	Medium calculation difficulty and required data
4	Medium calculation difficulty but requires lot of data OR High calculation and requires few data

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5	High calculation difficulty and requires lot of data

DATA AND MEASUREMENT

REQUIRED DATA

- C = business expenditures for things like machines, tools, land, and buildings

Investments	Indicators and Examples
Direct Public Spending	Direct payments to individuals (USDA Bioenergy Program)
	Grants (DOE Regional Biomass Energy Program, DOE Alternative Fuel Transportation Program)
	Loans and loan guarantees
	Infrastructure to new plants (roads, pipelines, other)
	Other incentives (federal, state, local)
	Other direct spending
Indirect Public Spending	Bioeconomy promotion
	Bioproduct procurement (FB4P)
	Research and development
	Workforce development/education systems (agricultural and science degree programs)
	Transportation infrastructure (highways, locks and dams, multimodal transportation)
Tax Policy	Production tax credits, tax rebates, depreciation allowances
Trade Policy	Tariffs and quotas

Figure 11 USDA. 2011. Biobased Economy Indicators

INPUT TYPE (qualitative, quantitative, …)

- Quantitative

DATA SOURCE

- Statistics entities and sectoral institutions are data sources.
- Published values of the capital costs of plants and equipment when new biofuel or other biobased production facilities are built can be used via aggregating from various institutions.
  Some institutions that work with relevant data are:
- Bio Based Industries Consortium http://biconsortium.eu/
- European Investment Bank http://www.eib.org
- Bio Based Industries Public Private Partnership https://bbi-europe.eu/

FREQUENCY (how often to use this indicator?)

- Annually (can be done for any interval that is useful for the research, though budgets are annual)

MEASUREMENT UNIT

- €

REQUIRED TOOL

- The information will be retrieved as a cumulative number. Data processing tools such as Excel can be used to store and process the data.

CALCULATION METHOD

- The calculation of GPDI (gross private domestic investment) has been taken as a basis here.
- GPDI = C + R + I considering:
  C = business expenditures for things like machines, tools, land, and buildings
  R = expenditures by landlords for things like home improvements or new buildings
  I = changes in inventories that are held by businesses

OUTPUT TYPE

- Aggregated quantitative value

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EXAMPLES	• " Capital Economics Limited. 2016. Evidencing the Bioeconomy: An assessment of evidence on the contribution of, and growth opportunities in, the bioeconomy in the United Kingdom" provides an assessment of investments and sectoral examples but does not relate to NBS.

LINKS AND REFERENCES	
KEYWORDS	• Investment • Private funding • Venture Capital
LINKS AND REFERENCES	• BERST Project. 2016. BERST Database. 2016 Edition. [Link]: https://berst.databank.nl/] [Last Access]: 10 October 2017 • Cambridge Econometrics. 2014. Criteria and Indicators describing the regional bioeconomy • USDA. 2011. Biobased Economy Indicators. • BioÖkonomieRat. 2010. Bio-Economy Innovation • Capital Economics Limited. 2016. Evidencing the Bioeconomy: An assessment of evidence on the contribution of, and growth opportunities in, the bioeconomy in the United Kingdom • European Investment Bank. 2017. Access-to-finance conditions for Investments in Bio-Based Industries and the Blue Economy • European Investment Bank. 2017. Agriculture and bioeconomy Unlocking production potential in a sustainable and resource-efficient way • EU. 2012. Innovating for Sustainable Growth: A Bioeconomy for Europe

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Factsheet Evaluation RACER

TOPIC	URBAN CHALLENGE	SUB-CHALLENGES
ECONOMY	11 | Green economy	11.3 | Direct economic value of NBS

INDICATOR	
NAME	11.3.4 | PIB - Private investment on bioeconomy

Green	criterion completely fulfilled
Yellow	criterion partly fulfilled
Red	criterion not fulfilled

For RACER legend and description see Table 8 on pp. 35-36.

RELEVANT	
R1: Linkage to the project aim:	This is indirectly relevant as this indicator states "sectoral readiness" through its capacity to draw private investment and grow and bioeconomy is a sector that can support/be supported by NBS:
R2: Policy support for policies:	It is related to EU's Bioeconomy Policy, however not in relation to NBS.
R3: Comparability:	The results are in a simple total Euro amount which can be integrated into any calculation and compared.

ACCEPTED	
A1: Policy makers:	No.
A2: Practitioners:	It can be taken as a readiness level indicator for policy/strategic plans.
A3: Other stakeholders:	No.

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CREDIBLE	
C1: Unambiguous results:	This is a total amount expressed in the desired currency, which is very easy to communicate. What has been included and excluded in the calculation can easily be noted to compare values.
C2: Transparency:	Yes, though depending on the transparency of the data sources.
C3: Documentation of assumptions and limitations:	This is highly dependent on the privacy and data collection policies of the data sources, which can be multiple sources for the private sector.

EASY	
E1: Availability of data to calculate the indicator:	Data should be already collected as it is a numeric value expressing economic activity, however, it may be dispersed and not made available to the researcher as it comes from private sources to public statistical bodies. Entities such as the Bio Based Industries Consortium demonstrate progress in this regard.
E2: Technical feasibility:	Yes, it is a statistical value that is easy to calculate given data is available.
E3: Reproducibility:	Yes, it is possible to use the indicator in numerous case studies.

ROBUST	
R1: Data quality:	Yes
R2: Sensitiveness:	No.
R3: Scale:	No, the indicator should be applied at city and metropolitan level, but would not be useful in neighbourhood and object levels.

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