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Research and Innovation Action

Topic: SCC-03-2016: New governance, business, financing models and economic impact assessment tools for sustainable cities with nature-based solutions (urban re-naturing)

Starting date of project: 1st of November 2016

Duration: 48 months

D3.2 – Report on Dynamic Assessment Methodology

Organisation name of lead contractor for this deliverable: EKO		
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Abbreviations

Table 1. List of Abbreviations

ABM	Agent Based Modelling
ANOVA	Analysis of Variance
BAU	Business As Usual
BIM	Building Information Modelling
CAQI	Common Air Quality Index
CERA	Cumulative Energy Requirements Analysis
COM	Covenant of Mayors
CTU	Comparative Toxic Unit
DALY	Disability-Adjusted Loss of Life
EEA	European Environment Agency
EMM	Expert Model and Method
ET	External Tool
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gases
GIS	Geographic Information System
HVAC	Heating, Ventilation and Air Conditioning
ISO	International Organisation for Standardisation
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MIPS	Material Input per Unit of Service
MFA	Material Flow Analysis
MSW	Municipal Solid Waste
N4C	Nature4Cities
NBS	Nature Based Solutions
OLAP	Online Analytical Processing
PAF	Potential Affected Fraction
PAS	Publicly Available Specification (by British Standards Institute)
SDG	Sustainable Development Goals

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SUA Tool or SUAT	Simplified Urban Assessment Tool
TOC	Table of Content
TRL	Technology Readiness Level
UPI	Urban Performance Indicator
URBS	Urban Runoff Branching Structure Model in English
WP	Work Package

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1 Executive Summary

The main focus of the Nature Based Solutions environmental impacts assessment work package 3 of the Nature4Cities project is to deliver a scientific framework for environmental assessment. In order to achieve this, the delivery of a sound methodology for quantitative evaluation of nature-based solutions for cities is key. This report contains the framework of a dynamic assessment methodology to allow evaluation of the impacts of Nature Based Solutions at different spatial scales across the life cycle of a project.

Purpose of study - The study aims to develop and provide a **dynamic assessment methodology** supporting time-based Nature Based Solutions performance tracking and monitoring using different environmental key performance indicators. So as to identify what and how much benefits a particular project, such as a green square, park, rainwater garden, waterway or other Nature Based Solution implementation has. It is crucial that the application of the methodology is efficient and simple in order to encourage use by municipalities, decision makers and other related parties. In the methodology the environmental Key Performance Indicators selected in previous works related to the development of the Nature4Cities Urban Metabolism Framework and Environmental Assessment Methodology, can be harnessed and used to assess the performance of different nature based solutions. Delivering an opportunity to interpret, plan and monitor Nature Based Solutions within an urban planning strategy context, facilitating decision-making, Nature based solutions project deployment, and transparency of what value is provided over time.

Methodologies - The deliverable outlines the required steps to conduct the dynamic assessment methodology. It is based on the idea of a particular project in an urban environment, like the implementation of a green wall on a building, to understand how it affects the liveability in terms of environment in the city. It consists of five steps, as graphically depicted in figure 1, to provide for an assessment of the current environmental situation at the site where a Nature Based Solutions project is to be implemented, to understand the targets for environmental improvements, and to assess over time once the project is implemented the environmental situation and whether the performance is met and what needs to be changed or improved.

Key findings and conclusions - The Dynamic Assessment Methodology is a novel approach to delivery performance evaluation of a Nature Based Solution project like a greenroof, greenwall, rainwater garden or other type, so as to make the value of such projects more clear and transparent, and to allow for studying different Nature Based Solutions implementations and comparisons to improve the delivery of such projects. It was found that linkage to performance tracking is instrumental, yet also requires further work to understand for each Nature Based Solution type the particularities for assessing different environmental aspects (air quality, soils and carbon storage, water retainment and so forth). A key recommendation for future projects is to link such assessment methodologies with open databases so that cities can learn from eachother in how different Nature Based Solutions projects have benefitted the city, overperformed, or underperformed and why. Resulting in critical insights that can steer future Nature Based Solution implementation.

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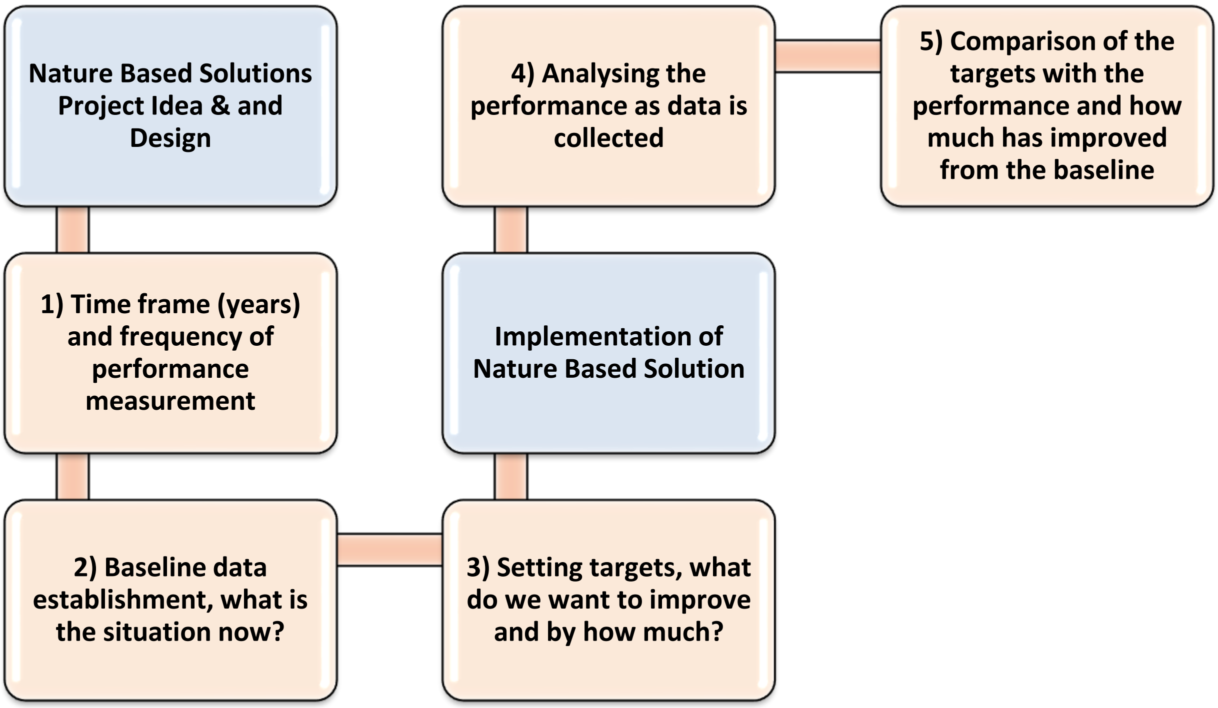

Figure 1 Steps in conducting the time series trend analysis for dynamic assessment

Link with N4C platform - Deliverable 3.5 is a public document detailing the dynamic assessment methodology to evaluate the urban trends within the N4C data management platform. The structure of the methodology serves to strengthen the assessment of different urban nature based solution scenarios that will be assessible in the Nature4Cities platform, linking to the context of providing solutions to several challenges: climate change, environment, resource efficiency, urban and citizen quality of life. The dynamic assessment methodology is one of the approaches for incorporation in the Nature4Cities platform to ensure that Nature Based Solutions projects can be monitored and evaluated on their osts and benefits in a dynamic manner to deliver both environmental and economic value.

Lessons learned & EC expectation - The evaluation of the environmental benefits of NBS is one of the key solutions paving the way for resilient cities, and to strengthen urban planning strategies. In that respect, this document responds the topic "SCC-03-2016: New governance, business, financing models and economic impact assessment tools for sustainable cities with nature-based solutions (urban re-naturing)" in a dynamic and proactive manner. Since adaptation of NBS implementation strategies for different urban challenges can have both positive and negative effects, there is a need for continuous monitoring following a robust methodology as developed in this document. For this reason, the works under this deliverable provide novel insights beside others for the research action identified in the report of EC 2015 (Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities).

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2 Introduction

2.1 Purpose

Work Package 3 is dedicated to environmental impact assessment of NBS scenario(s), covering an urban metabolism-based approach using MFA and LCA analyses. In order to justify the environmental efficiency and cost effectiveness of NBS, i.e. the monitoring of NBS performance, it is necessary to establish quantitative evidence of NBS performance using KPIs. Such evidence can guide city planning decision makers and/or related parties in their urban planning and urban strategy development activities. To facilitate evidence generation, a strategy has to be implemented that helps city partners to track the performance of NBS from their initiation through their lifecycle. The final objective is to better answer the needs of planners in various domains including “Climate change and mitigation”, “Environmental regulations and targets”, “Urban transformation” and “Behavioural and Social Change Impacts”.

The main objective of this report is to develop a methodology that can support dynamic NBS performance tracking, consisting of analysis of NBS performance trends using time-series KPI datasets. KPI assessments for the dynamic assessment are firstly dependent on data availability of the urban nexus flows of each NBS, with the time resolution of analysis determined by the temporal availability of NBS performance measurement data. Once baseline and in-use data is obtained, the time-series assessment methodology developed in this report can be employed to capture anticipated performance trends from present and past data, resulting in a dynamic NBS performance interpretation approach. As such, the dynamic analysis will support the related parties to clarify particular underlying trends in time series data points and help planners in forecasting and monitoring by fitting appropriate trend models. The end result is a dynamic assessment for environmental evaluation of NBS, that can reflect the dynamic nature of the urban ecosystems

The methodology is developed for the quantification of selected KPIs established in previous works related to the development of the N4C Urban Metabolism Framework (project Task 3.1)[1] and Environmental Assessment Methodology (project Task 3.3).[2] In addition to that, the relationship between environmental and the social-economic status of the urban citizen which was already studied in a task related to the definition and modelisation of citizens as urban agents will be linked to the methodology built regarding the N4C environmental framework. The environment assessment methodology developed under Task 3.3 will be used as a basis including all urban metabolism and LCA indicators that have been redefined with a time-based approach. The trend analysis to be performed will include climate change and resilience issues, environmental regulations and targets,

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[1] EKO, NBK, TEC, RINA-C, CAR, MUTK (2018). D3.1 – Inventory and report on N4C Urban Flows, Components and System Boundaries.Nature4Cities Project

[2] NBK, EKO, G4C, LIST, R2M, TEC, CAR, MUTK (2019). D3.3 – Report on Nature4Cities LCA goal and scope definition, urban environmental indicators and KPIs. Nature4Cities Project

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urban transformation issues and behavioural patterns. The integration of this dynamic methodology into the Nature4Cities platform is also a key issue that will be studied under this task.

2.2 Structure of the Document

The structure of the deliverable is displayed in the following Figure 2.

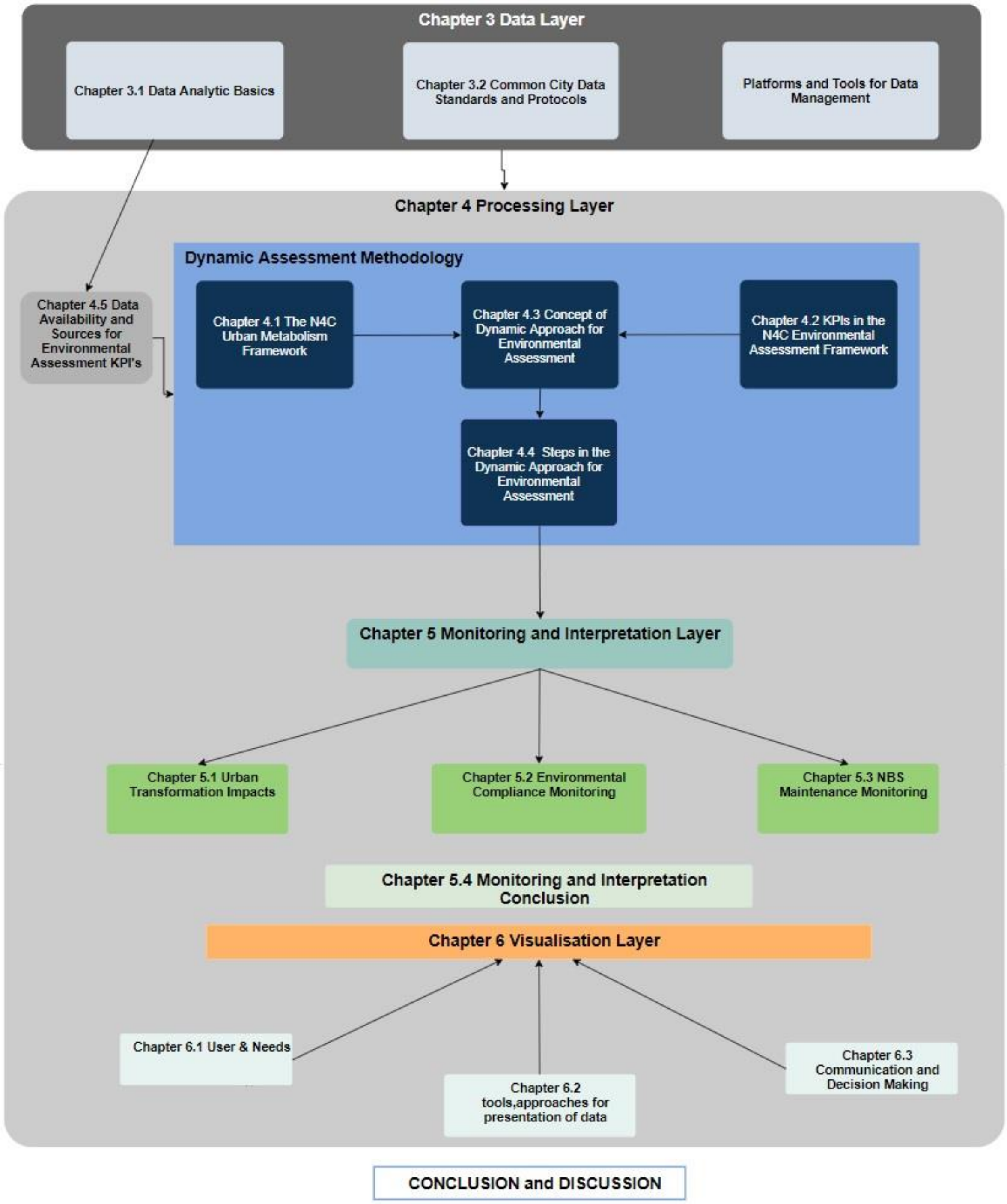

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Figure 2 The Structure of the Deliverable

2.3 Contributions of partners

Table 2. Partner responsibilities in Task 3.5

Tasks carried out	**Incl. in Chapters**	**Involved Partner(s)**
Review of Report and Quality Assurance	All Chapters	NBK, TEC, CAR
Introduction and relations to other Nature4Cities works	Chapter 2	EKO
Development of Data Analytics primer	Chapter 3	EKO
Establishment of common data frameworks and protocols and tools for city data analytics	Chapter 3	EKO
Dynamic Assessment Methodology for Environmental and Life Cycle KPI's	Chapter 4	EKO
Monitoring and Interpretation of KPI's for target setting and tracking	Chapter 5	EKO
Visualisation of methodology for specific users and graphics within the Nature4Cities platform	Chapter 6	EKO
Overall Conclusions and Recommendations of the Report	Chapter 7	EKO

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2.4 Relationships to other N4C tasks

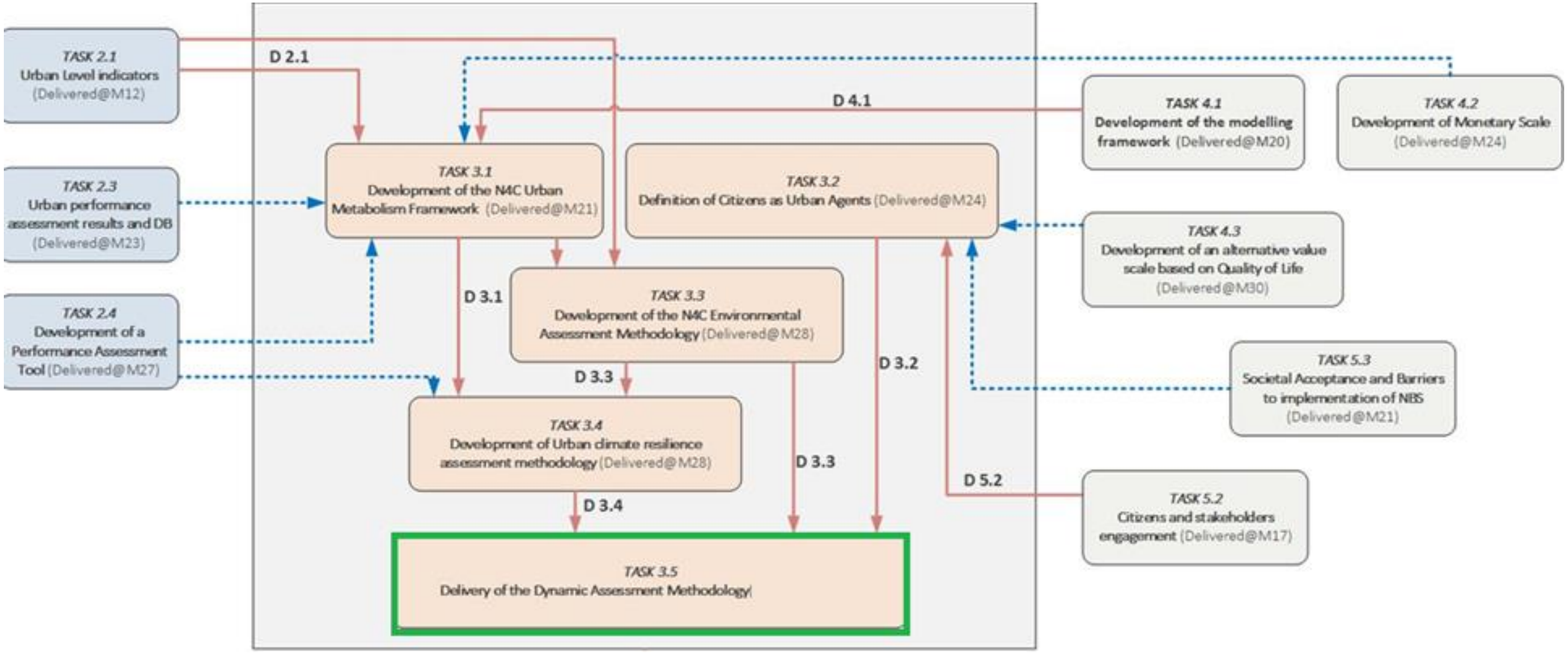

Figure 3 Task Relations

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2.5 Technical Glossary

Table 3. Technical Definitions used in this report

Technical Term	Definition
concept	Generalization of a type of thing; describing its essential features
concept model	Set of defined concepts and the relationships between them, chosen to be independent of design or implementation concerns, that can be used to describe a domain
dataset	Managed collection of structured data
entity	Thing with distinct and independent existence for which a concept can be assigned
interoperability	Ability of systems to provide services to and accept services from other systems and to use the services so exchanged to enable them to operate effectively together [Source: PAS 180:2014, 3.1.40]
interval of evaluation	Repetition frequency of the assessment
ontology	Definition of a set of representational primitives with which to model a domain of knowledge
relationship	Way in which two concepts can be connected
smart city	Effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens [Source: PAS 180:2014, 3.1.62]
time series	An ordered sequence of values of a variable observed at equally spaced time intervals is referred to as a time series. [Source: Glossary of Forecasting Terms-Rob J Hyndman]
trend analysis	Trend analysis (or trend-line analysis) is a special form of simple regression in which time is the explanatory variable. [Source: Glossary of Forecasting Terms-Rob J Hyndman]

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3 Data Layer: Analytics and Standards

The Data Layer in the N4C platform is a software structure which facilitates the organisation of data, to enable an expert user to view and interrogate data collected and to support the decision-making process of platform beneficiaries in developing, implementing and monitoring NBS. The data layer will need to contain data management and data analytic capabilities. In this section, we identify universal standards that could be utilised within the platform, for purposes of realising maximum interoperability of datasets from/to the platform. In Figure 4 below, details of the stages that provide for a well-functioning data layer in a software environment are summarised.

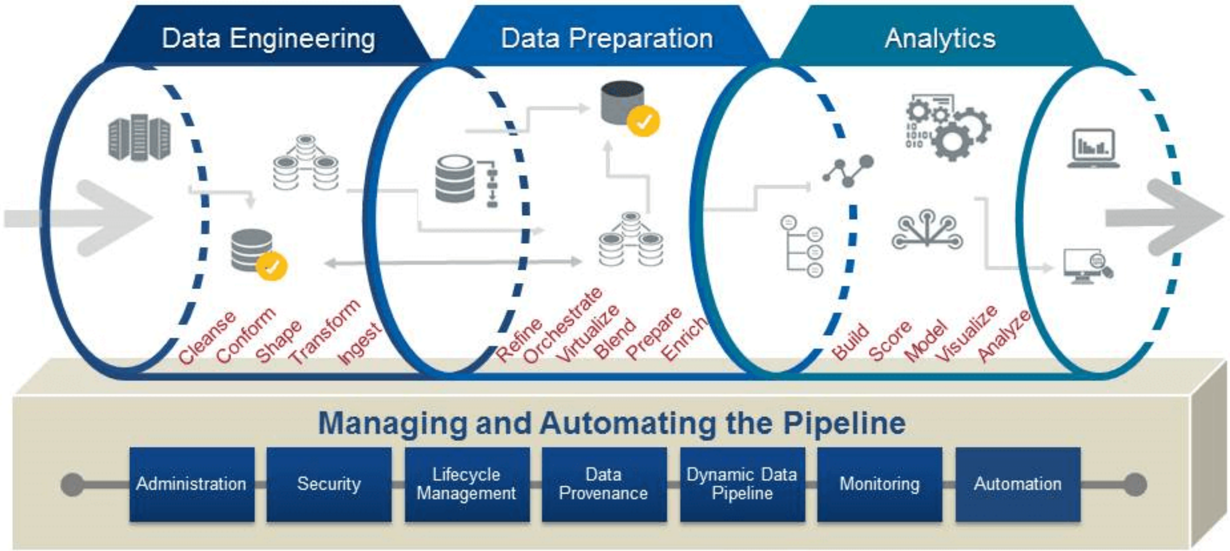

Figure 4 Phases in data management and analytics.

3.1 Data Analytics Basics

Data analytics is the process of selecting, cleaning, transforming and analysing data with an aim to discover useful interpretations to inform conclusions and support decision making. In the N4C platform data analytics is a process to abstract insights from large data resources to support end users in making informed decisions regarding the implementation of NBS solutions. There are multiple approaches to data analysis, we will continue by discussing the process and the types of analysis which will be utilised within the platform.

3.1.1 The need for Data Insights

The development of data analytics was accelerated in the 2000s when the Internet became a platform where people started to explore data management and analysis, made possible through easy sharing of data in a decentralised manner. Increasingly, organisations and people, including

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cities and their staff, no longer save data on hard drives and are using cloud-based data hosting and analyses capabilities. The ability to generate large quantities of data thanks to the number of smart devices available, has altered how organizations and individuals use information. However, a large challenge still remains in how to fully utilise the potential of the vast amount of data generated into generating useful insights for decision making. The current technological advancements in the field of data analytics, the open source nature of these development, and thereby accessibility of data analytics algorithms, increasingly offer a promising and reliable approach to start to valorise the insights that are needed by cities to improve their planning. For example, GIS based data is currently evolving into more enhanced City GML (CIM) datasets that can capture cities' spatial analysis and transport energy networks assessment, making various multi-dimensional and interrelated urban level assessments increasingly possible. Furthermore, the growing maturity of edge technologies and methodologies such as; machine learning, artificial intelligence and blockchain, continue to provide new ways support the implementation of data analysis needed for the proposed dynamic assessment.

The insights that can be gained from data analytics processes at a city level can be categorised into four layers defined in smart city concepts, as also depicted in Figure 5 below [1]:

- Operational insights, to evaluate characteristics and operational performance of buildings, communities and organizations. Uses data and data analytics to prove or improve their socio-economic and financial value.
- Critical insights, by real-time monitoring of people and infrastructure to assess incidents and up-to-date developments across sectors in a city so as to enable a rapid response, either to on-going projects or because of disruptive events.
- Analytical insights, derived from the exploration of city data to determine patterns, correlations and predictions for the future. Often leads to the development or innovation of systems or services or assessing whether challenges to citizens and organizations are adequately addressed.
- Strategic insights, provided by overarching data analytics framework monitoring approach that examines outcomes related to strategic objectives, decisions and plans for the city at a high-level.

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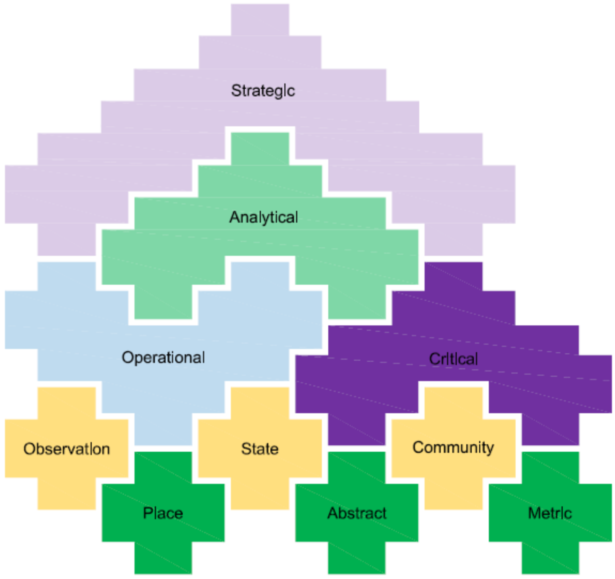

Figure 5 Smart City Levels of Data Insights [1]

The dynamic assessment method in this Deliverable 3.5 will provide for assessment at the analytical insight level, as it seeks to assess the performance of NBS using KPIs and understand changes for implementing subsequent NBS projects. The methodology can also form a building block for a strategic level of insights if it is coupled to a strategic monitoring framework of the city with associated targets, such as for carbon storage across the urban landscape. In the next sections, data analytics aspects are outlined that provide for analytical insights at a generic level.

3.1.2 Data Analytics Process

In Chapter 4, potential KPI's and their data sources that can be used in dynamic assessment in the platform will be identified. Usually it is the case that due to a variety of sources being used, the data is not structured in a standardized manner, it may contain irrelevant information, and also can contain errors. Before any analysis can take a place a 'cleaned' dataset needs to be created. Thus, the data obtained is required to be subject to data preparation and cleaning as part of data preprocessing depicted in Figure 6.

Data preprocessing procedures can include:

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- Checks for consistency, missing values, duplicate values, unusual discontinuities, or data outliers. Evaluation methods include assessing whether data matches up to an expected value, manual scanning of data values, time-series statistical discontinuity/break assessment, and outlier tests using a box and whiskers-plot procedure.
- Removal or imputation of missing data. By removal of duplicates, removal of outliers, adding data by interpolation if data is missing (imputation), or changing discontinuities by using a delta factor to address a jump between the prior and posterior part of a time-series.
- Quality verification of order of magnitude and similitude. Based on a within dataset assessment of the mean, minimum and maximum value of datasets via descriptive analysis exhibit the expected values the dataset should exhibit. And a between dataset assessment of the variance (ANOVA – analysis of variance) between datasets to understand if the mean value is significantly different.
- Data Harmonization to integrate multiple datasets from different sources. Based on a ruleset of harmonization, the simplest of which is direct addition of one dataset to the other to create an aggregate dataset. Often specific treatments are needed based on data transformation.

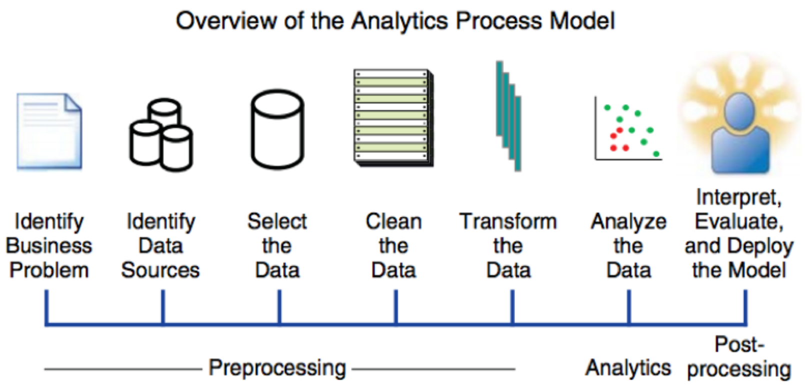

Figure 6 Data treatment and processing steps to obtain insights

After pre-processing the dataset will be consistent and less likely to contain any errors, false data entries or otherwise. A final step that may be needed, prior to analysis, is data transformation. Data transformation is a mathematical operation which changes the measurement scale of a data value. For example, changing the periodicity from hours to days, or aggregating data from the level of neighbourhoods to entire cities. Such transformations are needed depending on what temporal or spatial level, or for what unit type the data analysis needs to be carried out.

More complex data transformations can include algorithms that try to reduce the noise in the dataset (deviations that are measurement errors, or deviations due to the intrinsic variability of a measured process and therefore its associated data). For example, a kalman filter can be applied to a timeseries dataset to create a smoother dataset and reduce noise (such as deviations caused by measurements), by utilizing the variability in the data using a predictive algorithm. More complex data transformations are usually undertaken to make it possible to apply a particular data analytical

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method to a dataset. In many cases, transforming the dataset is a vital step before analyzing the data, as many statistical methods require data which follow a particular probability distribution.

The data analysis itself is the last phase in the process before the results can be published and the model deployed for interpretation. Data analysis can be categorised under four approaches, as listed in Figure 7 below, described as:

- Descriptive, serves to describe the current state of affairs, and how it relates to the past.
- Diagnostic, serves to understand the underlying reasons in a causal manner. Requires some form of statistical analysis.
- Predictive, serves to look at what probable future changes will occur given current and past changes. Requires some form of algorithms such as neural network algorithms, or statistical analyses, which look at present and past variability or trends and extrapolate these or allow for reproduction of past behaviours into the future.
- Prescriptive or Normative, utilizes past or current data to find with analytical algorithms better outcomes. Requires some form of multi-criteria analysis or optimization of different technologies, strategies, or actions.

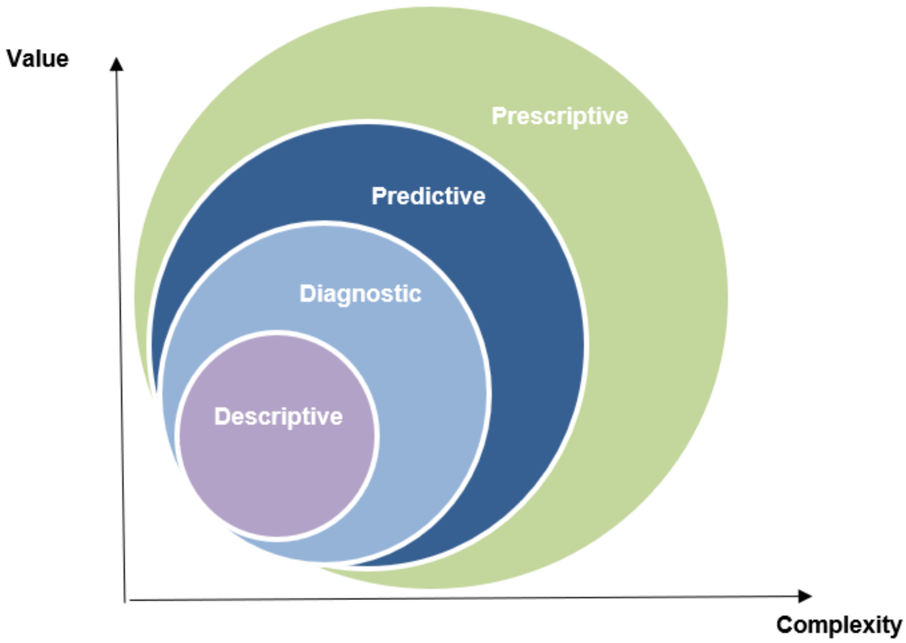

Figure 7 Types of data analysis

3.1.3 Time Series Analyses

Time series data can be used in various applications, one of which is for monitoring processes and another is to track changes in specific metrics. The primary idea behind time series analysis is that successive values in the data file have an internal structure of behaviours, because of regularities in

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patterns observed in nature, behaviour and physics, and thereby learnings can be drawn from represent consecutive measurements taken at equally spaced time intervals.

Two main aims of time series analyses are:

1. Behavioural assessment, to identify the underlying behaviour of the observed sequence in a dataset, or behavioural relation between multiple datasets, including their regular and irregular components.
2. Forecasting, to be able to forecast and predict future values of the series based on said behaviour.

Both aims are reliant on the ability to identify and describe the patterns or so-called roots of the time series in question. Only once a pattern is established, then the dataset be interpreted and further analyses can be carried out such as forecasting and prediction. Time series analysis as such can allows for the extrapolation of the identified pattern to enable the prediction of future events.

The three standard components used to describe series patterns, also applicable to NBS KPI data, are trend, seasonality, and unit root:

- Trend, consistent data changes over time in a particular pattern that do not repeat regularly, at least not within the time range captured out by data.
- Seasonality, the component of the data that repeats itself in systematic intervals over time.
- Unit root, the component of the data that is unpredictable and follows a stochastic (chance based) process.

The three components of the time series are usually all present in a time-series dataset from real-life data resources. For example, CO_2 emissions in an urban area from automobiles in a city where more and more people drive cars can rapidly grow over a few years (trend), but still follow seasonal patterns, ie. higher in the winter months when less people are inclined to walk or cycle and have unpredictable changes (unit root) because of unforeseen events and tourism.

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3.2 Common city data standards and protocols

Next to the development of standardised data analytics approaches, also specific standards and protocols have been developed for managing and processing data for cities. Cities and their management stakeholders, especially governments and management utilities, are generating an increasing amount of data in the age of Internet of Things (IoT) and big data. Whilst this can lead to the transparency, accessibility and interoperability of data repositories, also for purposes of NBS dynamic monitoring, this is only possible in an effective manner if data management protocols and referencing standards are sufficiently adhered to. For example, in their comprehensive literature review study, Beloin-Saint-Pierre, D., et al. [2], looked at the impacts of data availability and management (or the lack thereof) for cities in assessing city material flows using urban metabolism, finding significant impacts on the quality of the analytical process.

Since the methodology for D3.5 and at broader level the overall Nature4Cities platform can benefit from utilising city data standard and protocols, an examination of such standards was made. The purpose is to increase continuity and interoperability in sharing and storing data both internally and externally. For example, for business data an international standard for interoperability are D-U-N-S Numbers, which act as common unique reference indicators to identify companies [3]. Similarly, administrative and statistical geographies of datasets are often defined by government and tend to reflect the composition of local government. To allow for the incorporation of external data, as well as sharing data with external bodies, organisations must ensure they hold the correct data standards and protocols. A listing of such standards and protocols is provided in table 4 below, followed by an elaboration for each standard. The implementation of such standards will be determined under Work Package 6 of the Nature4Cities project.

Table 4 City Data Standards and Protocols

Standard	Geographic Coverage	Purpose	Relation to Data
ISO 8000	International	To ensure quality for portability.	Data management
ISO 15926	International	To assist the exchange and reuse of information.	Data interoperability
ISO 37120	International	Defines indicators to measure a cities performance.	Data standardisation
ISO/TC 211	International	Digital geographic information for smart cities.	Data standardisation
PAS181	International	Smart city framework guide	Data management
PAS182	International	Normalises and classifies data information.	Data interoperability
PAS183	International	Identifies how smart cities can record and store the best overall data to measure smart city performance.	Data interoperability
INSPIRE	EU	Framework work for a spatial data infrastructure.	Data standardisation/ Data Interoperability

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The International Organization for Standardization (ISO) has been developing standards since 1947 to facilitate efficiency in collaborative practices. ISO data related standards include:

- ISO 8000: International standard for data quality and governance. The standard defines the requirements for standard exchange of master data (most commonly used to manage critical business information) and establishes quality to ensure portability. The standard implements consistency in the encoding and formatting of data in order to improve the process of data exchange.
- ISO 15926: International standard to facilitate data integration, sharing, exchange and hand-over between computer systems. The standard is used to assist the exchange and reuse of complex engineering information. It currently consists of 13 parts including; a generic 4D data model for technical information, reference data for geometry and topology and methods for the integration of life-cycle data.
- ISO 37120: International standard to define indicators to measure the performance of city services and quality of life. This standard is used by the World Council of City Data to map the progress of the SDG's in cities across the world through highlighting the relevant data to be recorded.
- ISO/TC 211: Standardisation of digital geographic information for smart cities, including metadata and classification systems.

The British Standards Institute's (BSI) is a pioneering institution in terms of city data management and has developed several unique innovative world-class standards, hence it is included here in addition to ISO standards. The BSI's guide to establishing a model for data interoperability looks beyond the current use of data to facilitate city services, to encourage decision-makers to explore the reuse of data as a resource, so as to innovate the future direction of systems and services [1]. Relevant BSI standards for cities include:

- PAS181: Provides a smart city framework guide to allow cities to shape their delivery plan through establishing detailed strategies. Commonly used standard in Smart Cities.
- PAS182: International standard aimed at establishing a model for data interoperability through normalising and classifying data information. This ensures that information can be understood at each level, the derivation of data transcends between layers and the impact of a decision is reflected in the operational data. [4]
- PAS183: This international standard sets out a data sharing framework for cities to identify how a smart city can record and store the best overall data to ensure sounds decision making, it is supported by the City Data Sharing Toolkit. [4]

Finally, the EU has initiated and mobilised the INSPIRE directive in order to identify standards for data sets across the EU, and their distributed services [5]. INSPIRE aims to define common standards for 34 spatial data themes across the EU via a general framework for a spatial data infrastructure. This infrastructure will serve to improve environmental policies across the European Community through increased accessibility and interoperability of geographical information.

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3.3 Platforms and tools for data management

In the previous section, we studied data standards and how they can be utilised in the NBS decision making process. In this section, we will continue by looking at common tools and platforms currently used for data management. The assessment helps to assess the common capabilities of these platforms and what can be learnt from these existing examples in the development of the data management structures of the N4C platform under work package 6 of Nature4Cities.

In general, platforms are increasingly based on cloud data management, the process of integrating data online across distributed servers to make them accessible at anytime from anywhere, where all data storage and processing takes place in a cloud-based storage approach (For example: Panoply, Amazon Web Services, Google Cloud). The Cloud is becoming an increasingly popular technology to host data management platforms, and more of the data stack has become managed and fully integrated in cloud-based platforms. Cloud-based platforms can enhance data management strategy – from standardising and preparing raw data, to data ingestion, loading, transformation, optimization and visualisation.

Data management tools that benefit from using Cloud Servers can be broadly categorised into five types:

- Master and reference data management, a method for managing critical organizational data that forms a standard for large organisations to have data available from a single source. (For example: Dell Boomi, Profisee, SAP Netweaver, Tibco MDM).
- Extract, Transform and Load (ETL) and data integration tools, that allow moving data from resource into a data server (data warehouse) to enable transforming, summarizing and aggregating them into a format suitable for high performance analysis. (For example: Informatica Powercenter, Stitch Data, Blendo, Azure Data Factory).
- Data analytics and visualization – amalgamating and processing data from large data sources. This enables the ability to perform advanced data analytics, and allows analysts to endeavour to present the data in visualizations and dashboards. (For example: Tableau, Chartio, Microsoft Power BI).

The benefits of using such data management tools include; unifying data & breaking down silos, aiding the identification of environmental issues and offering decision support, and providing continuous results which enable long-term strategies by way of constant and continuous reporting.

Data management tools as listed above are increasingly integrated into a new suite of services called an open data management platform (DMP). DMP's are technology platforms used for collecting, storing and managing data. A DMP uses algorithms to process big data sets and organizes and collects data in real time, and can also integrate data analytics and visualization. Examples of DMP platforms include Collibra, Magnitude, Reltio Cloud, Amazon Redshift, IBM DB2, and Google BigQuery, and Lotame.

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A specific form of data storage, management, and analysis approach that is used within data management platforms is OLAP or On-Line Analytical Processing. It is introduced here because it provides for a dynamic approach to data interrogation, by examining multiple data-series and their relations in an intuitive manner (such as different NBS KPIs and their changes over time), and by allowing for drag and drop selecting of time periods and spatial scales, or other relevant meta-data characteristics. OLAP is a specific way of structured datasets in a central data warehouse that can improve the dynamic assessment in the Nature4Cities platform for development under WP6. The main benefit of using OLAP for storing, managing and access data in Nature4Cities platform is that it can increase the efficiency of decision-making processes when undertaking NBS solutions. They provide more control and timely access to strategic information, whilst the flexibility of the system allows users to become more self-sufficient with less expert inputs needed to gain useful insights from NBS datasets.

The purpose of OLAP is to allow for retrieving values from time series datasets across multiple dimensions, and interrogation the data across time, space or other characteristics in a rapid manner. To do so datasets need to be easily combined, aggregated, and disaggregated and processed in a multidimensional view to provide quick access to information for further analysis. OLAP is based on a data storage approach where a Data Warehouse (centralised store of data from multiple sources and databases) is first used to store and manage data, and then the data is structured to make the data accessible in a multidimensional manner to fully explore data to deliver insights (see Figure 8).

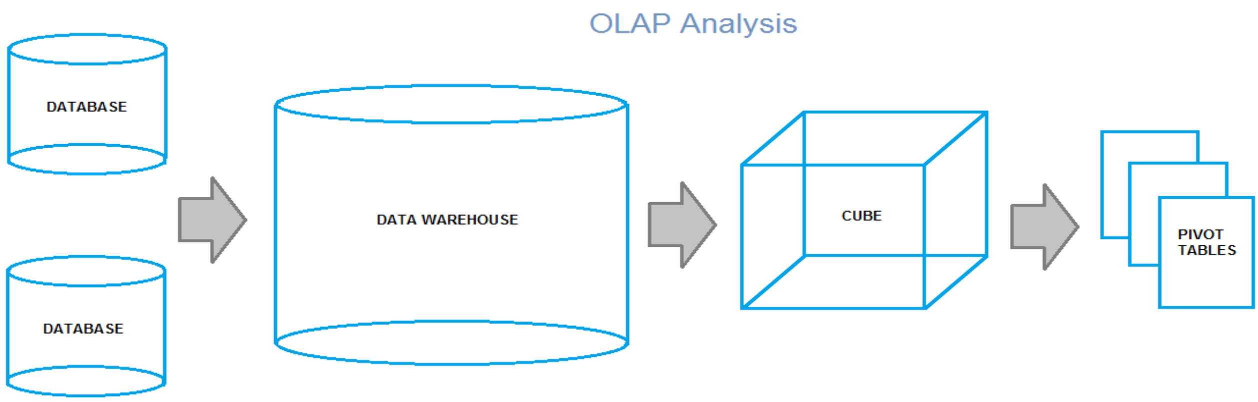

Figure 8 OLAP based data storage and analysis approach.

The approach in OLAP was developed to allow analysts, managers, executives to transform raw data into a form which reflects the real dimensionality. It enables users to gain insight into data through fast, consistent, interactive access and facilitates decision-making about future actions. It also allows for more complex calculations on the fly than simply summing data.

The key features of OLAP structured datasets are as follows:

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- Multidimension view of data, which is achieved through OLAP not only facilitate the user's ability to "slice and dice" data but also establishes flexible access to information and creates a foundation for analytical processing. See the example in Figure 9 below of an OLAP "cube" as a graphical representation of how data attributes can be combined or selected for NBS purposes.
- Time slices, the ability to integrate the component of time adds a unique dimension to the model and enable the OLAP data structure system to understand the sequential nature of time. Time is often used to measure the change in metrics and progress that has been made. A key feature of OLAP application is its ability to provide "just-in-time" information for effective decision making. This is computed data which reflects the complicated relationships and often results from dynamic calculations. This requires more than a base level of detailed data. The data model must be flexible to ensure the OLAP system can respond effectively to the changing platform requirements.
- Summations, in order to meet its requirements, an OLAP structured database must be able to complete complex calculations above that of simple aggregation. For example; share calculations (percentage total) and allocations (utilisation of hierarchies from a top-down perspective). Additionally, key performance indicators often require involved algebraic equations.

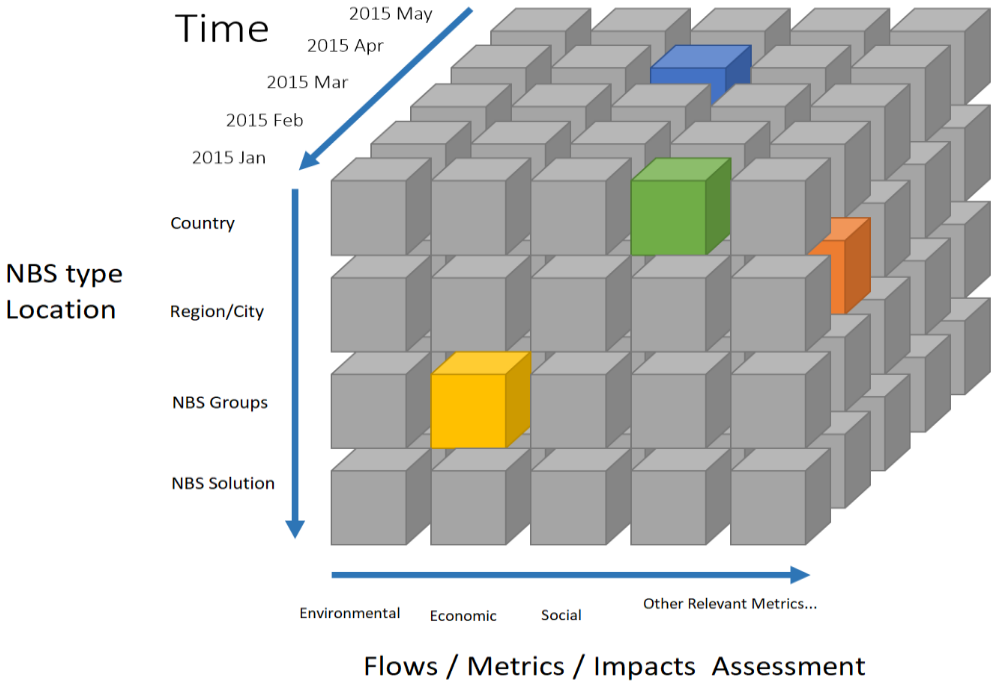

Figure 9 OLAP visual example for NBS datasets

Whilst there are many benefits to the use of OLAP structured datasets, the main shortcoming is that OLAP structured datasets they must be updated in batches, usually done during night-time on data serves. The limitation can create lags when dealing with large volumes of data, potentially preventing

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users from accessing the most current data and engaging in data analysis with the most up to date values. This is especially relevant if data is needed from the previous day or week.

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4 Processing Layer: Dynamic Assessment Methodologies

In the previous chapter the data management of the methodology was discussed from a generic perspective on data analytics and time series, data standards and protocols that can be utilised to ensure standardisation for cities when dealing with data, and platform and data structure for storage and handling of data. These form the main requirements for a solid dynamic assessment methodology. The implementation of the future trend analysis will be studied further from an IT perspective under WP6, as the IT side of the implementaion is not in the scope of this deliverable.

In this chapter the specific Deliverable 3.5 methodology is developed that builds upon the generic data analytics practices from the previous chapter, and upon the works carried out in Deliverable 3.1 and 3.3. On the other hand, the reason behind why the results from Task 3.4 were not used respectively is that Deliverable 3.4 document is not a methodology that directly calculates climate change mitigation/adaptation indicators, but rather guidelines to help decision-makers to choose an existing tool. Since these latter tasks were the starting point of the dynamic assessment they are briefly discussed in section 4.1. Subsequently, the KPI's utilised for the dynamic assessment from these tasks are discussed in section 4.2, followed by the outline of the dynamic assessment methodology itself in sections 4.3 to 4.5. Finally, the chapter closes with a discussion on the data sources available for the dynamic assessment.

4.1 The N4C Urban Metabolism Framework and Environmental Assessment Methodology

The N4C Environmental Assessment work package (WP3) was structured as shown in Figure 10. WP3 is composed of five complementary tasks that aim to address different aspects of environmental assessment of NBS.

The work package was **initiated by Task 3.1**: Development of the N4C Urban Metabolism Framework, which is concerned with providing a basis for modelling of NBS systems within urban settings. This basis is built upon the urban metabolism approach that is defined as the entirety of operating and investment cycles continuously interacting not only with each other but also with environmental and societal systems. The urban metabolism approach provided the necessary support to factor in relations between different sub-systems through analysis of urban material and energy flows.

During Task 3.1, the following information was generated for each NBS covered under N4C Project:

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1. Urban flows (nexus), necessary for environmental assessment that are changing as a result of implementation of NBS
2. Possible trade-offs of NBS, through qualitative analysis of improving and deteriorating flows (avoided flows as a result of NBS that may have adverse effect on environment were also considered)
3. Urban processes identification, belonging to different urban sub-systems such as energy supply, transportation or water supply, which are impacted by the changes in urban flows
4. System boundaries for each NBS, comprised of different urban processes to be utilized for environmental assessment applicable to object, neighbourhood and city scales of NBS implementation
5. Headline indicators, that are highly relevant for each NBS were determined based on the impacts/benefits of the specific on NBS on object, neighbourhood and city scale.

The complete methodology and outputs of Task 3.1 can be found in D3.1: Inventory and Report on N4C Urban Flows, Components and System Boundaries report.

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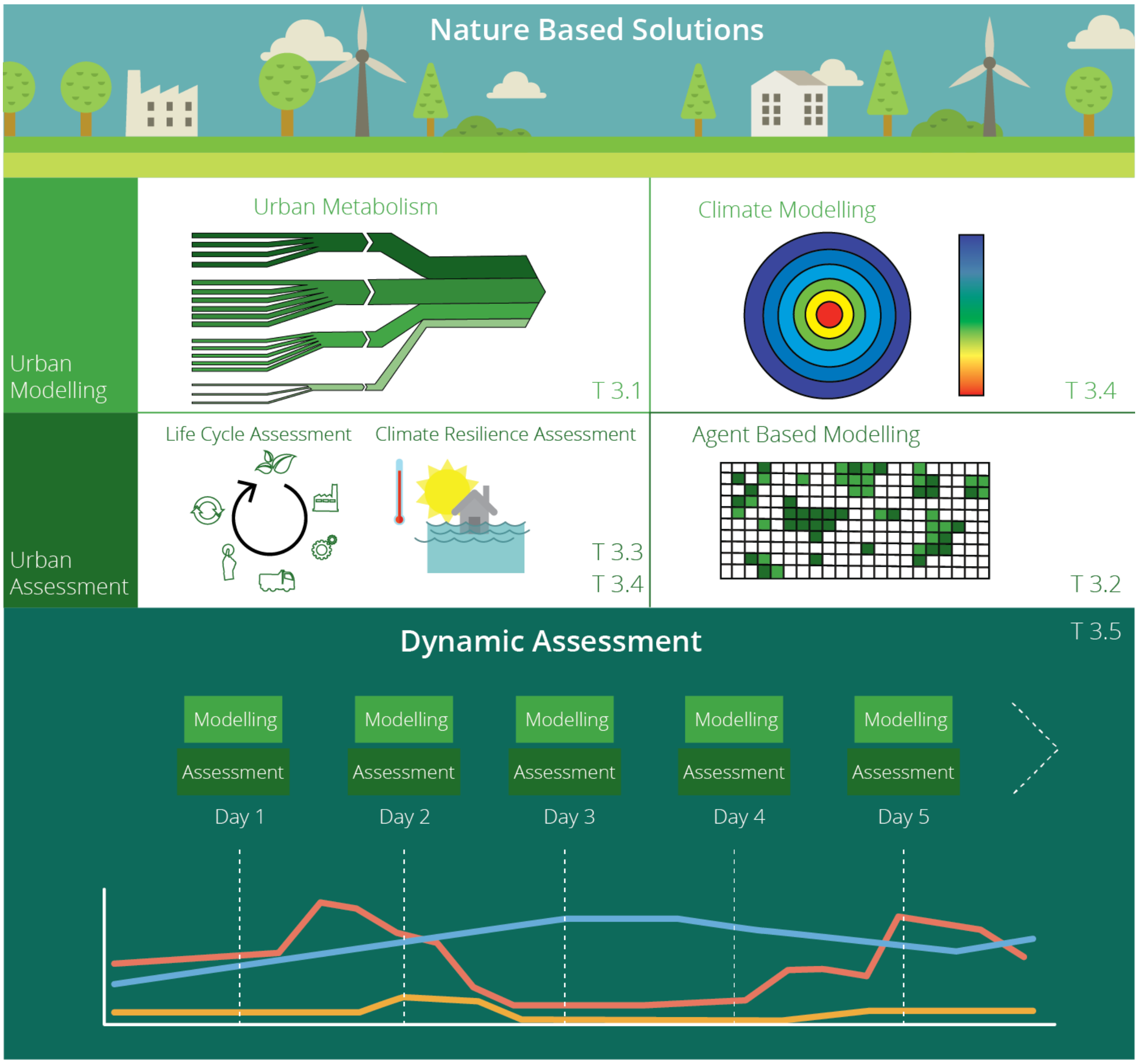

Figure 10 General structure of the environmental assessment work package (WP3)

An example of a system boundary setting is shown in Figure 1111 for the system boundaries including urban processes and nexus of the living wall system.

The **works carried out in task 3.3** covered the development of the N4C Environmental Assessment Methodology. As a case study, a cradle to grave environmental assessment using LCA study was conducted for a green wall system for which the functional unit was selected as the surface area (see Figure 11 for the system boundaries of the case study). The use of surface area makes it possible to compare between and across NBS types, as each NBS occupies a particular surface area. The time scale of the assessment in task 3.3 for the assessment was selected to understanding impacts aggregated for a 50 year perspective, in order to factor in the effects of long-term mechanisms, such as CO_2 sequestration or landfill emissions. Based on this functional unit and time duration setting, the life cycle inventory (LCI) dataset was gathered for the foreground NBS system

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and background processes that would allow the assessment to be made considering the cradle impacts.

In addition to the fully developed green wall system also for the following demonstration cases, the LCIs were established:

1. Green wall as a case study for energy efficiency in buildings (Green4Cities)
2. Urban farms as a case study for resource consumption (Alcala de Henares)
3. Bird-friendly school garden as a case study for public urban green spaces (Szeged)
4. Large urban public park as a case study for public urban green spaces (Çankaya).

The complete methodology and outputs of Task 3.3 can be found in D3.3: Report on N4C LCA goal and scope definition, urban environmental indicators and KPIs.

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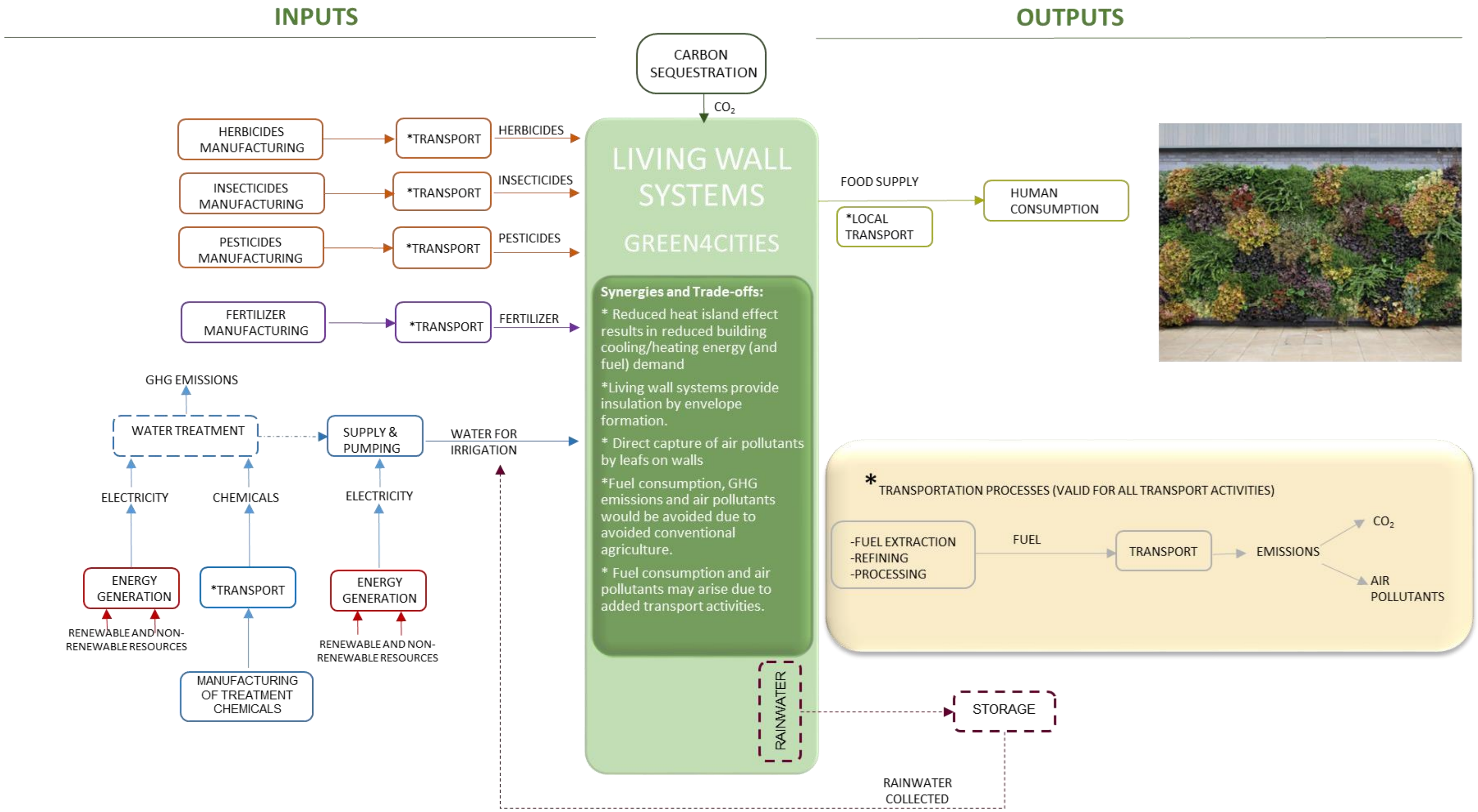

Figure 11 System boundaries of living wall systems from Task 3.3 in Nature4Cities

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The methodology **defined in Task 3.4** has a different approach to the ones developed in Task 3.1 and 3.3. On the one hand, Task 3.1 and Task 3.3 provides the methodologies that allow to make the assessment of NBS systems under the urban metabolism approach and the N4C environmental assessment respectively. On the other hand, and considering that Task 3.4 aimed to bring closer urban climate resilience assessment to the municipalities, the methodology defined was focused on establishing all the issues of interest to be considered in the whole assessment process from climate trends analysis till NBS effectiveness. As a result, identified issues have been organized in 5 fields that include the climate trends analysis, the identification and assessment of threats and hazards that could affect the urban environment, the strategies related to climate, the related indicators and the NBS as it is shown in Figure 12.

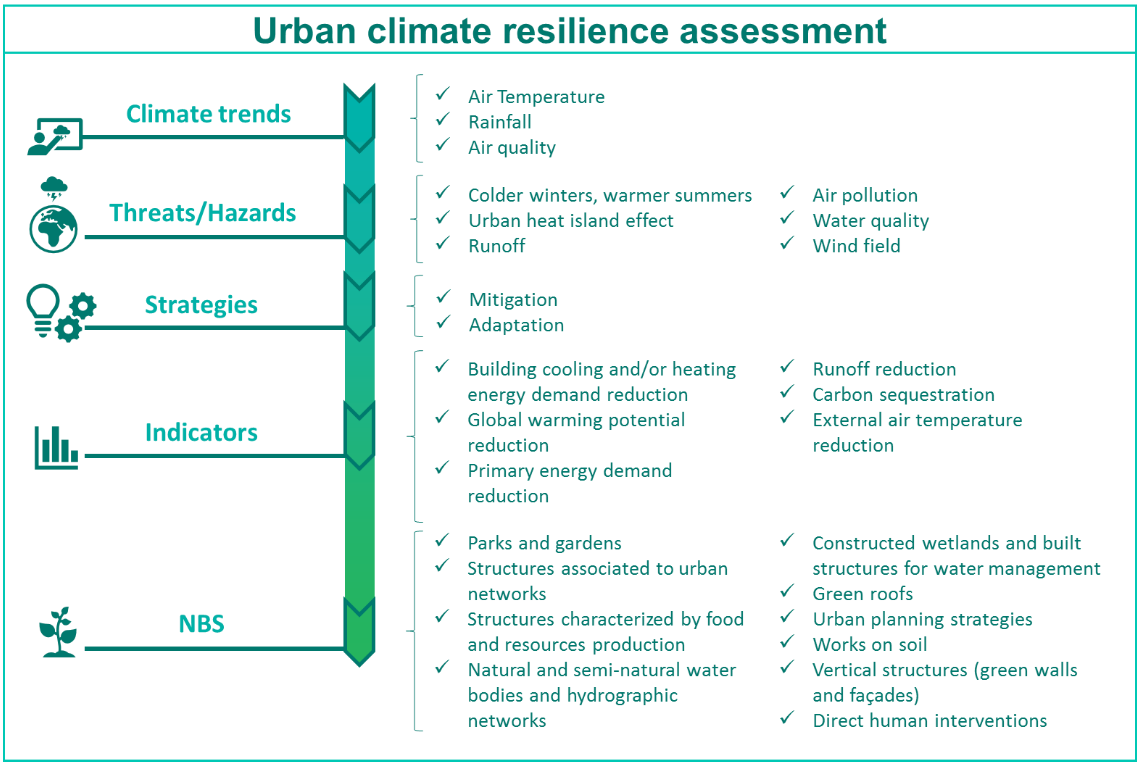

Figure 12 Issues covered by the urban climate resilience assessment methodology

After making this classification, the methodologies and tools that allow for the assessment of any of the issues included in Figure 12 were identified and analyzed. The findings were summarized in a matrix in which the main result of Task 3.4 is supported: the guideline to assist municipalities with the selection of the most suitable method or tool for the evaluation of NBS in the climate resilience context. Within the Nature4Cities defined methods, a suggestion will be made of the most suitable method for making an evaluation depending on the fields of interest that the municipalities indicate in the platform.

The result of Task 3.5 will be a dynamic assessment for environmental evaluation of NBS, that can reflect the dynamic nature of the urban ecosystems. The methodology is developed for the

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quantification of selected KPIs established in Nature4Cities D3.1 and 3.3. The assessment methodology developed under T3.3 is used as a basis including all urban metabolism and LCA indicators that have been redefined with a time-based approach. The trend analysis to be performed will include climate change and resilience issues.

There are several T3.4 indicators or intermediate inputs covered in D3.3, such as the building cooling and/or heating energy demand and the global warming potential. The study aims to understand which of the methods analyzed in Task 3.4, to allow for assessing the buildings cooling energy demand reduction and/or global warming potential, which are:

- NEST
- EPESUS
- Design Builder
- Fault Tree Analysis (FTA)
- Library of Adaptation Option
- Simile
- Enerkad
- EnviMET

The methods analyzed in Task 3.4 consider the climate trends in the field of air temperature, rainfall and/or air quality. In this Deliverable, Step 4 of the dynamic assessment will include the trend analysis of the baseline data. Although the climate trends are not explicitly specified, consideration of climate trends as a dynamic variable in the study would be a complementary perspective and approach in order to integrate the connection between Task 3.4 and 3.5 further.

4.2 KPIs in the N4C Environmental Assessment Framework

The environmental assessment methodology developed in the N4C project serves to improve decision support **during the planning phase** of NBS projects for the *selection of NBS alternatives* with the highest potential benefit. It also should help with the *Performance evaluation* of NBS **during the implementation** phase in a dynamic manner as developed in this task. In order to accomplish these two objectives, a two-stage evaluation strategy is developed here, which involves the scenario modelling of KPIs in the urban ecosystems, and the quantitative analysis of benefits measured from KPI performance monitoring.

The indicator-based assessment is shaped around the N4C environmental indicators that are classified into two categories (see Figure 13):

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- Urban flow indicators, which are material and energy footprint-based indicators for the urban environment, to quantify the physical changes in relation to NBS, including raw materials, CO_2, wastes, foods, and energy.
- Life cycle indicators, which are indicators that are used to express particular environmental impacts as a consequence of material and energy footprints using a Life Cycle Impact Assessment (LCIA) methodology

The urban flow indicators included in the dynamic methodology are obtained by streamlining the N4C indicator set obtained in WP2 of Nature4Cities, which includes the following nine KPIs (see Appendix A for detailed descriptions):

1. Annual CO_2 sequestration
2. Avoided GHG emissions
3. Energy efficiency
4. Per capita food production variability
5. Cumulative energy demand
6. Water scarcity
7. Raw material efficiency
8. Specific waste generation
9. Efficiency of valorization as a result of recycling processes

In addition to these nine indicators, during Task 3.1 of this work package, water, soil and air quality indicators were also listed as relevant to city NBS assessments.(See **Annex A – Detailed descriptions of Environmental Assessment KPI's**) Such quality aspects can be represented in terms of pollution flows in datasets, if the data is available from measurements, resulting in an easy incorporated into the environmental assessment approach. These water quality indicator as well as air and soil quality have also been covered under Life Cycle Assessment (LCA) (Task 3.3) and are included in the N4C Simplified Urban Assessment Tool (SUAT) (Task 2.4).

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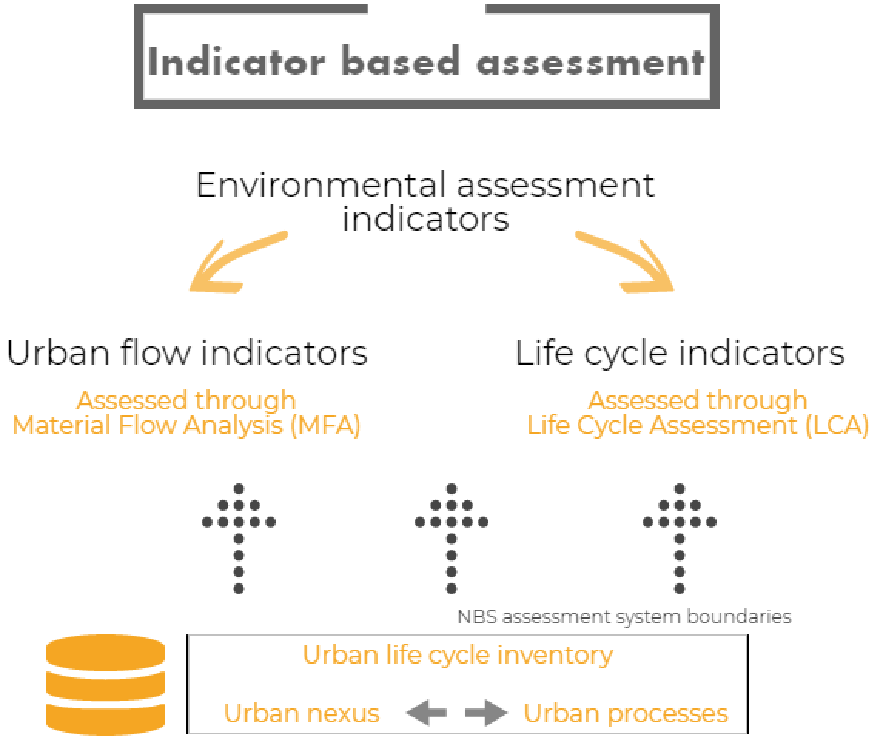

Figure 13 Quantitative indicator based environmental assessment

While urban flow indicators are analysed by material flow analysis (MFA), which is a commonly applied methodology for evaluating urban metabolism, the life cycle indicators are studied through Life Cycle Assessment (LCA). The main difference between urban flow indicators and life cycle indicators is that urban flow indicators aim to understand the systematic changes in the urban metabolism by measuring the extend of change in the quantity of flows and life cycle indicators aim to determine the environmental consequences created by these changes in flows through LCA methodology.

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The impact focused life cycle indicators included in the dynamic methodology were defined in Deliverable 3.3 in Table 9 and Table 10 with priorities assigned, respectively (see Appendix A for detailed descriptions):

1. Global climate change (High priority)
2. Acidification (Medium priority)
3. Eutrophication (Medium priority)
4. Ozone depletion (High priority)
5. Resource depletion (mineral, fossil, renewable) (Low priority)
6. Photochemical ozone formation (Low priority)
7. Human and ecosystem toxicity (Low priority)

In LCA such indicators are referred to as mid-point indicators. These make it possible to draw conclusions on three aggregate end-point indicators that measure total impacts on human health, ecosystem health and natural resources. As mentioned before, the combined 9 urban flow indicators and 7 life cycle indicators are described in detail in terms of what they measure and their calculation method in Appendix A of this report.

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4.2.1 Linkages to Climate Change Assessments

A specific assessment domain relates to Climate Change Adaptation to create more resilient urban cities. This aspect was studied in task 3.4 aimed to bring closer urban climate resilience assessment to the municipalities, focused on establishing adaptation aspects of interest from climate change trends analysis and their connection to Nature Based Solutions and their impacts. Identified issues were organized in five fields that include the climate trends analysis, the identification and assessment of threats and hazards that could affect the urban environment, the strategies related to climate change, the related indicators that are helpful, and the Nature Based Solutions as it is shown in Figure 14.

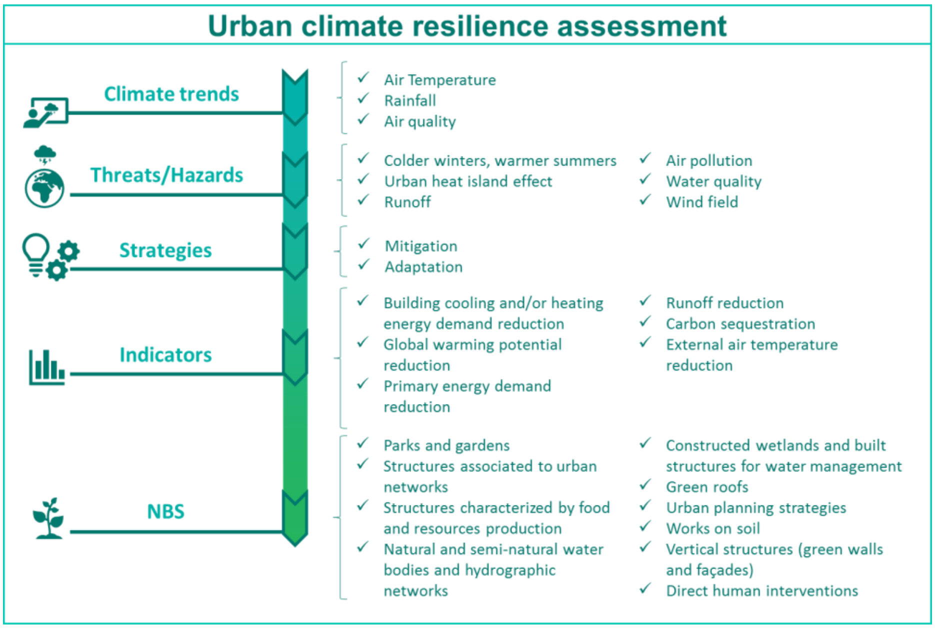

Figure 14. Issues covered by the urban climate resilience assessment methodology

After making this classification, the methodologies and tools that allow making the assessment of any of the issues included in figure A were identified and analyzed. The findings were summarized in a matrix as the main result of task 3.4, providing a guideline to help municipalities in the selection of the most suitable method or tool for the evaluation of NBS in the climate resilience context. Between these methods, the nature4Cities defined methods are included and will be suggested as the most suitable for making an evaluation depending on the fields of interest that the municipalities indicate in the platform.

The result of task 3.5 is a dynamic assessment for environmental evaluation of NBS, that can reflect the dynamic nature of the urban ecosystems. There are several indicators emerging from the T3.4 evaluation that are indicators or intermediate inputs for environmental assessment, such as the building cooling and/or heating energy demand and the global warming potential. The methodology in this report brings such indicators to a dynamic level, by integrating them with erformance assessment of Nature Based Solutions over their lifetime. Further works could be carried out to integrate additional indicators beyond the scope of this report, such as the methods analized in task 3.4 that consider climate change trends in the field of air temperature, rainfall and/or air quality.

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4.3 Steps in the Dynamic Approach for Environmental Assessment

In order to implement the dynamic assessment as conceptualised in the previous section, the raw time-series data associated with each KPI needs to be periodically updated, the KPIs need to be calculated, trends within the time-series need to be analysed, and appropriate performance forecasts need to be made. If any targets are set for the future they need to be compared with the forecasted performance. Based on the concept from section 4.3 the methodology is broken down into five analytical steps that should be followed, described in the next sections 4.4.1 to 4.4.5. As mentioned, this method allows for a dynamic evaluation will yield the following outputs:

- The level of benefits achieved by considering the difference between baseline scenario and assessment, which can be determined for the time of assessment and on a cumulative basis based on the past assessment results.
- Possible comparison between the actual NBS implementation with a selected benchmark scenario or technology.
- Comparison between targets and NBS performance to observe the progress towards the targets.

This repetitive scheme for dynamic assessment is considered to be applicable also for social and economic indicators as it is an indicator generic method. Note that the dynamic assessment should be carried out for each KPI individually since targets for different KPIs for each NBS are different from each other. Also note that the calculation methods of KPIs and their raw data requirements was established in Deliverable 3.1, and are further detailed in Appendix A

4.3.1 Step 1: Time frame and time resolution setting

The first step to carry out the dynamic assessment for each KPI associated with an NBS is to establish the time frame and time resolution of the assessment. Here the time frame of assessment indicates across what time period the assessment should be made, i.e. a target within the life-time of the NBS project that fits with urban planning timelines. The appropriate time resolution for how often the dynamic assessment should be repeated, i.e. the interval of evaluation, such a annually, should also be selected for each KPI. The selection of the interval can depend on a number of factors including the availability of NBS data, the feasibility of data collection, and the helpfulness of the repetition of the analysis at particular intervals. The time resolution of data should, therefore, be feasible and meaningful. In addition to that, it should be noted that time horizon chosen for the analysis of green wall implementation in terms of climate change indicator of LCA has sometimes inconsistency with the time frame in concern. This inconsistency can be explained by using the example of a building with a 75-year lifetime. An LCA conducted on this building will take into account every pollutant released during the entire life cycle of the building, from its construction to destruction, including the use phase, which considers maintenance, heating and air-conditioning activities. During these 75 years, GHGs will be released and will generate an impact on climate. By choosing an impact assessment method that uses GWP with a time horizon of 100 years, one might think that this LCA study considers the global warming impacts over 100 years. However, that is not really the

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case. In fact, the impact of an emission which occurs 50 years after construction, for example, will be considered from year 50 to year 150. To be consistent with the 100-year time horizon chosen for the analysis, there is a need to develop characterization factors that account for a flexible time horizon to correctly represent the effect of the timing of the emissions. [6] This is totally the same with an integrated Building + NBS system.

In order to determine the time resolution interval of the assessment for each KPI, the information generated under Task 3.1 will be utilized. Based on previous works, an NBS-KPI matrix is prepared to this end, in which headline indicators for each NBS are identified, along with the necessary material or energy flows to be monitored during the dynamic assessment based on which the KPIs that are calculated. Table 5 shows the format of the NBS-KPI matrix, and a complete matrix can be consulted in Annex B that includes all KPIs and flow example data.

Table 5 Format of the NBS-KPI matrix

		NBS					
		NBS_1	**NBS_2**	**…**	**…**	…	**NBS_p**
Urban challenge$_1$	**KPI_1**	$Flow_1$	--	--	--	--	$Flow_2$
	KPI_2	--	$Flow_3$ $Flow_4$	--	--	--	--
	…						
Urban challenge$_2$	**KPI_n**	--	--	--	--	$Flow_5$	--
	…						
Urban challenge$_m$	**KPI_m**	--	$Flow_x$	--	--	--	$Flow_y$

The most appropriate time resolution of the flow data as listed in Table 5 needs to be provided in each cell in the matrix, so as to help identify the interval of assessment for each KPI. The appropriate time resolution is the feasible resolution to calculate the KPI associated with the flow. For instance, the energy demand or energy consumption of a building can be measured on an hourly basis with the help of sensors or simulations. It is also possible to determine the energy consumption from monthly energy. Consequently, the interval of the assessment for a “building energy need” KPI can be hourly or monthly based on the availability of data. However, it is not meaningful to calculate the KPI on an hourly basis as this does not yield substantial insights. Monthly or annual data is more meaningful, and as such data can be aggregated from hourly consumption/demand to monthly or yearly data points. Therefore, the time resolution feasibility of the flow shown in Annex B is the lowest possible granularity for the dataset, which can be aggregated to a higher granularity.

Note that if there is more than one flow necessary to calculate a KPI, it can be checked which flow is necessary or most influential in setting the time resolution towards assessing the KPI performance targets. If there is more than one target linked to multiple flows, the decision maker may choose to

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prioritize between targets or consider the time resolution with the highest granularity to ensure the feasibility of assessment.

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4.3.2 Step 2: Baseline data establishment

Now that the timeframe and time resolution of the KPIs to be measured and their associated raw data are established, a baseline can be established of the NBS performance. The baseline can be established at different levels of spatial aggregation of NBS depending on what is the desired dynamic measurement. It can be measured either for individual NBS infrastructures with clearly defined boundaries, or for aggregations of multiple NBS projects that are comparable as they share a similar functional unit (in our methodology m^2 of NBS area) with selected KPI, and a common aggregate baseline at the same boundary can be established, such as within a city neighbourhood's boundaries.

The baseline can consist of the current situation without the NBS if not yet implemented for the infrastructure area or the spatial aggregation across the city. If there are already NBS infrastructure's implemented, the baseline would consist of the initial KPI performance data points if their measurement data is available. The approach to measuring and collecting the NBS KPI raw data is established in work-package 7 of the N4C project.

4.3.3 Step 3: Target setting

After the baseline of the KPIs to be measured is established from the raw data in the appropriate time resolution, **target setting** should ensue. This step can be skipped if the dynamic assessment is - not - going to be used to compare the performance of the NBS with regards to any targets. Otherwise, the target values and dates should be set at the beginning of the NBS implementation phase, or at the start of the NBS evaluation phase for existing NBS infrastructure, by decision makers and/or planners.

To match the set baseline the target should be selected at the same level of spatial aggregation, either for an individual NBS or for an aggregation of multiple NBS infrastructures within the established spatial boundary. The improvement level of a target, and the date at which the target needs to be reached, should be chosen within the appropriate planning context. Examples of different context are city targets for urban transformation, international commitments/agreements such as Paris Agreement or sustainable climate and energy action plans and/or environmental policies/regulations for air quality, waste management or resource efficiency. Note that comparisons as a part of dynamic assessment not only can be made with respect to set targets as described above but also with respect to benchmark values of other similar NBS cases to check if the NBS performance is optimal. City targets are mostly described at city level and evaluated with the aggregation of the data sourced from neighbourhood and object scale impacts. For this reason,city scale targets, depending on the NBS in application, are directly or indirectly supported with the NBS implemented, if data is aggregated from single NBS sites to city scale, making it appropriate to draw the attention of this supportive action of NBS to reveal the benefits or loss realized respectively. Hence, up or down scaling factors could be used like population, number of buildings(together with building types),etc. depending on the NBS concept.

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The end result of the step is a list of targets for each KPI where target setting is relevant in the urban context, the level of aggregation within a spatial boundary for which the target is defined (either individual NBS or an aggregation thereof), the ambition of the target in terms of improvement, and the date at which the target will need to be reached.

4.3.4 Step 4: Time-series future trend analysis

The fourth step is the trend analysis of the baseline data for a particular NBS site combined with a particular performance indicator, so as to understand the extent to which improvement progress is being made for that particular indicator covering the NBS of interest. The baseline can be set either as the site of interest without the NBS implementation or with the NBS just having been implemented for assessing the entire lifecycle of the NBS. Several statistical time-series methods can be utilised to evaluate the trend, seasonality, and the unit root of the time-series, as more generically described in section 3.1. The purpose of time series analysis is generally twofold: to understand or model stochastic mechanisms that give rise to an observed series and to predict or forecast the future values of a series based on the history of that series [7].

In order to initiate future trend analysis, it is necessary to acquire a set of data recorded at regular time intervals. The change in data over time will draw a dynamic pattern involving long term trend ignoring any short term effects, seasonal variation pattern which is predictable according to the respective seasonal resolution and random fluctuations happened in every set of data. In that way, the use of one of these concepts will help to predict the future values based on the past data. In practice, a suitable model is fitted to a given time series and the corresponding parameters are estimated using the known data values. The procedure of fitting a time series to a proper model is referred to as Time Series Analysis [8]. A number of standard models include:

- Linear, a model type where all the variables in the data series are additive.
- Quadratic, a model type where at least one of the variables is raised by the power of 2
- Logistic, a model that includes exponential growth that dampens out

The models above used in time series analyses are used across many different fields. Often valuable strategic decisions and precautionary measures are taken based on the forecast results. Since these are directly tied to decision making, like in the N4C methodology here, fitting an adequate model to a time series is very important [9]. A good fit means that the models can reproduce the original values in the dataset well, and also can reproduce new data-points originating from the same and similar phenomena or processes.

To understand whether a model is adequately fitted standard procedures have been developed. After establishing one or several possible mathematical models for the time series, the accuracy and

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precision of the time series need to be tested. Accuracy refers to how close the statistical model can reproduce the true values in the original dataset, whilst precision refers to how far apart the reproduced values are from each-other also when the statistical fit is done multiple times on multiple datasets. Precision is thereby a measure if the uncertainty and variability in the dataset, whilst accuracy how far off the statistical model is on average. A measurement approach to this is to calculate the R squared or the coefficient of determination of the statistical model, which ranges between 0 and 1, with 0 the furthest off and 1 an exact reproduction (highest accuracy and precision).

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4.3.5 Step 5: Comparison of trends with targets

The final fifth step is the **comparison of trends with set targets** and analysing any gaps in reaching the target. In that step, depending on the time resolution of the KPI in concern and the trend analysis conducted in Step 4, the distance between the benefit, which will possibly be acquired by the time series future trend analysis and the set target, is evaluated. In that sense, the result of the assessment will determine the potential of the demand for intervention like maintenance of NBS or renovation, restoration or rebuilding of NBS i.e. feedback mechanism followed by crisis management. Although it is possible to feed the mechanism driving the intervention strategy development, it is out of the scope of this deliverable.

Moreover, tracking progress with trend analysis gives the opportunity to reveal the potential of the NBS(s) implemented or in planning stage whether it can reach to the target set by the national or international agreements for the environmental challenges or city's' expectations within this scope. This dynamic pattern revealed by the future trend scheme also pinpoints the estimated year that KPI value will have attained the objective.

To ensure the robustness of operation during urban planning and monitoring period, it is crucial to take into consideration the intervention strategy which is used for eliminating the difference between the defined target and the estimated trend respectively. Hence, understanding the trend analysis together with set targets can assist the decision makers significantly to act in a proactive manner to close that gap.

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4.4 Concept of the Dynamic Approach for Environmental Assessment

One of the most important outputs of the environmental assessment WP in N4C Project is to develop a dynamic approach that extend the environmental evaluation development in Task 3.3. The idea initiated in Chapter 2 and 3 is to develop a standardised framework to analyse the performance and track whether future targets associated with implementing NBS are on track. This forms the final aspect of the environmental assessment methodology, which serves to deliver results for comparative purposes, both between before and after NBS project scenarios, between different NBS alternatives, and also for performance evaluation during the implementation phase. The reason for doing so is to increase the evidence that identifies the potential of NBS to be beneficial for the decision makers, both during planning and implementation of NBS projects.

The core of this Task 3.5: Delivery of Dynamic Assessment Methodology is to propose a framework by which the combined methodological approach developed in Tasks 3.1 and 3.3 can be applied on a dynamic basis, whilst NBS projects are operational.

The dynamic methodology should deliver the following benefits:

- Providing support for planning of the implementation phase.
- Monitoring the performance of NBS throughout the infrastructure's lifetime.
- Determining the need for intervention on NBS to improve or maintain the infrastructure.
- Supporting periodic maintenance actions to be taken whenever necessary.

To cover these benefits a dynamic assessment approach is proposed that contains two stages of analysis:

1. Determine the benefits that are achieved by NBS through comparison of NBS performance with a baseline (no NBS scenario)
2. Prediction of the environmental targets, so as to understand if performance targets established for the specific NBS project will be met in time, and therefore to understand whether interventions are needed to make sure targets are met.

The main concept behind the dynamic approach is explained with a hypothetical NBS case showcased in Figure 15. The hypothetical case is based on a green wall project where a 8% decrease is expected in terms of the $CO_{2\text{-eq}}$ emissions per m^2 of NBS area(functional unit). This reduction figure in $CO_{2\text{-eq}}$ emissions per m^2 is determined according to the comparison made between casual building without Green wall and building with green wall implemented. This performance monitoring is directly related with "Avoided GHG Emissions" KPI. This KPI for greenwall case is evaluated according to different parameters including building energy efficiency together with the carbon capturing process of green wall and other auxillary items affecting the result respectively.

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Due to these multiple items result in a dynamic pattern, direct proportioning of this KPI with respect to a defined time resolution is not always valid. This can be also explained with the possible variations in heating and/or cooling demand, the maintenance period and the green wall status throughout the life time of the NBS as well.

Figure 14 shows three lines, which represent the baseline (no NBS situation) in blue, NBS performance established from monitoring in orange, and the NBS performance target set in grey. In our cases, this grey line indicates a purpose by prompting different target pinpoints to be possibly obliged to reach in due course and identified with respect to city itself or national/international agreements/promises for the sake of climate action plan. Depending on the KPI in concern, this target could be above or below blue line. The blue line shows a constant value for $CO_{2\text{-eq}}$ emissions in the no NBS case, resulting in a straight line(conservative hypothesis) at the original emission value. This simplification is for hypothetical purposes only, as it can be argued that a result of building ageing and climate change the heating and cooling demands will change if necessary, maintenance is not carried out or if the HVAC systems in the building is altered.

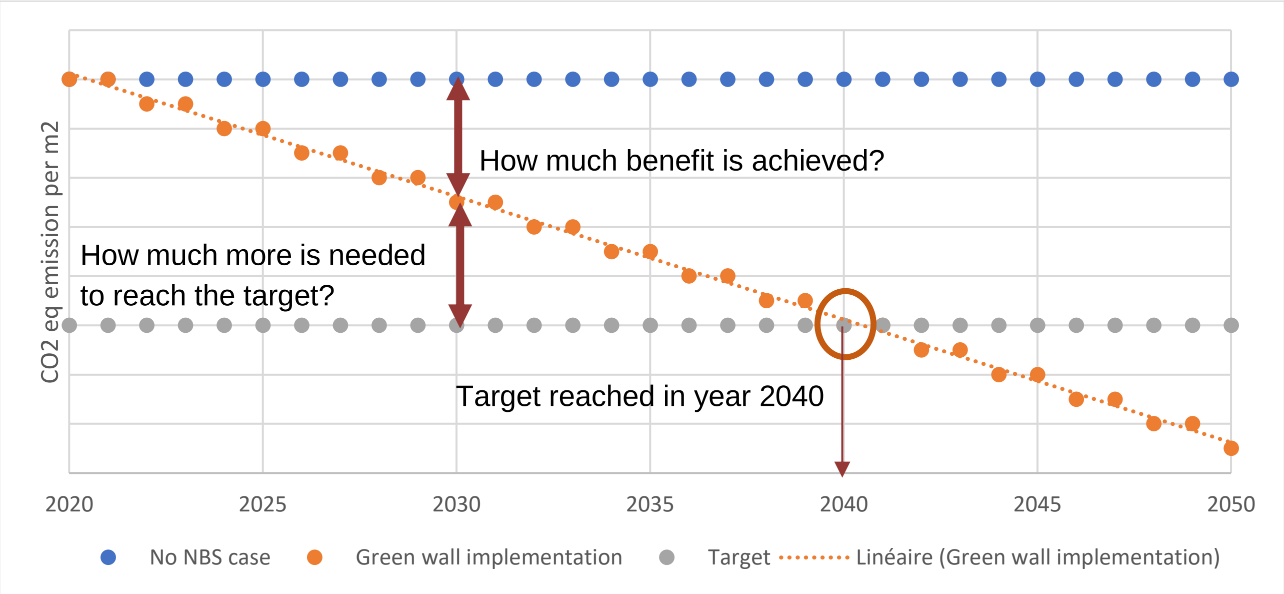

Figure 15 Hypothetical green wall case with baseline, monitoring and NBS target

Another assumption that is made for demonstration purposes is that over time the effectiveness of the green wall NBS increases in reducing GHG emissions. As a hypothetical exaggeration of the flourishing of the green wall, and a strengthening effect in reducing HVAC heating and cooling needs of the building. Therefore, the orange line follows a downward trend along the lifetime of the NBS. In reality, such improvements are limited, and they are introduced here only for hypothetical purposes.

The orange line can be obtained by calculating the total GHG emissions associated with heating and cooling energy use of the building repetitively together with implemented green wall life cycle on a yearly basis.Morover, it is crucial to consider any structural changes in the building as a consequence

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of before and after greenwall implementation scenario. Also keeping track of any changes in the HVAC system or other renovation changes related to the green wall, and filtering out the impact of large occupational changes that could occur due to building usage which can increase heating or cooling demands. Notwithstanding, for every data point on the orange line the result of the GHG related KPI calculation carried out each year is shown. Finally, the grey $CO_{2\text{-eq}}$ emissions per m^2 emissions target line is also represented as straight line.

The assessment methodology requires three important datasets and data points including:

- The level of GHG reduction obtained by the green wall each year in comparison to the baseline.
- How far away the obtained benefits are from the target value in each year.
- In what year the target GHG emissions is reached.

Whilst Figure 15 shows an example of monitoring of the NBS performance on a periodical basis, the dynamic assessment serves to support decision makers even further. Now let us assume that we are in the year 2030, and that the building with green wall $CO_{2\text{-eq}}$ emissions per m^2 have been measured for the past ten years, and that planning decision makers want to make sure that the green wall can support further $CO_{2\text{-eq}}$ emission reductions intended for 2040. Then, based on a data analytics approach, the current and past performance can be extrapolated using a forecasting method until 2040 to understand the distance between the current state, and the desired target (see Figure 16).

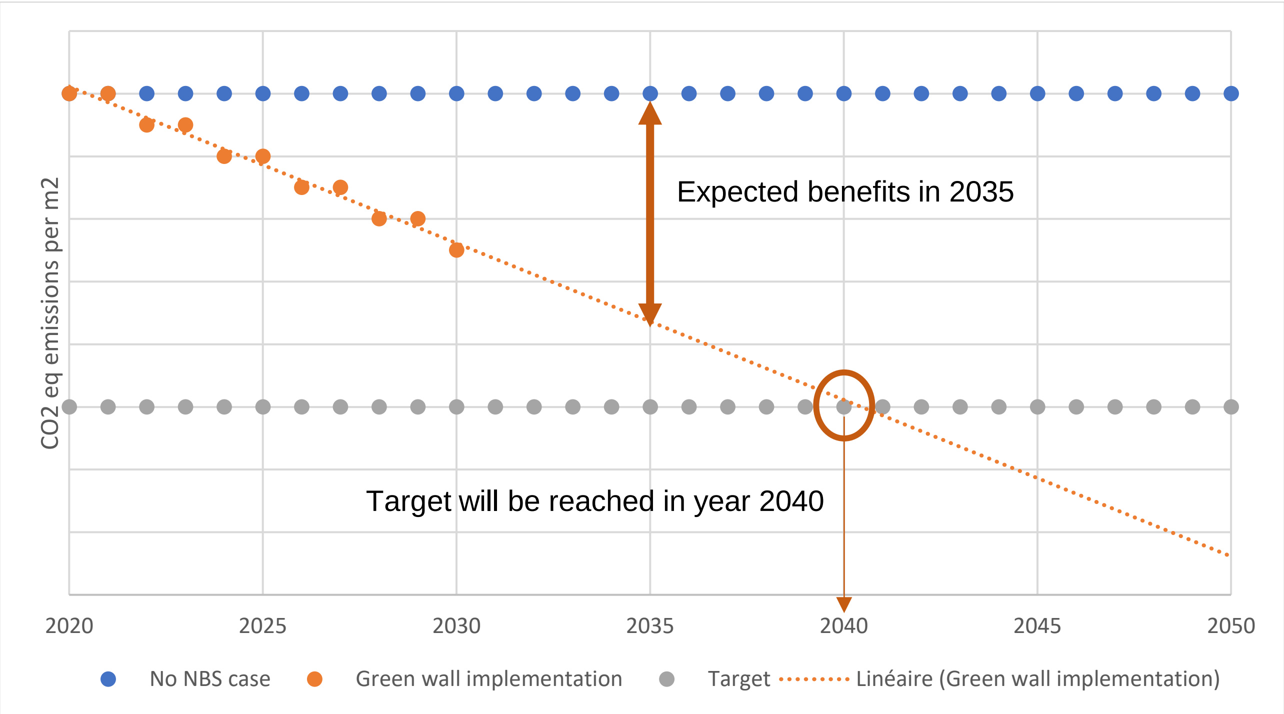

Figure 16 Forecasting of assessment results

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There is possibility that the data analytics results indicate that the targets may not be reached as depicted in Figure 17. This figure gives an important feedback to the decision maker, if the level of reduction and target year should to be satisfied, there is a need for intervention in the building and its green wall NBS system, which requires precautionary action. From the information illustrated in Figure 177, it is possible to ascertain what the level of improvement should be if the target is to be reached in the intended year of 2040.

Different scenarios to close the target gap can be studied and intervention can be planned based on the level of effectiveness expected. The continuous monitoring of the NBS can also be used as a feedback mechanism to observe whether the intervention serves the purpose to meet the targets according to plans as illustrated in Figure 188, where blue and yellow lines represent different intervention alternatives meeting the target year of 2040 and 2042, respectively.

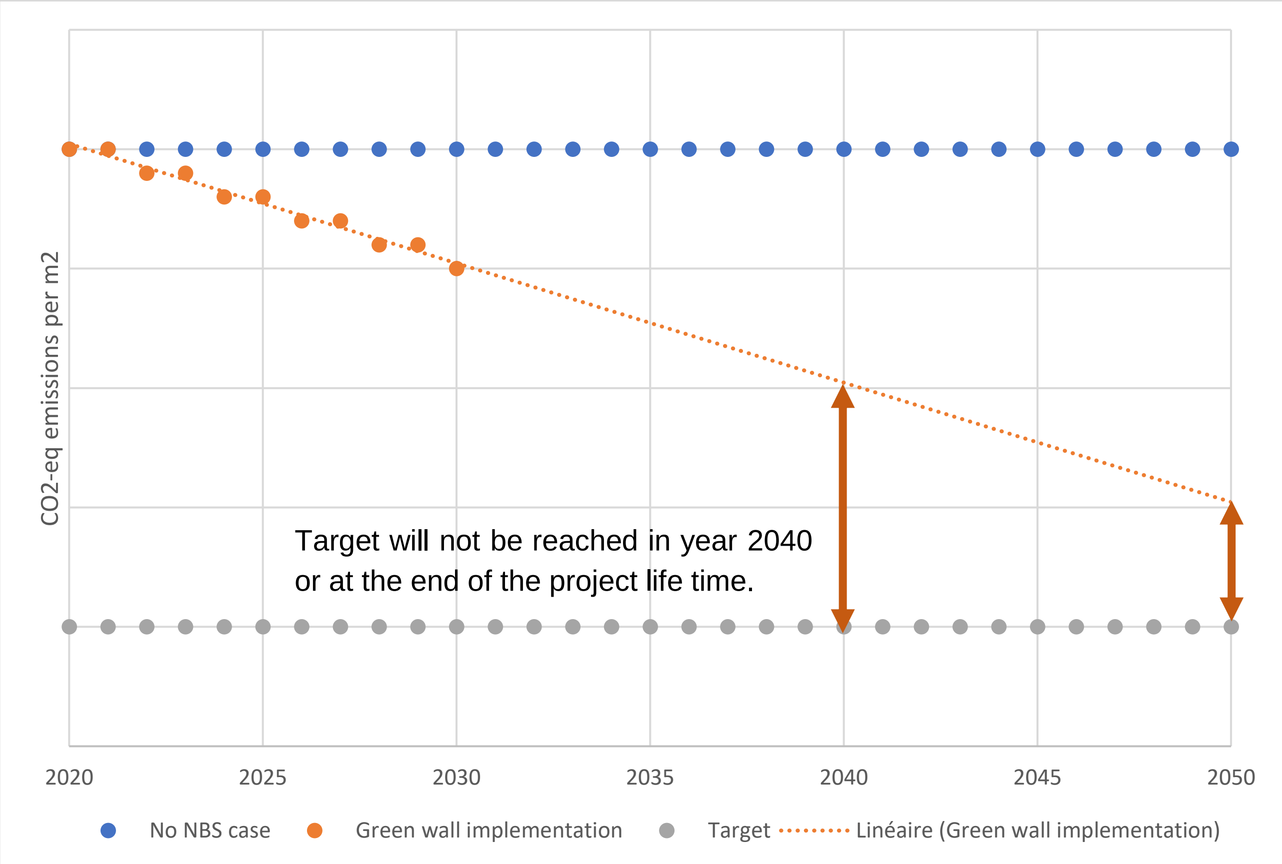

Figure 17 Forecasting of assessment results revealing a need for intervention

It should be noted that the dynamic assessment methodology proposed here does not involve the decision as to which intervention strategy should be employed, but rather reveals the need for intervention and evaluate its effectiveness through monitoring, including revealing whether further improvements are needed at a future data in adjusting the green wall or another NBS to reach the

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targets. The gap between the NBS performance obtained through KPIs, and the target levels (such as level of reduction in GHG emissions in the hypothetical case) or the target date obtained by dynamic assessment, can help the decision makers and planners to understand what rate of improvement is necessary to close the gap.

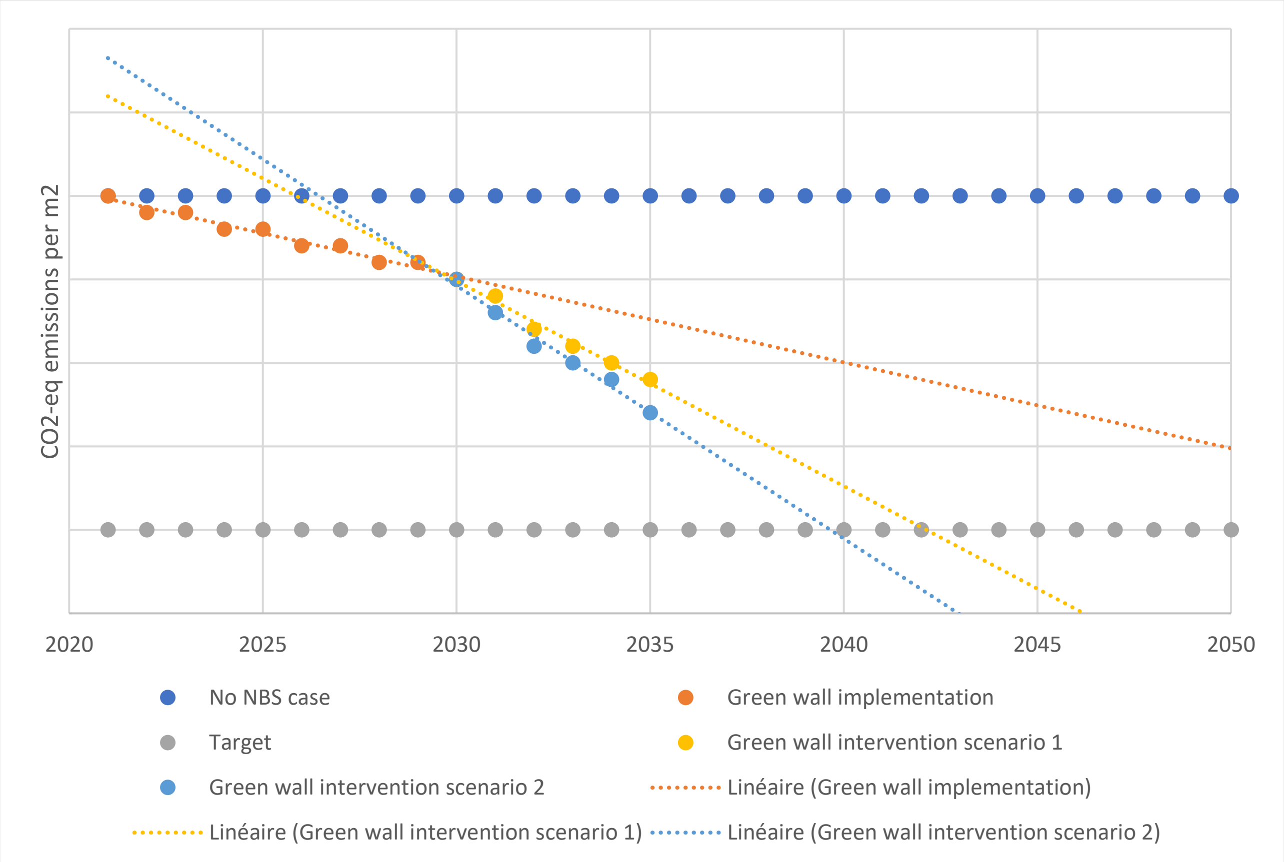

Figure 18 Assessment of intervention scenarios

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4.5 Data availability and sources for Environmental Assessment KPI's

The determination of an exact interval of assessment can be finalized by considering the data sources. Reported units in databases, expert models and measurement methods can guide N4C platform expert users to understand the appropriate time resolution of KPIs and their underlying raw data, as per step 1 in the methodology (section 4.4.1). In other words, the expert users will have to do this in the platform. As part of this process flow related data need to be collected. Once the type of flows, necessary to calculate the KPIs are known, as described in Appendix A, the available data source for each flow can be identified. Whilst in the Nature4Cities project for each pilot an extensive data collection process is being carried out, for wider use purposes a preliminary identification of generic data sources for other cities has been carried out under this report for each flow which is described in this section.

In general, it is possible to obtain baseline flow data for that particular NBS site before the NBS implementation or at the start of measurement from:

- Generic/public databases such as the European Air Quality Index database (https://airindex.eea.europa.eu/) or the European Data Portal (https://www.europeandataportal.eu/data/#/datasets?locale=en&query=energy)
- On-site measurements such as building energy consumption measurements via sensors in a building, and
- Calculations/estimations through external expert models, such as i-Tree for CO_2 sequestration.

To evaluate every KPI selected for dynamic assessment, data availability is the most important aspect of the process. Different data sources are needed to obtain both baseline and NBS scenario data. In order to obtain data necessary for each urban flow, there are three different routes:

- Generic/Public Database (Examples in Table 6 to 9 below), for example, for air quality, an air quality index can be quantified from a generic source with respect to the air pollutants monitored by the governmental institutes, usually available via public info.
- Measurement and Direct Measurement, for example from measurement via in-door building sensors
- Expert Model(s) (as identified in WP2 of Nature4Cities), such as the models covered in the Nature4Cities SUAT or external expert models for instance "i-Tree Eco" for climate mitigation KPIs and "EnergyPlus" via Design Builder for resource efficiency categories

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Ideally, for each usage, locally available “urban flow” & “data source” relations would be identified for each pilot and city, as carried out in Nature4Cities WP7. However, this can be a complex task, and sometimes it is too costly to acquire the necessary data, because of which users may need to revert to generic data sources. For this purpose in Tables 6 to 9 below generic data sources for climate, environmental and resource based dynamic assessments are listed that can be consulted. Note that these examples are more extensive than then urban flow indicators mentioned in the dynamic methodology since the methodology can be applied to other indicators as well. In addition, the time resolution for each urban flow is determined with respect to the time resolution of data source used.

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Table 6 KPI (Climate Category) and Data Source examples

Topics	Environmental KPI for Dynamic Assessment	Data Source 1	Data Source 2	Data Source 3	Data Source 4	Data Source 5	Data Source 6
Climate	***Carbon Sequestration***	Biomass and Climatic Data					
	Avoided GHG Emissions	Sustainable Energy Action Plans (SEAP) and Sustainable Energy and Climate Action Plans (SECAP)	National/City Level GHG Inventories	Commercial/Free LCA Database	Direct Measurement	International Energy Agency(Fossil Fuel Combustion)	Eurostat
	Peak Flow Variation (PFvar)	National Meteorological Services					
	Water Quality(WQ)	Waterbase-Water quality (EEA Database)	Wise Water Framework Directive Database (EEA)	Urban Audit (DG REGIO and EUROSTAT)	Direct Measurement		
	Total Runoff	National Meteorological Services	Water Height Measurement at River Outlet	Topological data(3d buildings/Map)			
	Total Rainfall	General Directorate of Meteorology	Rainfall captured				

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Table 7 KPI (Environment Category) and Data Source examples

Topics	Environmental KPI for Dynamic Assessment	Data Source 1	Data Source 2	Data Source 3	Data Source 4	Data Source 5	Data Source 6
Environment	***Common Air Quality Index(CAQI)/Specific Pollutant Impact***	European Pollutant Release and Transfer Register	Air Quality in Europe(Air Quality Now)	European Air Quality Index(EAQI)(EEA)	Up-to-date air quality measurement (EEA)	Urban Audit (DG REGIO and EUROSTAT)	Urban Data Platform (JRC and DG REGIO)
	Soil Quality	Direct Measurements	Analysis Results				

Table 8 KPI (Resource Category) and Data Source examples

Topics	Environmental KPI for Dynamic Assessment	Data Source 1	Data Source 2	Data Source 3	Data Source 4	Data Source 5	Data Source 6
Resource	***Energy Efficiency***	Energy Bills	Electricity consumption statistics	International Energy Agency (IEA)	World Bank	Electricity and Fuel Distributor(s)	Statistical Institution
	Per Capita Food Production Variability	FAOSTAT	Urban Data Platform (JRC and DG REGIO)				
	Buildings Energy Needs	Electricity consumption statistics collected for residential, industrial, transportation and commercial sectors	National Meteorological Services(For modelling purposes)	Land Office			
	Cumulative Energy Demand	Commerical/Free LCA Database	Urban Audit (DG REGIO and EUROSTAT)				

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Topics	Environmental KPI for Dynamic Assessment	Data Source 1	Data Source 2	Data Source 3	Data Source 4	Data Source 5	Data Source 6
	Absolute Water Consumption	Municipal Authorities	Water Supply and Treatment Companies	Market price of potable water			
	Water Efficiency	Water Supply and Treatment Companies	Urban Audit (DG REGIO and EUROSTAT)				
	Water Scarcity	Life Cycle Initiative	Urban Audit (DG REGIO and EUROSTAT)	Water Supply and Treatment Companies			
	Raw Material Efficiency	Eurostat	National Statistical Institute				
	Specific Waste Generation	Eurostat	National Statistical Institute	Ministry of Environment and Urban Planning	Urban Audit (DG REGIO and EUROSTAT)	Municipal Waste Facilities	Private Solid Waste Collector
	Efficiency of Valorisation as a Result of Recycling Processes	Waste Treatment Company (Private or Public)	Public Services	Municipal Bodies	Expert NGO		

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Topics	Environmental KPI for Dynamic Assessment	Data Source 1	Data Source 2	Data Source 3	Data Source 4	Data Source 5	Data Source 6
	MIPS	Wuppertal Institute Germany	"Material Input for Specific Raw Materials and Products" in the book "Das MIPS-Konzept - Weniger Naturverbrauch - mehr Lebensqualität durch Faktor 10" from Prof. Schmidt-Bleek				

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5 Monitoring and Interpretation Layer: Holistic Urban Analyses

In order to pass to the interpretation stage of dynamic urban performance assessment, the main issue is to investigate what actions need to be taken based on the evaluated dynamic pattern in the data series of the NBS in concern. One of the most important application of time series analysis is that it supports the interpretation activity of the future variation/behaviour based on the available past data. This will give rise to monitor the dynamic nature of environmental challenges in a city and to support decision makers, to intervene and get things back on track, and create lessons learned for the future implementation of NBS related urban planning strategies and project implementation. The use of systems of monitoring and interpretation can as such be used for three reasons:

- To assess how the urban environment can be transformed with individual or multiple NBS in a pro-active manner, with evidence provided by KPI's for the design and implementation of particular NBS (section 5.1).
- To assess how a city complies with environmental targets for compliance purposes with environmental law or other regulatory instruments (section 5.2).
- To assess how the maintenance of NBS can be improved or the design can be improved by renovating the NBS in place (section 5.3)

Seasonal, cyclical or random variations with respect to the temporal allocation of the data in use show the relationship between two variables which may be increasing, decreasing or static within a period of time (see Figure 19. This can be monitored by means of linear or non-linear regression analysis (step 4 in section 4.4). In that sense, “the trend” terminology, which prompts the tendency of the data whether going upward or downward in a defined period, comes into play.

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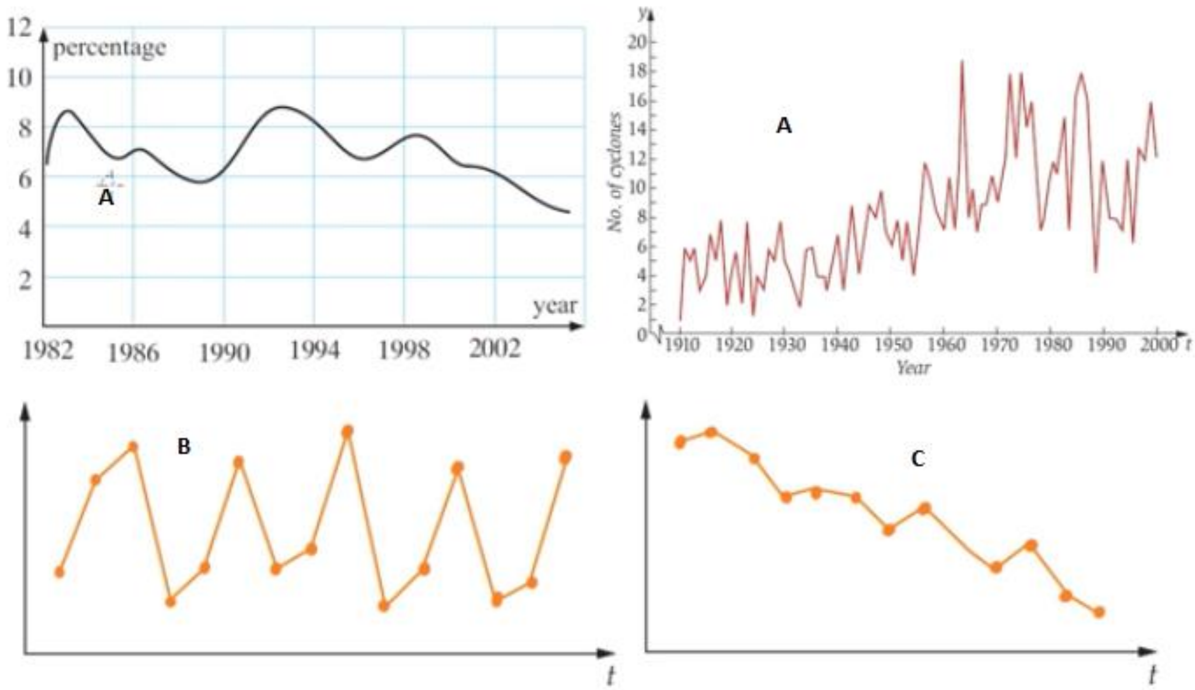

A=Cyclical variation B=Seasonal Variation C=Negative Secular Trend (Random variation)

Figure 19 Variation in Components of Time Series

5.1 Urban Transformation Impacts Assessment

In the context of the N4C project, one of the major intentions is to integrate NBS with measuring the urban nexus material, energy and environmental flows, to tackle different urban challenges. There is a need for the validation of the urban performance measurement framework for monitoring and comparing NBS with respect to a baseline. For this purpose, an assessment methodology to evaluate the results of the dynamic assessment together with urban transformation over the life cycle of the NBS project or asset is developed. Although the transformation concept can be explained both in terms of positive and negative perspective like in LCA indicators also capturing the negative impacts on their life cycle such as “environmental cost”, in N4C project, the main intention is to use NBS scenarios as beneficial as possible in an urban context.

The different challenges that a dynamic assessment framework can help with include estimating the **urban life quality for citizens related to urban flows** (continuous & stock of NBS and their related flows) and respective citizen perceptions. Citizen perception which is already considered in the socio-economic category was studied profoundly in Deliverable 3.2 with respect to ABM concept. The short- or long-term transformation in urban life quality can be evaluated via KPIs trend analysis, for KPIs such as human and ecosystem toxicity (see section 4.2). So this will help to monitor and

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evaluate the urban metabolism direction towards whether a sustainable future or not. Depending on the estimations done with respect to the trend analysis, it is possible to take measures to reach the set targets in due course. Hence, this evaluation framework will enable cities to consolidate their urban planning activities and monitor their progress. [10]

Secondly, urban challenges cover the need to improve **the city environment of soils and atmosphere**, including air quality, which is directly influenced with urban transformation. Several KPI's in section 4.2 relate to this area including acidification, eutrophication, ozone depletion, and water scarcity. The measurement of these indicators requires a system approach. For example, Parks and gardens establishment can have positive effects on air quality of the area in concern if populated with sufficient trees and other plants that filter the air. The type of green places can attract many people if built attractively. However, if at a city scale it attracts many people who will utilise their car to the destination, this can increase air quality and pollution due to fuel usage, and not result in an overall positive benefit. Planning of NBS within a city scale context and taking into account citizens mobility to utilise the NBS is thus of key importance.

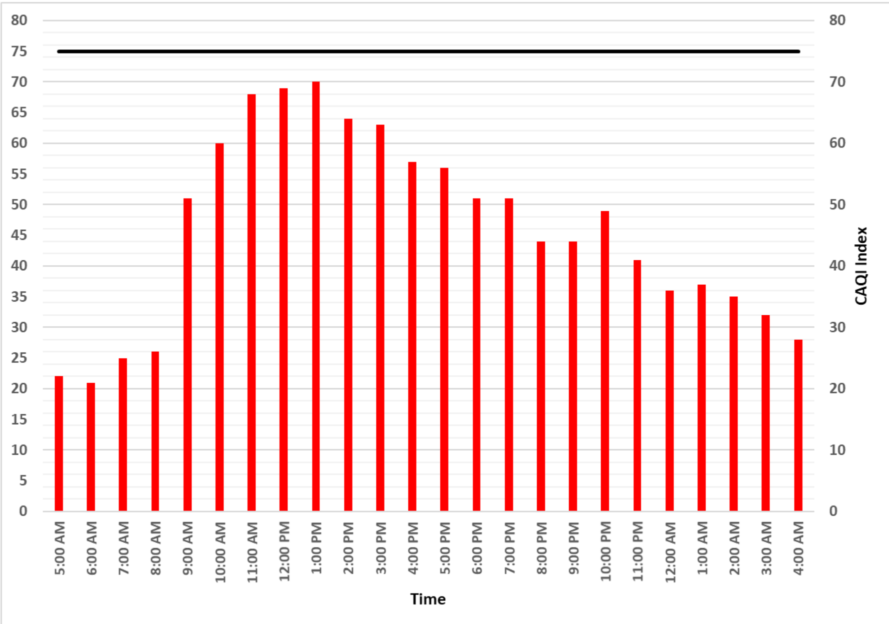

Figure 20 An Example: the City of Lyon CAQI Index(Hourly)

Figure 20 is drawn to illustrate the air quality situation in Lyon, assuming that an urban park having a huge space for picnic and paths for walking, cycling, running and etc. is located in the city centre of Lyon. Moreover, an index of above 75 is considered as high pollution. As it is seen from the graph, after 9 AM in the morning, CAQI starts to increase since the park is getting people from different location using their car and/or public transportation so the air pollution increases because of the traffic background. In addition to that, this dynamic monitoring will help us to see the decrease in night time. Red bars in the graph show the monitored data and the black bar shows the upper limit

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index value as "75". Orange trend shows the dynamic variation of the CAQI(KPI) with respect to the time.

This is an example based on hourly time resolution for a dynamic environmental assessment and if it is needed to reveal a daily situation, a daily average can be used as a time series data. Hence, decision makers could understand easily the time based variation pattern for a selected KPI with respect to the implemented NBS.

The third challenge to integrate with NBS is how nature-based-solutions assist in absorbing **carbon dioxide from the atmosphere**, so as to contribute to helping the problem of climate change that affects the functionality of the ecosystem substantially. The observed positive trend in climate is directly linked to the release of greenhouse gas and NBS can help to increase the carbon content in the soils in which plants grow. In that respect, NBS in an urban context having a connection with GHG based key performance indicators will serve as a monitoring media supporting not only mitigation targets but also adaptation action. Two KPI's assist in this evaluation including annual CO_2 sequestration and avoiding GHG emissions. As a consequence, this forecast based evaluation provides an excellent opportunity to use NBS to support the transformation to carbon neutral cities in a proactive manner.

5.2 Environmental Compliance Monitoring

The assessment of KPI's showing the level of environmental hazards and alleviation in different challenge categories are key objectives, which should be evaluated dynamically. Many environmental regulations exist for which compliance is required. These are summarised in Table 9 below, selected for how they relate with the implementation of NBS and the N4C project.

An example of such an environmental compliance target are regulatory targets for carbon emission reductions, the European Union has set short-term (2020 and 2030) and long-term targets (2050) to achieve Paris Agreement objectives. In the following figure (Figure 21) a slow decrease in terms of the amount of CO_2 equivalent to present is shown, with the red dotted line showing the speed of measures required under the reduction framework. When translated down to a city scale equivalent reduction requirement are needed. The aggregation to a city scale can be done by summing the indicator values for multiple NBS aslong as a common unit of measurement (also refered to as functional unit) is used. In the methodology in this report square metre is used for this purpose. For example, a large park will sequester a certain amount of CO_2 in the soil over time, by summing the m^2 of parks in the city and their measured CO_2 sequestion value a city scale value can be obtained, both as an aggregate and as an average per m^2. In this way, the ability of NBS across the city to sequester carbon can be used to track compliance with existing targets. Dynamic monitoring can provide a simple and convenient way to monitor and evaluate the "avoided GHG Emissions" KPI

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compared with the defined target. As a consequence, the regression trend reveals the truth behind the urban transformation.

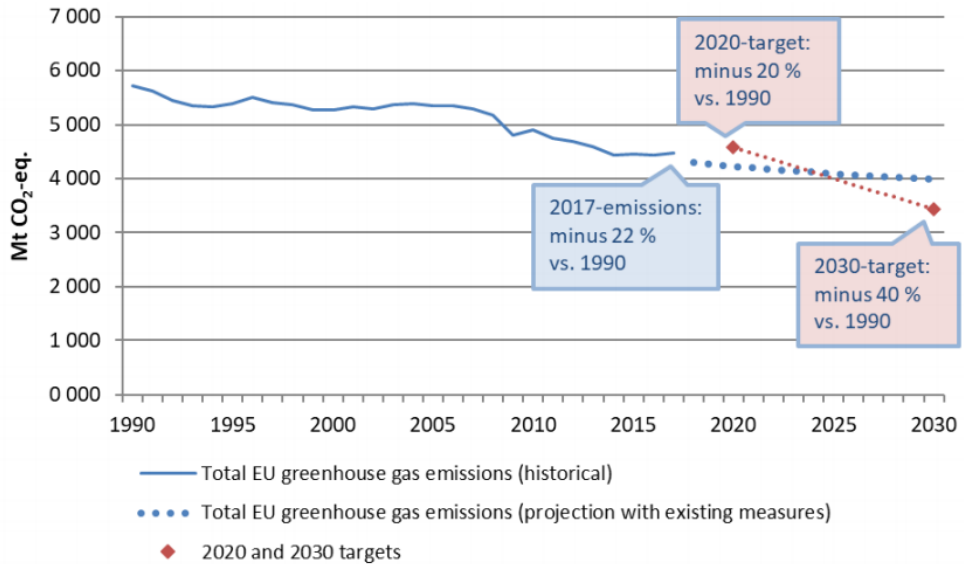

Figure 21 Total GHG emissions in the EU (historical emissions 1990-2017, forecast emissions 2018-2030) (in million tonnes of CO2 equivalent) [11]

The yearly based time resolution in Figure 2121 is conducted for the sake of time series analysis to determine the position of the value in concern with respect to the designated target. The projection dotted lines is the forecast line which is measured via linear regression. It will help the decision makers and observer whether it is necessary to interfere and modify a/any parameter(s) to reach the target. So, in our case, this can be the maintenance of the NBS implemented, the location of the NBS in planning stage (before implementation stage) or other parameters to be considered as a remedy.

Table 9 Environmental Legislations Related with N4C Environmental Challenges [12]

Parameter	Brief Description
Air Quality	Rules on clean air plans and programs, the assessment of the quality of ambient air, monitoring requirements and procedures by means of applying common methods for all pollutants
Water Quality	Water Framework Directive based on the principles of integrated river basin management and the participation of the public in the decision making process is the main legal arrangement that aims to protect and improve the quality as well as the quantity of all water bodies in the EU.

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Parameter	Brief Description
Waste Management	The Waste Framework Directive sets up a waste management hierarchy. According to the waste management hierarchy, waste management strategies must aim primarily to prevent the generation of waste at its source. Where this is not possible, waste materials should be reused and if re-use is not possible, then be recycled. Those waste materials that cannot be recycled should be used for another recovery (e.g. energy recovery). Safe disposal by incineration or in landfill sites is the option of last resort in hierarchy. Alongside the Framework Directive, the EU acquis in the field of waste management includes legislation on landfill of waste, shipment of waste and numerous special waste streams (batteries and accumulators, end-of-life vehicles, waste electrical and electronic equipment, packaging and packaging waste etc.).
Nature Protection	This includes conservation of wild birds conservation of natural habitats and of wild fauna and flora, keeping of wild animals in zoos, prohibiting the use of leghold traps, the protection of species of wild fauna and flora by regulating trade, the importation into Member States of skins of certain seal pups, trade in seal products, FLEGT licensing scheme for imports of timber and obligations of operators who place timber and timber products on the market.
Industrial pollution control and risk management	The main legislative arrangements are Industrial Emissions Directive (2010/75/EU) and Seveso II Directive (96/82/EC) on the Control of Major-Accident Hazards Involving Dangerous Substances. In the scope of Industrial Emissions Directive, it is aimed to merge Directive 2008/1/EC on Integrated Pollution Prevention and Control (IPPC), regulating the issues on integrated permit system, prevention of pollution during the production phase, management of pollution caused by production process, best available techniques (BAT) and public participation, together with other 6 sectoral directives. The aforementioned sectoral directives are: Large Combustion Plants (2001/80/EC) Directive, Waste Incineration Directive (2000/76/AT)(WID), Solvent Emissions Directive (1999/13/EC), 3 Directives About Waste Caused By Titanium Dioxide Industry (78/176/EEC, 82/883/EEC, 92/112/EEC). In this respect, the directives other than Large Combustion Plants (2001/80/EC) Directive was repealed by Industrial Emission Directive by 7th January 2014. The Large Combustion Plants Directive were repealed by 1st January 2016.
Noise	There is a single Directive (2002/49/EC) on the Assessment and Management of Environmental Noise.

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5.3 NBS Maintenance Monitoring and Renovation studies

The final use of the dynamic assessment methodology is to assess the performance of NBS on the fly, so as to adjust the NBS maintenance plan to improve the performance, or to carry out major NBS renovations. Improvement measures of the maintenance plan can relate to water provisioning, clipping and cutting of greenery, different fertilisation, introduction of different plant varieties, change in the areas of the NBS that are accessible to the public. Major NBS renovations can relate to the replanting of entire areas of the NBS, introducing more citizen friendly infrastructure such as paths, cycling routes, or lights, adding a large irrigation and/or fertilisation systems, such as for green walls or green roofs.

The challenge is how to relate the interpreted data to what needs to change in the maintenance plan, or in the layout and design of the NBS. Monitoring the seasonality as described in Figure 18 is a key instrument to understand how over time the performance improves or reduces relative to a baseline. By comparing various flows as defined in section 4.2, with the OLAP approach as described in section 3.3, an understanding can be gained how particular inputs to the NBS are potentially affecting particular performance metrics. For example, how water inputs change over time and affect the total biomass in the NBS and thereby affect soil carbon storage. An algorithm can be built that detects abnormalities for monitoring purpose, and thus shows when there is too much or too little maintenance in terms of providing water, fertilization or too much or too little cutting and trimming.

To understand how NBS can be renovated for improving their performance, the comparison of different NBSs classified during WP 1 studies (See Appendix of Deliverable 1.1) is helpful. Comparisons per m^2 of NBS can be made in terms of particular performance indicators between two or more NBS sites. If the design elements of the NBS are also known, for example, the plant species in a rainwater garden or the proportion of exposed versus covered soil, specific factors influencing the performance can be studied. In this case the ability to retain water under large rainfall events. The study of major NBS renovations to optimise their performance will thereby be greatly assisted by making dynamic assessment data openly available and creating a comparable database between NBS of similar types. This will also help the design of greenfield NBS sites.

5.4 Monitoring and Interpretation Conclusions

In conclusion, monitoring and interpretation phases are significant to comment on the future projection of Urban Performance Indicator's (UPIs) supported by the past and current data available. For the quality assurance of these phases, it is necessary to check the coherence and consistency of the data provided continuously. This is one of the most important actions to be performed for the explication of the NBS implementation in an urban scenario. This will ultimately yield in different advantageous outputs such as:

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- Performance monitoring
- Periodic maintenance monitoring
- Support for urban planning and NBS implementation
- Support for determination of intervention period to maintain a healthy correlation between the urban infrastructure and NBS implemented.

In order to understand and make use of the benefits acquired from interpretation stage, it is better to utilize visual skills like bar charts and/or dashboards which shows the dynamic variation in a more comprehensive way for the municipalities including all related departments so everyone from different position in terms of title and hierarchy can participate in the discussion. This visualization concept will be described in the next Chapter 6 of this deliverable.

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6 Visualisation Layer: User Specific Reporting

The data visualization layer of the Nature4Cities platform will communicate insights from the data sourced through visual representations. Due to the way the human brain processes information, using charts or graphs to visualize large amounts of complex data proves easier for platform beneficiaries than pouring over spreadsheets or reports. Data visualization is a quick, easy way to convey concepts in a universal manner in order to facilitate a more efficient and better-informed decision-making process. However, a poor presentation can be misleading and complicated visuals often fail to communicate as intended. In order to deliver the most productive visualizations, in this section we will draw upon the use cases described Deliverable 8.2 to discuss the potential benficaries of the platform, their respective needs and what can be learnt from existing data presentation tools and approaches.

6.1 Users & needs

In order to create a successful platform, consideration of the end beneficiary of the platform is vital when designing the visualisation layer. User Centred Design is being increasingly recognised as a means to ensure that the resulting end product meets the market demand and is used in the manner in which it was intended.

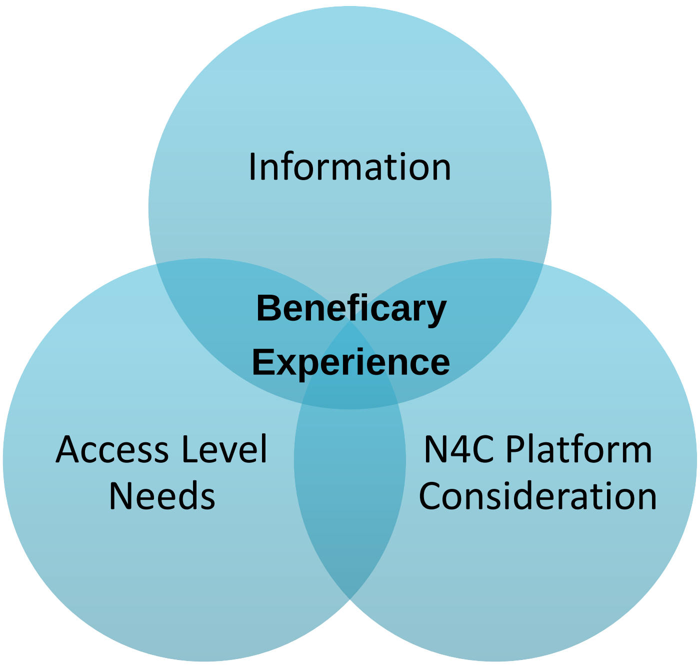

Figure 22 User Centred Design

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Paying due attention to the needs of the end beneficiary will enhance the ability of the Nature4Cities platform to offer support within NBS decision making process. We will draw up the use cases considered in Deliverable 8.2 to analyse the access needs and platform considerations for the potential beneficaries detailed in Table 10 below. It is acknowledged that it is often not possible to meet the needs of all beneficaries simultaneously, therefore the next step will be to determine how the platform access levels will differ for each use case. To do this, we will strive to understand the context in which the platform will be used and the differences in the technical ability of the beneficaries.

Table 10. Platform beneficaries and their needs

Potential Beneficary	Access Needs	Platform Considerations
Citizen	Energy Efficiency, Air Quality Index, Environment Indicators	• Easy to understand statistics and KPI measurements • Concise information • Clear explanatory language • Clear and easy to interpret visualizations
Expert	Energy Efficiency, Air Quality Index, Environment Indicators, Resource Indicators, Climate Indicators	• Visualizations technical enough to draw conclusions from • Inclusion of complex data • Availability of the most up-to-date data
Municipality	LCIA Indicators, Energy Efficiency, Air Quality Indec, Environment Indicators, Resource Indicators, Climate Indicators	• Clear overview of all data • Ability to zoom in on sections of data • Decision making prompts • Availability of the most up-to-date data

Well-structured data visualisation can improve insights and make visible, aspects of the data set which might otherwise be overlooked [13]. A study by Kennedy and Hill highlights why the consideration of target end users and the persuasive aim of the visual is important when designing the visualisation layer [14]. The paper discusses the relationship between data presentation and emotions, stating how the characteristics of visuals, such as colour and scale, can be utilised to achieve productive persuasion in decision making platforms. It is important to acknowledge how

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misunderstandings and misinterpretations can result from different cultural traditions. Colours, for example, may have different symbolic meanings in different parts of the world.

6.2 Tools, approaches for presentation of data

Emerging tools and techniques provide new opportunities for visualizing data and making it more interesting and attractive to benficaries. Dynamic table, chart and map generators allow expert users to manipulate their collected data and create unique visualizations to support beneficiaries during the decision making process. Current highly used tools include:

- Tableau - suitable for use with big data to create graphics and visualizations that are easily comprehensible

  Ref: https://www.tableau.com/en-gb

- Fusion Charts – JavaScript based visualization package with a variety of both static and dynamic charts

  Ref: https://www.fusioncharts.com/

- Qlikview – offers analytics and intelligent insights on top of visualizations

  Ref: https://www.qlik.com/us

- Plotly – Uses programming languages to allow for ease of integration and producing more complex visuals

  Ref: https://plot.ly/python/

In this section, we will look at how effective data presentation has been achieved in existing tools and the approaches which have been taken. It is important to keep the communication goal and beneficary of the platform in mind when deciding on visualisations. The Nature4Cities platform will have a choice of 3 access levels for each use case defined in N4C Deliverable 8.2; Citizen, Expert and Municipality.[3] Each will contain a variation of the example dashboard below. The home dashboards will be designed in WP6. The works in this deliverable will feed into the final design and it is suggested here to split the dashboard into four components (scenarios) where appropriate:

- Climate change and mitigation
- Environmental regulations and targets
- Urban transformation
- Behavioural and social change impacts

[3] NBK, ACC, CAR, ARG, R2M (2017). D8.2 – Nature4Cities Platform Use Cases. Nature4Cities Project

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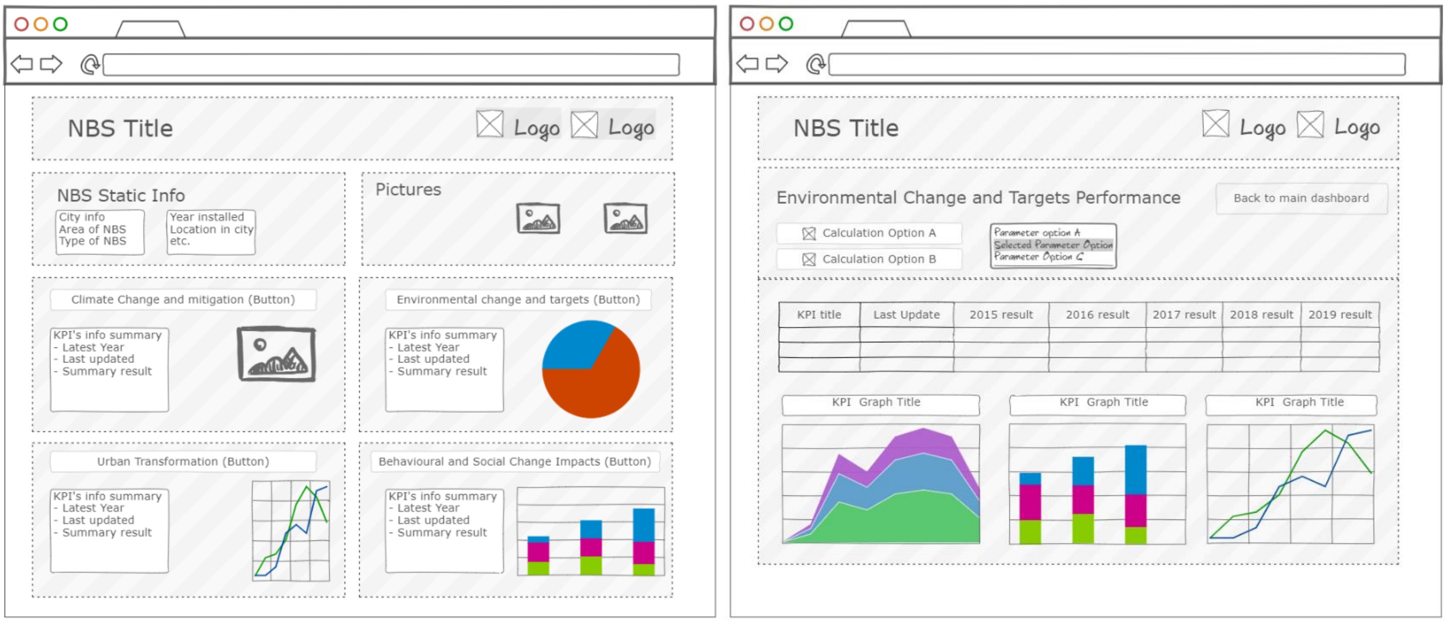

Figure 23 Example Dashboard Layout

Each component will present a subset of KPI's covering processed geographical, environmental and social metrics. As you can see in the above example, graphical displays will be utilised to present these metrics in the most effective manner for each use case. We propose that the initial dashboard contains simple, easily accessible visuals as a starting point, whilst the linked pages allow advanced benficaries to explore further complexity.

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<u>**Graphical displays**</u>

Line charts: BAU vs with NBS estimate - Standard line charts are often the best visualisation for comparing data across a time frame. They are temporal graphs defined by their linear and one-dimensional characteristics. The lines make the trends and pattern of the data set easily accessible. A general increasing or decreasing trend can be identified by just glancing at the graph, making them useful for citizen benficaries with little statistical background. Values at specific points can be emphasized to draw the user's attention or to highlight the period of measurement. Due the variety of measurement periods for the KPI's listed in section 4.2, noting the time resolution by empathising values could prove important in providing clear information to any platform beneficary.

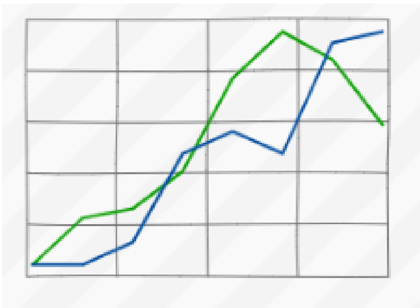

Figure 24 Line Chart example

Stacked Area Chart - Stacked area charts follow the same structure as the standard line charts described above, however provide a greater insight into the composition of the line plotted. This type of graphical display is most often used to present data which depicts a time-series relationship. It provides a quick comparison of the data trend/proportion of each category.

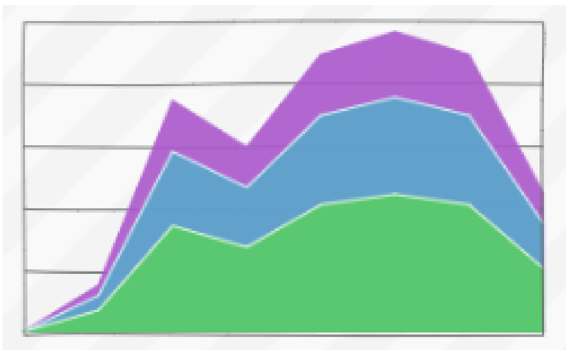

Figure 25 Stacked Area Chart

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Stacked Bar Charts - Stacked Bar Charts are useful visualisation tool to present composition data. The multi-dimensional data visualization is useful for breaking down big data sets in order to display key takeaways.

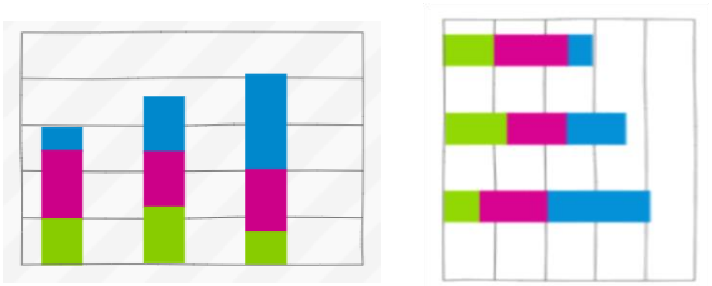

Figure 26 Stacked Bar Chart Examples: horizontal and vertical

In the Nature4Cities platform, this type of chart could be utilised to highlight the main contributors to LCIA indicators or the composition make up of specific toxins in the air or soil. Presenting the data in a stack bar chart not only allows for comparisons of relative values but also aggregated differences between NBS solutions. It is important to use distinct colours and clear labels to avoid confusion between layers. The human eye can often interpret horizontal stacks faster, especially with large numbers of bars. This is particularly the case in Western culture, due to the ingrained preference of reading from left to right instead of up to down.

Pie Charts - Studies have proven that the human brain struggles when it comes to comparing the size of angles. Therefore, pie charts are not efficient to use for comparing changes in value over time. Even with the addition of clear labels, the alternative graphical displays above prove to be better for comparative data. However, the pie chart is beneficial for displaying static composition information. The circular shapes portray a proportion of a whole, enabling fast relative interpretations by the user. When used, the pie chart will be coupled with clear labels and distinct colours. In the below example, the pie chart is proposed for use on the home dashboard for displaying aggregate information.

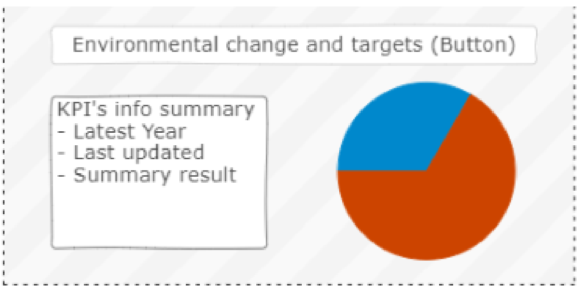

Figure 27 Pie Chart Example

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6.3 Communication and decision making

In the previous sections, we have discussed how the visualisation of data must meet the needs of the platform beneficaries. In this final section, we will build upon our previous findings by exploring how the aforementioned visualisations can succeed in communicating the aim of the platform and support the decision-making process. Before providing examples of how the platform could be used to support NBS decisions, we will discuss the cognitive process behind decisions and how that should be considered in designing the final dashboards to display each of the three access levels for the use cases described in Deliverable 8.2.

The decision-making process when considering NBS solutions will be based on the data displayed and comparison of potential outcomes across the different nature-based options. Factors that could influence a user's decision-making outcome include;

- past experience
- a variety of cognitive biases
- an escalation of commitment and sunk outcomes
- individual differences (including age and socioeconomic status)
- belief in personal relevance

A heuristic is an approach to decision-making that uses a logical framework and is based on little information. Before making a choice, the beneficiary might not have the time, resources or necessary expertise to compare all the different information, in these circumstances' heuristics are relied on to aid fast decision-making processes. It is for this reason that data visualisation must strive to be clearly interpretable at a glance, especially within the interface for citizen beneficaries. Heuristics are otherwise viewed as mental short cuts that reduce the cognitive load attached to decision making [15]. Whilst these mental shortcuts are often useful, they can also lead to errors or cognitive biases. Therefore, the Nature4Cities platform must take into consideration how heuristics may be encountered by beneficaries of the platform and strive to display the data in a manner which deters from error. An array of heuristics are used by individuals in a decision-making process and the platform considerations are detailed below (see Table 11)

As well as heuristics, how green spaces and the environment are valued will influence a beneficarie's tendency to implement a nature-based solution. The value placed upon NBS can be split into three categories; economic value, social value and environmental value (see Figure 27).

Finally, the platform will cater to a range of beneficaries and support various decision processes. Below we will consider 4 different examples of where the N4C platform could be utilised and detail characteristics of data visuals that should be considered to ensure the platform is meeting the needs at each level of access.

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Table 11 – Heuristics in relation to platform usage

Heuristic	Definition	Platform Considerations
Representative Heuristic	Individuals are prone to estimate the likelihood of an outcome based on previous experiences or prototypes.	• Knowledge of previous NBS failure/success might warp interpretation of presented data
Availability Heuristic	Individuals are more inclined to receive information that is readily available.	• Complex visuals could result in lost or inaccurate messages • Long links of pages might lose users attention
Anchoring and Adjustment Heuristic	Individuals first 'anchor' by making an estimate of the outcome and then adjust their estimate based on further information	• Decisions on NBS might be made on the first dashboard despite further exploration to the more detailed displays. The home dashboard therefore must provide an accurate overall representation of the data.

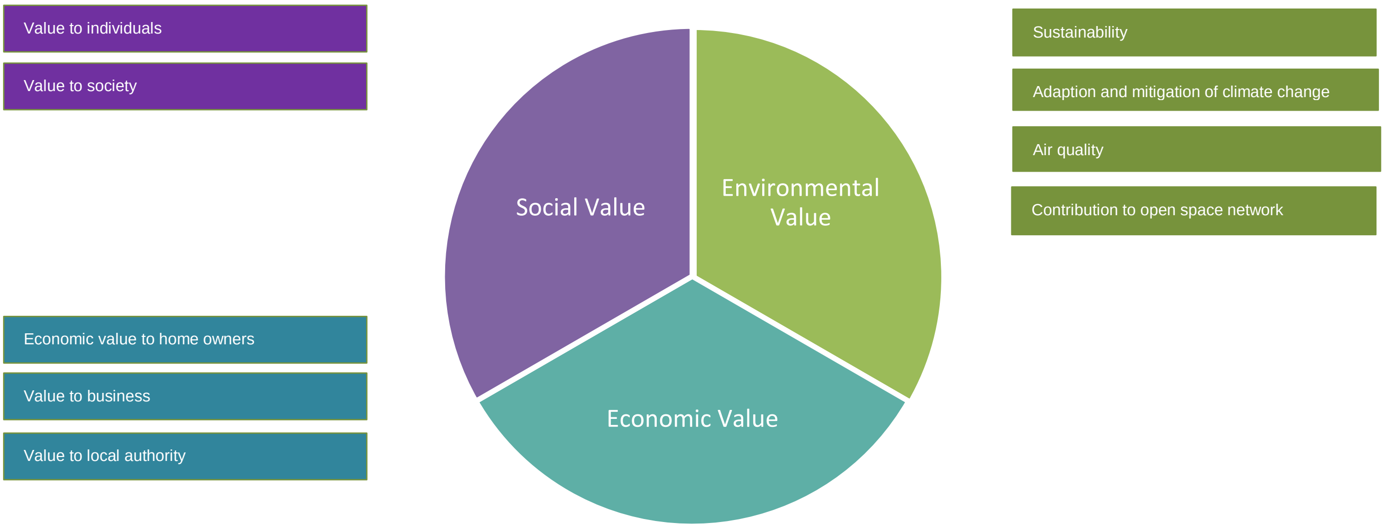

Figure 28 Value of Nature Based Solutions

Example 1: Urban Planners and Designers for overall neighbourhood/area development plans (high-level) that wish to evaluate whether their green infrastructure or explore the possible of including NBS in order to meet desired targets (e.g. carbon storage in the soil or green cover area etc.).

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Expected Access Level	Expert
Decision Making Process	Need for development indentified → Urban Planners/ Designers tasked with proposing development plan → Solutions and Designs explored → N4C's platform used to display benefits of difference NBS implementaions → NBS decided → N4C's platform monitors affect of NBS on KPI's after implementation
Platform Needs	• Comparison of real time data to desired targets. • Variety of NBS options
Communication Considerations	• Ability to access data breakdowns and explanation of target calculations • High social value of NBS • Representative heuristic

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Example 2: Property development where architects design within an infrastructure project the m² of green space that is minimally required (or if it's a green property development more spatial input) who want to set for particular NBS a baseline and track targets are reached for that particular property once implemented (say rainwater catchment or carbon storage).

Expected Access Level	Expert - NBS designer
Decision Making Process	Property development initiate → Minimal requirements of m² green space needed due to country regulations → Design entered into N4C platform → NBS baseline set and changes tracked → NBS decided
Platform Needs	• Ability to set NBS baseline • Trackable progress and targets
Communication Considerations	• Availabilty heuristic • High environment value of NBS

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Example 3: Investment decision makers for specific green infrastructure projects of a municipality/city, such as a governmental/city infrastructure investment commission, a high up civil servant that gives the financial go-ahead in a finance department of a city (or ministry), or a project investment board of a bank that provides co-funding

Expected Access Level	Municipality - NBS investment decisions
Decision Making Process	Municipality/city commissioned for specific green infrastructure project → N4C platforms used to display benefits of project → Platform outlines NBS options if scope for choice → NBS baselines can be used to support project funding and validity of design → NBS decided
Platform Needs	• To provide co-benefit information (such as carbon storage info)
Communication Considerations	• High economic value of NBS • Value to society of NBS

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Example 4: Use of Nature4Cities platform by the General public during a consultation evening on infrastructure projects organised by the municipality

Expected Access Level	Citizen
Decision Making Process	Infrastructure project ititiated → General Public engaged → N4C used to display key take aways → Public can ask questions based on information displayed → Public can provide informed opinion on NBS preference → NBS decided
Platform Needs	- Visuals interpretable at a glance without drawing inaccurate conclusions. - General overview of NBS scenarios and predicted outcomes of each.
Communication Considerations	- Avoid use of complicated language and overcrowded/complex data presentation - Assume low statistical analysis background, display key takeaways clearly. - Economic value to homeowners of NBS - Environmental value (health impacts) of NBS - Anchoring and Adjusting heuristic likely to be used

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7 Conclusions and Discussion

7.1 Conclusions on task Results

This deliverable presents the dynamic evaluation methodology to be performed for different NBS scenarios assembling the main aspects mentioned during WP3 studies. To begin with, MFA and LCA approaches in urban metabolism concept are the two viable branches of environmental impact assessment technique applied in this work package. These methods are widely used in different conditions and situations however it implementation and monitoring of NBS in urban context. In other words, the main purpose of this task was to define the dynamic methodology for environmental challenges for the Nature4Cities project and beyond.

For this purpose, nine indicators from Task 3.1 were shortlisted as flow-based urban indicators and 7 mid-point and 3 end-point impact category indicator from Task 3.3 were applied as indicator for the dynamic assessment methodology covering climate, environment and resource themes. These indicators respond to the consecutive loops for the cause-effect chain of urban challenges but there is a significant difference between urban flow indicators and life cycle indicators. The quantity of urban flow varies systematically within the system boundary while on the other hand life cycle indicators try to estimate the environmental impacts due these variations determined by LCA practice. Moreover, the connection between environmental and the social-economic status of the urban citizen which was covered in N4C D3.2[4] is connected to the methodology with inputs as described in Chapter 0 of this report (KPIs in the N4C Environmental Assessment Framework).

In order to support the decision makers in the context of urban planning, it is necessary to understand the environmental efficiency and cost effectiveness of a project in concern, in our case, it is the application/implementation of NBS in different urban spatial scales. To determine the status and the future projection related with the implementation of NBS, monitoring and tracking of the operation via KPIs usage answering different urban challenges is one of the best options facilitating urban strategy development activities. For this reason, it is crucial to develop a methodology nourished by the time series analysis for dynamic NBS performance monitoring and evaluation. This time series concept is utilized for the dynamic KPI assessment with the help of relevant time resolution respectively. Due to this fact, the temporal availability, which determines the time resolution also known as interval of evaluation, of the data for KPI quantification is one of the difficult and crucial aspect to handle properly. Inventory analysis is necessary for an existing NBS and for the baseline assessment to compare the time based alteration with respect to a reference point.

[4] EKO, DW, METU, UN, LIST (2019). D3.2 – Report on Agent Based Analysis Approaches identifying citizen agents and their behaviours for Nature Based Solutions. Nature4Cities Project

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Dynamic monitoring of NBS performance provides a holistic vision covering the needs of municipalities and related parties within the context of different urban challenges, targets and regulations. Five types of uses are foreseen: to assess pro-actively how the urban landscape can be transformed to improve the quality of life of citizens, to improve the environment including soils and atmosphere to improve the assessment of carbon sequestration and climate change mitigation within the city, to improve the performance measurement of particular NBS's for maintenance purposes, and to help with renovation of brownfield NBS sites and improved design of greenfield NBS sites.

It is recommended that the implementation of the dynamic assessment methodology is paired with making any NBS data openly available in a structured manner, based on the m^2 of NBS and the type(s) of NBS studies, as identified in the ontology in WP1. This will facilitate the comparison between NBS sites, so as to identify how the design can be improved and made much more effective, as well as allow for better renovation of NBS sites.

The results obtained from dynamic assessment gives rise to some beneficial comparison studies between targets and NBS performance. Moreover, it is possible to monitor the situation by comparing actual NBS implementation with different scenarios

First, periodical data needs to be gathered for the evaluation of each KPI, and subsequently the indicators can be quantified. Next, trend analysis has to be performed both for baseline and NBS implementation scenario, and finally performance forecasting can be carried out by comparing trends with set targets. Moreover, this methodology, which is considered as one of the major objectives, gives the opportunity to make a comparison between reference scenario (i.e. BAU or baseline) to understand how much benefit is acquired or not during identified time frame. To sum up, the methodology can be prioritized and arranged with the five steps described below:

1. Time Frame and Time Resolution Setting
2. Baseline Data Establishment
3. Target Setting
4. Time-Series Future Trend Analysis
5. Analysis of Trends with Targets

WP 3 is mostly dealing with the urban metabolism covering nature-based development against environmental challenges upon implementation of NBS. Moreover, the urban metabolism framework of N4C studying the interactions between different unit processes is built upon material and energy flows. These flows have a strong relationship affecting the quality of life in urban context so in order to maintain the sustainability (temporal aspect) of this quality concept, dynamic assessment of KPIs including monitoring and precautionary assessment objectives reveals the time based NBS performance struggling with the urban challenges. In this way, the dynamic analysis will support the decision makers to interpret the projection of a KPI according to the trend analysis. This will also

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assist urban planners in forecasting and monitoring of the urban challenges and reflect the dynamic nature of the urban ecosystems.

The assessment results based on the dynamic analysis should be visualised according to the user requirement. This visualization step, which is defined in Chapter 7, is the representation of the insights derived from assessment results. It simplifies the comprehension step of human being rather than using data table, long reports, etc. The potential beneficary perspective linked with human perception will define the tools and approaches needed for the presentation of the monitoring results.

The dynamic nature of urban metabolism together with their inbound and outbound flows is considerably important subject to cope with and providing useful insights for decision makers. This is achieved by N4C project general work package structure answering and facing this issue in a holistic manner. As a conclusion, a dynamic methodology including time-series trend analysis of environmental KPI is developed in this deliverable. The main target of this document is to evaluate continuous data depending on the relevant time resolution for performance monitoring and precautionary assessment of KPI linked with different urban challenges. In that respect, it will be quiet beneficial to interpret the future projection of different urban scenarios where various types of NBS implementation are possible. As the environmental assessment tool(s) will be implemented in N4C platform in WP 6, the main purpose of this study defining the methodology will be achieved eventually and let decision makers (municipalities, experts, citizens and other related parties) comprehend and perceive the dynamism of urban metabolism more clearly leading to act and build strategies upon these results.

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7.2 Discussion on Effectiveness of Methodology & Recommendations

The concept developed in this document for time based NBS monitoring via selected KPI(s) serves as a dynamic assessment methodology for environmental assessment of NBS in an urban context reflecting the dynamic nature of the urban ecosystem including NBS. To review and debate over the methodology, this section can be categorized into four branches such as:

Interpretations

In order to develop sustainable and resilient urban strategies, it is crucial to understand the challenges occurring and accumulating in the course of time that citizens are facing every day. This will end up eventually in an uninhabitable environment forming a corrupted urban metabolism. In that respect, it is necessary to follow up the orientation of the trend of such challenges properly, in other words monitoring this dynamic pattern will offer several benefits to the municipalities, decision makers, experts and others. The results derived from time series assessment are useful insights showing different checkpoints whether it is achieved or achievable or not.

Implications

The outputs of time series dynamic monitoring will establish a direct link with decision making management framework which is an effective way to evaluate the NBS applicability within an urban context. In this respect, the trend analysis, will prompt variation with respect to the relevant time resolution, makes it possible to see how the performance indicator will evolve in the future. This will guide the organizations and people in charge to establish a good urban planning basement before and after NBS Implementation scenarios. As a next step to advance this methodology a number of standardised protocols need to be developed, combined with ready-to-implement data collection methods and hardware/software systems tailored to each NBS type. To this end, the implementation will need to be studied from the perspective of what information the user needs to enter and what the platform provides. For example, the time frame resolution, the baseline setting, periodical data provisioning for the monitoring of NBS and the target setting. Also, the implementation of the future trend analysis will be studied further from an IT perspective under WP6, as the IT side of the implementation is not in the scope of this deliverable.

Limitations

It is obvious that the boundaries or the frame of this methodology are shaped with respect to the available limitations. These restrictions include the KPI’s and associated parameters affecting the assessment process, and the availability of data to assess these. The interpretation step relies on this limitation which can create a deficit to show comprehensive figures to describe the tendency and the status of the NBS properly. The following table represents the limitations in the dynamic assessment methodology.

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Table 12 Dynamic Assessment Methodology Limitations

Limitation	Remark
Data availability	Requires a data collection system that is suitable for each NBS type and related to each NBS type. The N4C project provides a pioneering effort in learning how to build such a system.
Data quality	Requires a harmonized quality system that still needs to be built for NBS in particular. Fortunately such systems are readily available from existing data analytics disciplines
Data complexity	Requires end-to-end easily implementable software that makes it possible for the user to not have to deal with complex data, yet still provides the benefits using automated data analytics algorithms and visualisations
Knowledge/Expertise	Insufficient capacity may exist at the city or company scale in terms of how to valorize NBS benefits which requires expertise and knowledge within these organisations to tie it to existing decision cycles
Uncertainty of the time series analysis	The measurement of single NBS sites can induce significant uncertainty, as individual measurements are prone to error. It will be needed to build up a series of benchmark datasets for each NBS type, so as to compare one NBS site with another and understand if the measurement has a low amount of uncertainty
Measurement Time interval selection	The NBS measurement can be done at various time-intervals. Depending on the KPI and purpose of the measurement it may be helpful to obtain weekly, monthly or just annual measurements. A system for this still has to be worked out.
Random trend variations	Since NBS are living systems, their input needs and provided outputs can change randomly over time within an expected bandwidth. Sometimes these can lead to sudden really large deviations from the norm that need to be taken into account

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TRL of monitoring equipment	At the moment there are limited low-cost sensors for measuring NBS and it is not a practice commonly used by cities, such as the monitoring of soil moisture in parks at a few sensor sites to understand watering needs. Significant work is needed to make this a readily implemented practice.

Recommendations

In order to reduce the amount of uncertainty and increase the accuracy together with the consistency of the results derived from dynamic assessment, it is necessary to develop the methodology according to real case studies providing real continuous data. In addition to that, particular attention is needed that every application or case study has its own pattern which will ultimately shape the fabric of dynamic assessment uniquely. So the feedback from different trials which will enlighten the path for the establishment of a sound dynamic monitoring technic is an essential mechanism to conduct in that sense.

Another important aspect is to keep in mind that the data measurement error can occur randomly or not which will eventually end up as an outlier data. So it is crucial to determine which data will be used in evaluation process and sometimes this will help the evaluator to assess the credibility of the data source.

The final word on the matter, another healthy way to bring down the uncertainty of the dynamic evaluation to a degree, an open (public) database can be created involving various NBS and their KPI Performance Data matrix together with the design parameter of the NBS such as plant species types and their numbers, the total surface area used, etc. As a consequence, this will very likely improve the setting of the baseline and support experts/citizen/user working on this subject to understand much better the NBS performance in selection stage.

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Annex A – Detailed descriptions of Environmental Assessment KPI's

The transition of environmental urban features from BAU to a more sustainable state is one of the major objectives of urban planners, decision makers and citizens. For this purpose, urban monitoring action in order to understand long term solutions related with NBS implementation will be a temporal enlightenment facilitating the trend evaluation for decision makers, urban planners and other relevant shareholders respectively.

The fundamental aim of this task is to deliver a dynamic model that evaluates urban metabolism together with NBS performance. To achieve this, the most relevant environmental indicators have to be selected which are able to reflect the variations in time series and the future trends as well. In this way, an extensive definition of the indicators in question will be necessary due to their substantial effect on drawing the borders of the assessment methodology. In this chapter, indicators derived from Task 2.1, Task 3.1(Urban Flow Indicators) and Task 3.3 (Life Cycle Indicators), categorized into three main branches of urban challenges such as Climate, Environment and Resource, are identified as below.

Environmental Assessment Indicators and Definitions

The list of indicators mentioned here covers both the urban flow indicators as listed in Chapter 4 of this report and those listed in Deliverable 3.1 in Table 3 under Chapter 4.2 of the Deliverable. The additional effort has been carried out to be as informative as possible for expanding the dynamic methodology for other users, researchers or analysts.

Urban Flow Indicators

Climate

Currently, every city in Europe is responsible for building a carbon-neutral urban development strategy. In order to push this issue, Covenant of Mayors in European Commission has set the target

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for European Cities to reduce the emissions by building an action plan including green space management and utilization of NBS. Building resilience to climate change has two complementary parameters; adaptation and mitigation. Both remain key when formulating solutions to address GHG and water management challenges.

Annual Carbon Sequestration

As a climate change measure, a popular concept called "urban greenery" is applied by city governments. This is achieved by promoting tree planting (vegetation) and implementing relevant vegetation NBS resulting in a reduction of Greenhouse Gas Emission. [16] This reduction is directly related to the accumulation of Carbon Dioxide in trees and soil via respiration. Thus, carbon sequestration is one of the crucial indicators to assess when considering the effectiveness of an NBS. We will continue by considering accumulation by vegetation.

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, such to enable spatial and temporal comparisons of the capacities of different NBS. 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. [17]

The following formula is used to calculate the stored carbon in biomass at a specific time "t".

$$Cb_{t+1} = Cb_t + Kc[Gb_t - Ms_t - T_t - H_t]$$

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 ($m^3ha^{-1}yr^{-1}$)

The amount of CO_2 absorbed by the biomass per year is a dynamic event, on the other hand the cumulative amount of CO_2 absorbed over 50 years can be deemed a "static event" depending on the time interval that the user is dealing with. To calculate this indicator, in line with dynamic assessment procedure, it is intended to use total sequestered value derived from Expert Box (Task 2.4) and utilize it directly to quantify the total sequestered carbon in a relevant sequence for dynamic environmental evaluation. This expert box in SUAT requires the user to input vegetation types along with climate zone, tree species, size parameters, etc. The output will then be the annually sequestered carbon by the existing or new NBS.

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Finally, by utilizing the CO_2 uptake and release amount of the given plants, together with carbon storage LCI flows, it is also possible to calculate this indicator via LCIA. This is possible due to the existence of “CO_2 Sequestration” as a Life Cycle Indicator available in climate change category.

INFO BOX-1 [29]
Generalization:
During the measurement of CO_2 stored in trees based on mass of tree
•35% of the green mass of a tree is water so 65% is solid dry mass;
•50% of the dry mass of a tree is carbon;
•20% of tree biomass is below ground level in roots so a multiplication factor of 120%

$$CO_2 \text{ sequestered per tree (kg)} = \text{Tree mass (kg of fresh biomass)} \times 65\% \text{ (dry mass)} \times 50\% \text{ (carbon \%)} \times 3.67 \times 120\%$$

Avoided GHG Emissions

One of the pressing issues for the urban ecosystem is GHG Emissions. This indicator aims to quantify the amount of greenhouse gases (GHG) avoided as a result of NBS implementation. To achieve this, GHG characterization factors are required for conversion of all GHG emissions to CO_2 equivalents. Different kinds of nature-based solutions act in different positive ways such that some reduce CO_2 outputs whilst others absorb CO_2.

Yearly avoided GHG can be calculated using the variation between a baseline scenario of having no NBS implemented (usual state) and a scenario where an NBS has been implemented. The difference between the two solutions should be continuously monitored, depending on the time resolution available, as the variation is likely to be affected by the maintenance of NBS and the vegetation growth rate during the time period of evaluation.

Moreover, avoided GHG emissions can be quantified at two different levels; midpoint level (accounting of equivalent CO2 emissions) and endpoint level (human and ecosystem health impacts). As it was stated in Task 2.1 of the N4C Project, the midpoint indicator will be utilized and no specific tool is required for this purpose. All GHG emitting processes including combustion, energy generation and transportation are considered for the avoided GHG emissions calculation. Moreover, it will also be an option to incorporate data from direct measurements.

Peak Flow Variation (PFVar)

The peak flow is the maximum value of the flowrate and reveals the potential indirect effects of a given rain event. Peak flow variation is defined by the relative error between the peak flow of the catchment with NBS and the peak flow of a catchment without NBS. The calculation is done with simulated data or the average value of a sample derived from the rain/runoff time series taken from

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the monitoring output, measuring media or authority. Thus, it shows the performance of an NBS in reducing the flowrate. The results of this indicator can be utilised during the initial planning stage to envision possible future problems.

PF_{Var} can be calculated via Hydrological model or measurement/monitoring over a defined period.

According to the scenarios identified in Deliverable 2.3 for "catchment scale" and "city scale", peak flow variation can be calculated with the following equations deduced from URBS and TEB-Hydro Hydrological Models.

$PF_{Var}=-0.0233Veg^2-1.4264Veg-3.105$ (Equation deduced for Gardens and Parks)
$PF_{Var}=4.22Veg-0.381$ (Equation deduced for Street Tree Scenarios/Catchment Scale)
$PF_{Var}=-0.0233Veg^2-1.4264Veg-3.105$ (Equation deduced for Green Roofs)

Veg= Veg is the vegetation discrepancy percentage calculated between the scenario and the reference case study.

URBS [18] is a model simulating hydrological flows and describing all hydrological processes in urban stormwater budget. It can operate over long rain periods. TEB-Hydro [19] is another model able to calculate the surface runoff. The methodology for the quantification described above is achieved via SUAT operated by the experts and the output derived from this tool will be used as an input for environmental dynamic assessment.

Water Quality

Urban water management takes into consideration the total water cycle, facilitates the integration of water factors early in the land planning process, and encourages all levels of government and industry to adopt water management and urban planning practices that benefit the community, the economy and the environment. Urban water refers to all water that occurs in the urban environment and includes consideration of; natural surface water and groundwater, water provided for potable use, sewage and other 'waste' waters, stormwater, flood services, recycling of water (third pipe, stormwater harvesting, sewer mining, managed aquifer recharge, etc.), techniques to improve water use efficiency and reduce demands, water sensitive urban design techniques, living streams, environmental water and protection of natural wetlands, waterways and estuaries in urban landscapes. The aim of urban water management is to create cities and towns that are resilient, liveable, productive and sustainable. [20]

A range of pollutants in many of Europe's waters threatens aquatic ecosystems and may raise concerns for public health. These pollutants arise from various sources, including agriculture, industry, households and the transport sector. They are emitted into water via numerous diffuse and point pathways. Once released into freshwater, pollutants can be transported downstream and, ultimately, discharged into coastal waters, together with direct discharges from cities, industrial

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discharges and atmospheric deposition. Clean, unpolluted water is essential for our ecosystems. Aquatic plants and animals react to changes in their environment caused by changes in water quality. [21]

Water quality parameters are measured with respect to the specific water pollutants like heavy metals or general pollution indices such as biological oxygen demand (BOD) or chemical oxygen demand (COD) of which their time resolutions can be found from the relevant regulations.

Moreover, this indicator can be measured by means of:

- ✓ Water Pollutants Removed/Released
- ✓ Toxic Pollutants Into Water
- ✓ Eroded Soil into Waterbodies
- ✓ Nutrients to waterbodies causing eutrophication
- ✓ Infiltration to groundwater

These factors can be considered as input flows for dynamic assessment of this indicator. This will be achieved by the application of SUAT as a source of “input data” related to the KPI flow of NBS. For example, the phytoremediation concept (Figure 298) will be used to explain the methodology and KPI relation in attempts to provide a better understanding. This concept, which is based on the use of plants and trees and their interactions with microorganisms for the treatment of polluted soils, has two significant urban flows for water quality assessment. The incorporated flows are toxic pollutants into water and water pollutants removed both having mass per volume unit that will be used in SUAT. After NBS implementation, the difference or variation between before and after scenarios derived from the output taken periodically from SUAT leads to drive the dynamic assessment methodology.

The impacts of soil, air and water pollutants on water ecosystems can be simply described with LCIA indicators, including; eutrophication, freshwater ecotoxicity, acidification of main freshwater ecosystem accumulated exceedance and damage to ecosystem diversity. Figure 298 is just one example considering freshwater ecotoxicity dynamic variation due to the phytoremediation (NBS) process for a 12 month period.

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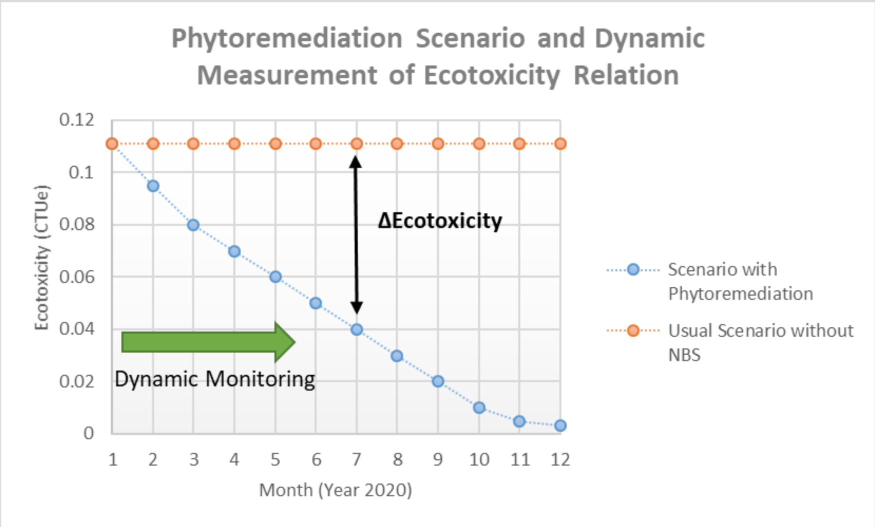

Figure 29 An example of phytoremediation implementation and the ecotoxicity variation in time

Total Runoff/Total Rainfall

-Total Runoff Volume:

This volume will describe the impact of the NBS through the comparison of a catchment with or without NBS. This parameter can be identified from the flowrate at the outlet of a considered catchment and or neighbourhood. This is also explained as the total runoff volume during a selected period of time.

Runoff volume may be separated into;

1. During-Event Runoff Volume
2. Dry-Weather Runoff Volume

And this item can be evaluated via;

1. Rain/Runoff Time Series
2. Observed Runoff (before and after NBS Implementation)
3. Simulated Runoff

This parameter also monitors the impact of the potential of NBS for recovering a natural hydrological response according to the catchment overall behaviour. Data required for the estimation of the indicator needs 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). Finally, this KPI can be quantified and monitored by means of external tools which will be implemented to the N4C platform. (ET 5 and/or ET 7)

-Total Rainfall

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Total precipitation in a period of time which requires meteorological data stating the rainfall captured

The ratio of Total Runoff/Total Rainfall(RRR)

The percentage of the amount of the water discharged into river or stream. This ratio is useful to assess the ability of NBS reducing possible flood event in urban area and the amount of water acquired.

RRR= $\frac{\boldsymbol{Total\ Runoff}}{\boldsymbol{Total\ Rainfall}}$ (It can be unitless or percentage if the formula multiplied by 100)

Environment

In this category, air and soil pollution-based indicators will be elaborated upon. Air pollution is one of the most severe environmental problems affect urban areas. Air pollution is often caused by anthropogenic activities such as mining, construction, transportation, industrial work, agriculture, smelting, etc. However, volcanic eruptions and wildfires are natural processes that contribute to pollution levels sporadically.

This continuous pattern makes the air quality variable crucial to monitor dynamically. Therefore, time and source-based variation should be monitored with a relevant time resolution to understand the trend and build a sustainable strategy for decision makers for the selection of NBS or to estimate the appropriate time for NBS maintenance. If toxic chemicals are present in the soil in high concentration, this will lead to soil pollution. All soils, whether polluted or unpolluted, contain a variety of compounds (contaminants) which are naturally present. Such contaminants include metals, inorganic ions and salts (e.g. phosphates, carbonates, sulphates, nitrates), and many organic compounds (such as lipids, proteins, DNA, fatty acids, hydrocarbons, PAHs, alcohols, etc.). These compounds are mainly formed through soil microbial activity and decomposition of organisms (e.g., plants and animals). Additionally, various compounds get into the soil from the atmosphere, for instance with precipitation water, as well as by wind activity or other types of soil disturbances, and from surface water bodies and shallow groundwater flowing through the soil. When the amounts of soil contaminants exceed natural levels (what is naturally present in various soils), pollution is generated. In that respect, soil quality is an important point of interest to be defined and monitored its position by providing a channel identifying the performance over time so called dynamic evaluation. [22]

For these two aspects, the following indicators are selected to be used in dynamic monitoring in an urban metabolism to reveal the direct/indirect effect of the NBS implementation.

Common Air Quality Index or Specific Pollutant of Impact

The EEA states that “air pollution is the single largest environmental health risk in Europe.” Air quality remains a major concern due to its direct impacts on the living (human, plant and animal),

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infrastructures and ancient buildings. In order to monitor and evaluate this indicator, there are several different indices currently in use around the world, resulting in different representations of air quality respectively. CAQI proposes a simple comparison of European Cities' Air Quality through dynamic measures to ensure effective and timely reporting.

The visible air pollution (smoke, dust, smog) has disappeared from many cities due to local, national and European initiatives. Nevertheless, the current air quality still affects people's health. In most cities, industrial air pollution is or tends to be replaced by traffic related air pollution. Furthermore, occasionally air quality poses an immediate threat, for example during industrial incidents or pollution episodes. Fortunately, this cause of air pollution is rare.

Air quality remains a common problem across almost all major cities. Typical air pollutants in concern are listed in below table. [23]

Table 13 Common Air Quality Indices categories and related pollutants

Roadside Index(1)	**Background Index(2)**	**Roadside Index**	**Background Index**
Mandatory Pollutant	***Auxiliary Pollutant***	***Mandatory Pollutant***	***Auxiliary Pollutant***
NO_2	$PM_{2.5}$	NO_2	$PM_{2.5}$
PM_{10}	CO	PM_{10}	CO
		O_3	SO_2

(1) Roadside Index: Generally poorest air quality found in busy streets

(2) Background Index: Outdoor air quality in the city experienced by the average citizen

Applied time resolution for CAQI in Europe can be categorised into three group;

1. An hourly index
2. A daily index
3. A yearly index

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CAQI CALCULATION INFO BOX-2

EU directives assess hourly values of NO_2, daily average values of PM10, 8- hour average values for O_3 and CO (in addition to a range of year average criteria).The worst pollutant determines the index. For each pollutant a sub-index is calculated according to a grid that translates concentration measurements into a ranking on a scale from 1 to 100. The highest sub-index value at a given time determines the overall index. In addition to the hourly index, a daily index is calculated using the maxima of the hourly sub-indices (or, in case of a city reporting PM10 only on daily basis, using the PM10 daily grid for that subindex).

This is very common for indices, in particular for indices that have an alerting role to play. Some health based indices claim that interactions between pollutants have to be considered (for proper health assessments) these indices are complicated and less frequently used. If an index is used to monitor air quality policy in terms of health benefits, such an index could be considered.

The calculation order is: first the sub-indices per monitoring station, the overall index for each station, the highest overall index becomes the city index. This procedure is applied separately for the traffic and the background indices. [22]

Lyon Yesterday Details

Hour	ROADSIDE INDEX		BACKGROUND INDEX	
	Index value	Pollutant	Index value	Pollutant
0	22	NO2	18	NO2
1	21	NO2	17	NO2
2	27	NO2	17	NO2
3	26	NO2	18	NO2
4	51	NO2	23	NO2
5	60	NO2	24	NO2
6	68	NO2	29	PM10
7	69	NO2	32	PM10
8	70	NO2	25	NO2
9	64	NO2	26	PM10
10	63	NO2	32	O3
11	57	NO2	35	O3
12	56	NO2	35	O3
13	51	PM10	35	O3
14	51	PM10	38	O3
15	44	PM10	40	O3
16	44	NO2	41	O3
17	49	NO2	38	O3
18	41	PM10	38	O3
19	36	PM10	35	PM10
20	37	NO2	41	PM10
21	35	NO2	26	O3
22	32	PM10	29	O3
23	28	PM10	28	O3

Pollution	Index Value
Very Low	0 / 25
Low	25 / 50
Medium	50 / 75
High	75 / 100
Very High	> 100

Figure 30 A Sample Data Series for Lyon Hourly CAQI and Pollution Index Value Legend [24]

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According to the table in Figure 3030, in the city of Lyon, the hourly air pollution data was used to indicate air quality using an index. This hourly data graph, with respect to the time, will monitor the air pollution index variation dynamically. (Figure 3131)

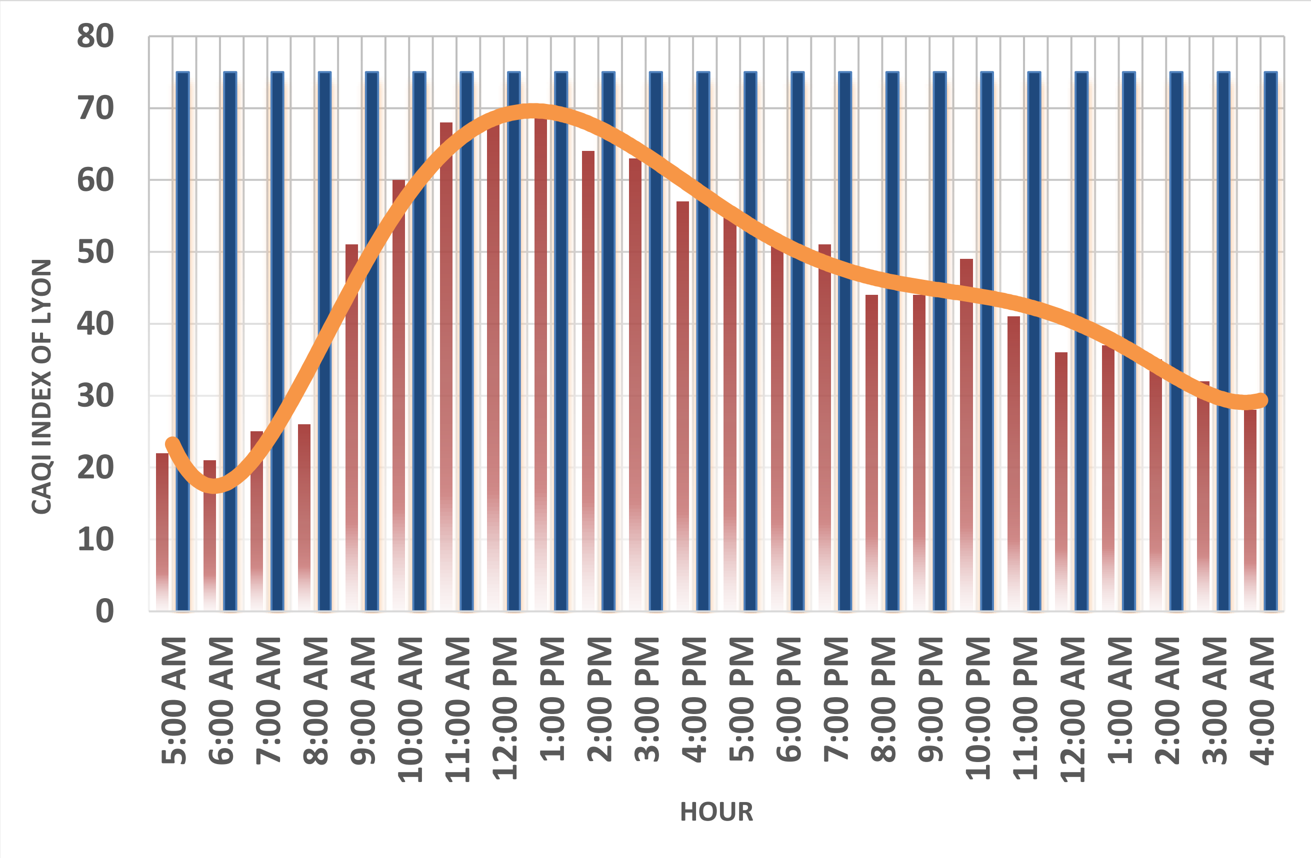

Figure 31 Graph of Hourly CAQI of Lyon

LCIA (by means of LCI flows including air pollutants) can be monitored along with impacts of air pollutants on human health, which can be described with the support of midpoint/endpoint LCIA impact categories. It is assessed via Human Toxicity, Tropospheric Ozone Concentration increase, Ozone Depletion Potential (midpoint LCIA indicators) and Damage to human health (endpoint LCIA indicator).

Soil Quality

In urban areas, the soil is an important layer which has to be arranged with a management framework to improve its quality. The construction work in the cities needs a diagnostic study to monitor the soil quality (lithology, geotechnics, physic-chemistry, etc.). Moreover, residential green space, improvement in ease of movement of citizen, preservation of biodiversity, limiting the stormwater impact (drainage rate capacity), urban farming with the support of soil amelioration and other contexts are all related to the indicator.

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Nutrients and toxic pollutants transferred to or removed (by means of different remediation activities) from the soil are also considered as soil quality parameters prompting the state of the soil. **Any chemical harmful to soil health** sourced from production processes, application as contamination treatment media or transportation and fertilizers (production-transportation-spreading-organic/chemical) in use could be evaluated and determined as a chemical flow avoided. In addition to that, due to the possible erosion process occurring in the soil, **the weight of the eroded soil** into waterbodies during a period of time will be another aspect showing the soil quality.

There are different approaches to evaluate the quality of the soil however "**Organic matter content"** of the soil is one of the crucial measures of soil quality together with all relevant processes releasing organic matter including agricultural processes. Soil sampling and characterization studies applied in-situ or in laboratory can be used for this purpose and it is possible to use as the contamination level of the soil. Hence, soil organic matter is the only parameter that will be considered in this indicator category and the necessary data for the assessment will be taken from SUAT(Deliverable 2.4) Expert Box which evaluate the soil organic matter in form of performance bar with numerical values ranked in terms to best(1) and worst(0) scenario.

Ultimately, it could also be evaluated via Acidification of Terrestrial Ecosystems (midpoint LCIA indicator) and Damage to Ecosystem Diversity (endpoint LCIA indicator).

Resource

In the concept of urban metabolism, the circular model and the role of compactness in urban resource efficiency. Cities requires natural resources and energy to sustain the daily life and activities of the urban population. However, there are opportunities to minimise input and output flows. Urban planning, based on a vision of the future, developed with local stakeholders and crossing administrative borders, is a key factor in increasing the density of urban areas, developing mixed land use, avoiding the unnecessary uptake of land and soil sealing, reducing car dependency and encouraging the use of public transport, walking and cycling. Cities are key players in minimising the use of resources and in developing the circular model. Generally, municipalities provide utilities and control public services for citizens and businesses that influence the majority of resource and energy use and the production of emissions and waste. Local authorities have the capacity to implement responses on multiple scales. [25]

Resource efficiency is categorized by environmental indicators evaluating the energy, water and raw materials in relation with relevant SDGs. In N4C urban context, the main objective is to establish Food, Energy and Water nexus together with raw material and waste efficiencies supported by Nature Based Solutions.

Energy Efficiency

This indicator can be explained as the percent change of consumed energy in relation to fuel demand per capita or per selected timeframe to the baseline levels. The priority of this KPI varies depending

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on the type of NBS implemented. It can be applied in both generation and consumption or demand processes. On a city scale, estimation of consumption/performance ratio can be achieved with the energy figures derived from built environment. Energy generation is considered and enhanced with renewable sources with the help of local renewable energy production combining with the related NBS. This indicator excludes the industrial energy consumption within the city limits.

Energy efficiency is used to uncover the level of improvement of energy performance on building and city scale with the help of NBS implementation respectively. Moreover, the benefit acquired from local renewable energy has an added effect on this performance value which has significant effects for policy makers. This indicator can be calculated from the energy consumption per time or per capita with respect to the baseline data. The consumption figures are available in energy bills from buildings/municipalities and statistical data for direct estimation. Energy consumption per m^2 area of a building can be determined with building energy simulations or relevant literature factors for indirect estimation that is less clear and transparent with respect to direct one.

Material Flow Analyses of urban metabolism acts as an accounting tool and provides the measures of energy efficiency identifying the amount of all kind of resources in use including energy related flows within the system boundary. With the support of MFA, energy consumption figures like energy consumed in terms of kWh/m^2/time, cooling load, amount of domestic hot water usage, etc. are used to monitor the status of this KPI. Therefore, the dynamic MFA, data frequency and availability will define the temporal resolution to be used respectively.

Per Capita Food Production Variability

The per capita food production variability compares the variations of food production across countries and time. This is a Food Security Indicator of FAO, reflecting the stability dimension of the subject and how applicable it is to NBS related to Food Security. Per capita food production variability corresponds to the variability of the net food production value in constant year 2004-2006 thousand International $ divided by population. For the calculation of variability, the standard deviation of food production trend per capita, in other words deviation from the trend of food production, is used so the effect of depletion/improvement of food production in favour of the implementation of NBS (different types of urban agriculture) can be assessed.

Nevertheless, in N4C project, this indicator may be modified to increase its suitability for the dynamic assessment methodology covering different themes related to food production in a defined area or per capita. For example, the yield of two different vegetables in an urban farm. One of the vegetable yields 75 kg per m^2 in a year and the other does 100 kg per m^2. In addition to this, these two vegetables are evaluated in terms of their environmental impacts by means of LCA. These two assessments establish the planning phase where decision maker decides the vegetables to be planted and/or NBS opportunity to be implemented as well. If the first stage is completed positively, monitoring phase comes into stage where food amount per area or food amount per capita will be evaluated with respect to the relevant time resolution. This will help the decision maker (municipality,

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citizen(s) and others) to see the integration and periodic checking of the urban farm which can deviate with different parameters between selected time intervals.

Building Energy Needs

The indicator primarily corresponds to the energy demand of buildings connected to the thermal energy required for heating and cooling purposes. This indicator has two spatial impact scales; an object and a neighbourhood. Moreover, depending on the application area of NBS (whether building or district), it could have a direct impact like variation in building energy demand or indirect impact like CO_2 emission related with the electricity and natural gas usage rates.These impacts can be evaluated through utilising the difference in the consumption figures. As this KPI is based on climate data, building and occupancy model data, Building Energy Modelling should be investigated for the evaluation. The below example, which illustrates passive cooling (Figure 3231) with the help of a tree blocking the heat, aims to provide further explanation of the methodology described above;

Figure 32 Illustration for Building Energy Needs Indicator Assessment5

In this example the performance indicator can be quantified in two ways;

I-Assessment Method (Calculation based)

In this route, energy modelling software is used for theoretical calculation.

5 www.greenandpractical.com (Passive Cooling)

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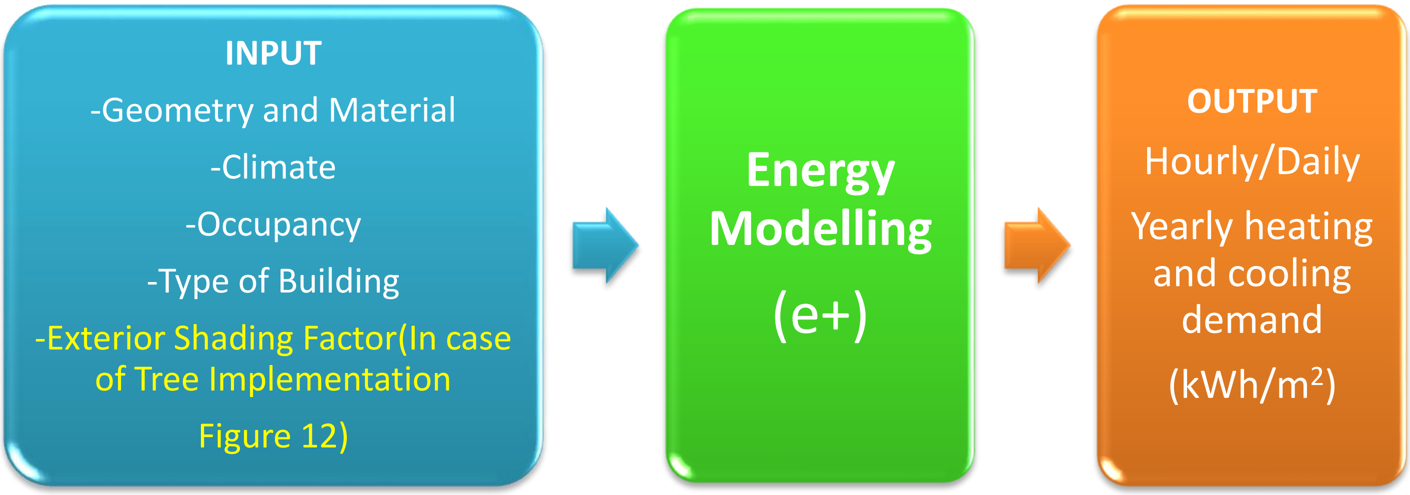

The flow chart above describes the energy modelling stages including data gathering from building design documents (i.e. from BIM software), weather data from relevant institute, occupancy and type of building can be acquired from different sources such as GIS, design documents, etc. Moreover, it is also possible to make fair assumptions during the modelling calculation stage. After tree implementation, exterior shading factor should be used as an input in order to evaluate the energy variation with respect to the implementation and seasonal time period. For example, during winter, depending on the type of tree utilized, the rate of defoliation affects the mechanism for heat/sunray blockage which eventually affects the energy calculation.

II-Monitoring Method (Measurement based)

In this method, direct measurement via sensors and online analysers are realized for the monitoring purposes. For example, in case of shading tree implementation, monitoring for cooling and/or heating energy can be done in conditioned building and non-conditioned one which are divided into tree implemented and non-implemented. In summary, there will be four different scenarios which will be affected from different situations/parameters. This is a direct data logging operation which can be used for the comparison of the measured data with calculation-based results.

The dynamic assessment of the Building Energy Needs indicator, in a defined period of time, is supported by the selection and application of one of these two different methodologies. This allows for a user defined time interval depending on the temporal resolution of the sensors in monitoring method or input flow data availability in calculation-based assessment.

Cumulative Energy Demands

This aggregated energy demand is related to the renewable and non-renewable energies that are to be studied throughout the lifecycle of a good or a service. For that purpose, 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 including direct use of energy and indirect use of energy

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such as construction material usage. It is calculated with the quantity of energy and raw materials consumed by the system under investigation so the indicator is evaluated by multiplying the flows of raw materials and energy by the characterization factor and then summed to get the cumulative value for the indicator in terms of MegaJoule(MJ) equivalent. Hence, LCA tool, which will simplify the calculation, or MFA, which will be a complex measurement tool due to its data intensive structure, are both applicable methods to assess this indicator.

Water Scarcity

According to the ISO 14046 standard (ISO 14046. 2014), water scarcity is the “extent to which demand for water compares to the replenishment of water in an area, such as a drainage basin.” This is to satisfy the need of LCA practitioners for one simple indicator that can be used for simplifying LCA studies when the interest or complete impact models for a full damage assessment on human health or ecosystem quality are not available. The goal is to assess marginal changes in a system, i.e., that the water consumption of the analysed system is not significantly changing the water scarcity on its own. Available Water Remaining (AWARE) method evaluates the relative potential of water deprivation, to either humans or ecosystems. [26]

AWARE is based on the quantification of **the relative Available Water Remaining per area once the demand of humans and aquatic ecosystems has been met**, answering the question “What is the potential to deprive another user (human or ecosystem) when consuming water in this area?”. The resulting characterization factor (CF) ranges between 0.1 and 100 and can be used to calculate water scarcity footprints as defined in the ISO standard.

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. World water equivalent values can be found in the Life Cycle Initiative official website[6].

Raw Material Efficiency

The percentange change in consumed non-metallic minerals, metal ores, biomass and fossil energy carriers so called primary raw materials per capita as a result of implementing appropriate NBS compared to the baseline levels is the general description of this indicator. So primary raw material consumption per capita data with respect to the baseline data both obtained from statistical database and/or public authorities will evaluate the efficiency of raw material usage as shown in the below equation.

$$\text{Raw Material Efficiency(\%)} = \frac{PRMCPC(Before\ NBS\ Implementation) - PRMCPC(After\ NBS\ Implementation)}{PRMCPC(Before\ NBS)} x100$$

where;

6 www.lifecycleinitiative.org

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PRMPC=Primary Raw Material Consumption per Capita

In this indicator category, it is better to point out and evaluate every raw material efficiency separately. Urban processes including relevant urban flows are the main parameters which will show the temporal based dynamic alteration of the raw material efficiency. Urban nexus chosen from Deliverable 3.1 for this indicator category are described at the below table. (Table 14)

Table 14 Raw Materials and Relevant Processes

Considered Raw Materials in Urban Nexus of N4C Project	Relevant Processes
Chemicals used for water treatment	Water treatment, wastewater treatment, manufacturing processes for chemicals, transportation of chemicals
Compost	Composting, energy generation, fuel consumption, water consumption, transportation
Construction materials avoided	Manufacturing of construction materials manufacturing, transportation of construction materials
Construction materials required	Manufacturing of construction materials manufacturing, transportation of construction materials
Fertilizers-chemical/organic/avoided	Fertilizer manufacturing, fertilizer transport, fertilizer spreading
Fuel consumption avoided	Fuel extraction, fuel refining and processing, fuel transportation, fuel combustion
Fuel consumption for vehicles	Fuel extraction, fuel refining and processing, fuel transportation, fuel combustion
Fuel demand for heating purposes	Fuel extraction, fuel refining and processing, fuel transportation, fuel combustion
Herbicides-chemical/organic/avoided	Herbicide manufacturing, herbicide transportation, herbicide application
Insecticides-chemical/organic/avoided	Insecticide manufacturing, insecticide transport, insecticides application
Metals extracted from soil	Extraction/recycling processes by plants, conventional bioremediation technologies
Pesticides-chemical/organic/avoided	Pesticide manufacturing, pesticide transport, pesticide application
Water demand from supply system-for human consumption	Water treatment, pumping operation for water supply, manufacturing and transportation of treatment chemicals, energy generation, disposal activities for treatment residues

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Considered Raw Materials in Urban Nexus of N4C Project	Relevant Processes
Water demand for irrigation	Water pumping from groundwater, energy generation, water treatment if necessary
Water for maintenance	Pumping operations, water treatment if necessary

Specific Waste Generation

This indicator is measuring MSW generation per capita in a specified period of time. This indicator represents and reveals the potential for resource efficiency concept since if the urban metabolism has close loop material flow so there will be no waste generated meaning that material circularity approach is utilized respectively. In that sense, this KPI will monitor the efficiency of the society together with the amount of natural resources consumed and waste treatment operations.

Specific Waste Generation= $\frac{W}{p}$

where;

W: [period] MSW (kg/[period])

[period]=Daily/Monthly/Annually

p: population

MSW: This 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.

Efficiency of Valorisation as a Result of Recycling Processes (ERP)

This indicator demonstrates the efficiency of the recycling process used to produce the recycled feedstock (for specific materials and recycling processes) so the main objective is to evaluate the positive or negative improvement in the valorisation of waste and by-products. This indicator is affected from different parameters such as the process used, the amount of materials in application and the material itself. It requires lots of data to consider for the calculation. On the other hand, there are already calculated values that can be derived from various sources, however generic values for efficiency can change a lot with time by the demand, the application and the tech used for recycling. In general, yearly or daily waste recycled from recycling processes, incineration process, composting, energy generation, water pumping and treatment and other relevant processes can be used to quantify in terms of “mass per time resolution” in order to evaluate this KPI dynamically.

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Life Cycle Impact Analysis Indicators, MIPS and Definitions

LCA is a standardised methodology, which gives it its reliability and transparency. The standards are provided by ISO 14040 and 14044 and describe the objectives of the four main and traditional phases of an LCA study. (Table 15)

Dynamic assessment of LCA is directly connected with the flow scheme of this document describing the four phases of LCA in different chapters involved in TOC. The main aspect of performing dynamic LCA study starts with setting three phases of LCA constant during the assessment phase such as the scope, the evaluation parameters (KPIs) and the time resolution. Only the data will change, which will be collected in the second phase of the LCA. The impact assessment performed in every instant selected according to the appropriate temporal resolution will give the opportunity to create the trend pattern supporting the interpretation and monitoring steps of dynamic assessment. The implication is that both the foreground (i.e. the description of the system with energy, materials, pollutants flows etc.) and background data (i.e. LCI datasets from LCI databases such as ecoinvent, ELCD) will change over time. In our case, during and after NBS implementation, the interpretation and monitoring processes reveals the damage taken or benefits acquired (both for environment and human) with the help of midpoint and endpoint impact categories. As a consequence, this dynamism will simplify the task of decision makers during the establishment of urban planning strategies including NBS applications.

Table 15 LCA Phases and Their Objectives[7]

Phases	**Objective**	**Relation with this Deliverable (Dynamic Assessment Methodology)**
Goal and Scope	The goal & scope definition ensures the LCA is performed consistently.	Chapter 2.1
Inventory Analysis	Looking at all the environmental inputs and outputs associated with a product or service for executing LCA	Chapter 3 Chapter 4.5
Impact Assessment	Drawing the conclusions that allow user to make better business decisions. Categorizing the environmental impacts, evaluate them by what is most important to user (municipality, expert, citizen, etc.) and translate them into environmental themes.	Chapter 4 (in general) Chapter 4.2 Chapter 4.4 Chapter 8.1 Chapter 8.2

7 https://www.pre-sustainability.com/sustainability-consulting/lca-methodology-basics

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Interpretation	Checking the conclusions drawn whether they are well-substantiated meaning that the data and the procedures support conclusions or not	Chapter 5

An LCA models a product, service, or system life cycle. What is important to realize is that a model is a simplification of a complex reality and as with all simplifications this means that the reality will be distorted in some way. The best way to deal with this problem is to carefully define the goal and scope of the LCA study. After identifying the LCA goal and scope, data linked with the use of raw materials, energy, waste, pollutants and etc. associated with the system or product has to be gathered carefully. This is the hardest stage to deal with during this practice. [27]

The pressure on the environment related to consumption and production in human systems was identified as a prior subject in the 2030 Agenda for Sustainable Development by the heads of state and government and requires the development of products and services with reduced impacts to human health and the environment. For these purposes, LCIA methods, environmental impact category indicators, and environmental damage indicators are challenged by numerous and complex supply chains that span the globe and spread over several years. In that respect, the model, methods, and indicators that would qualify for broader use in an LCA context must be flexible, robust, and able to deal with lack of geographically and temporally refined information. [28]

LCIA is the third step of LCA and needs an inventory analysis which draws a general picture describing the conclusions to provide the decision maker with a better and clearer understanding. In that step, environmental impacts are categorized and assessed according to the expected items by the user so these parameters are converted into environmental themes which were already identified for N4C context in Deliverable 3.3. The final phase, where interpretation phase is in operation, is needed to validate and control the conclusions drawn whether they are supported by the data in an appropriate manner.

There are various impact assessment models exist to characterise the inventory flows and evaluate their potential impacts differently. As an example, the following figure (Figure 332) is one of the model describing the LCIA framework monitoring midpoint categories having a damage (endpoint) classification with respect to the LCI results respectively.

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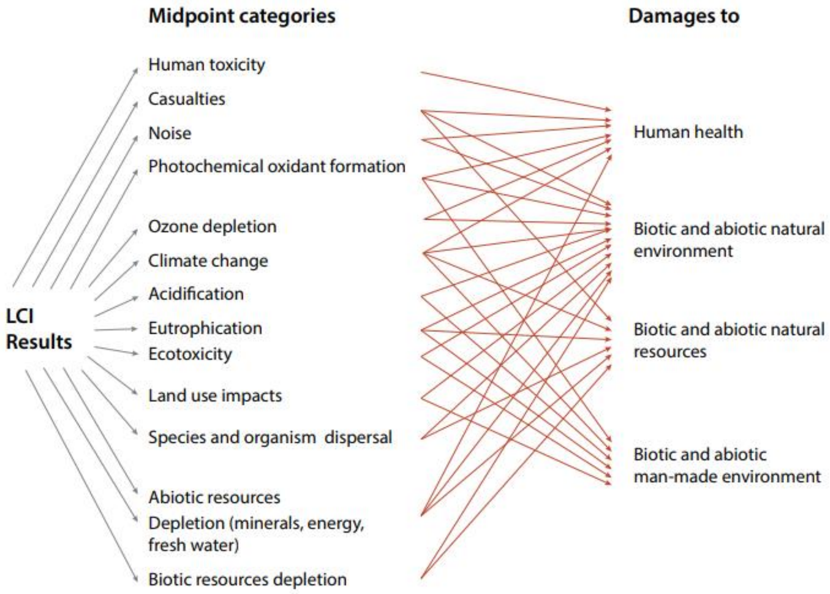

Figure 33 Generic LCIA framework 8

In order to identify midpoint and endpoint life cycle impact categories, "Recipe 2008 Characterization Report" is utilized respectively.

Generic formula for the midpoint characterization is;

$$I_m = \sum_i Q_{mi} m_i$$

where;

m=mass or the magnitude of intervention

Q_{mi}=Characterization Factor (i=intervention and m=midpoint impact category)

I_m=The result of midpoint indicator

For the endpoint characterization, one of the formula without using the data from intermediate midpoints can be described as;

$$I_e = \sum_i Q_{ei} m_i$$

where;

m=mass or the magnitude of intervention

8 Jolliet et al.2004

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Q_{ei}=Characterization Factor (i=intervention and e=endpoint impact category)
I_e=The result of endpoint indicator

The second way for the endpoint characterization;

$$I_e = \sum_m Q_{em} I_m$$

where;
Q_{em}=Characterization Factor (m=midpoint impact category and e=endpoint impact category)
I_m= The result of midpoint indicator
I_e= The result of endpoint indicator

Table 16 Impact Categories and Related Flows

		Method	Outputs of the LCA	Unit
MIDPOINT Impact Categories	**Climate Change**	ILCD 2011 Midpoint+ version 1.09	$CO_{2equivalent}$	Mass
	Ozone Depletion		$CFC_{equivalent}$	Mass
	Acidification		$SO_{2equivalent}$	Mass
	Freshwater Eutrophication		$P_{equivalent}$	Mass
	Marine Eutrophication		$N_{equivalent}$	Mass
	Resource Depletion(Mineral&Fossil)		$Sb_{equivalent}$	Mass
	Photochemical Ozone Depletion		$NMVOC_{equivalent}$	Mass
	Human Toxicity		CTUh	Cases per Mass
	Ecotoxicity		CTUe	PAF m3 year/Mass
ENDPOINT Impact Categories	**Ecosystem Damages**	ReCiPe Endpoint (Hierarchist* version), version 1.13	Species x Year	-
	Human Health Damages		DALY	-
	Natural Resource Damages		$	Monetary Value

*Hierarchist (H) is based on the most common policy principles with regards to time-frame and other issues. Uses the medium time frame e.g. a 100 year timeframe for global warming, GWP100.

Material Input per Unit of Service

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This indicator can be defined as a practical and comprehensive approach of evaluating resource intensity of a product or a service. This intensity is classified into five categories in MIPS methodology such as abiotic raw materials, biotic raw materials, earth movements, water and air.

Environmental impact assessment of different NBS is one of the main objectives of the Nature4Cities project. The MIPS methodology is an important tool enable the comparison opportunity with respect to the reference point (baseline) to indicate the impact of the NBS. The basic equation used for this purpose is stated below;

$$MIPS = \frac{MI}{S} = \frac{Material\ Input}{Service\ unit}$$

Following figure is well drawn to describe and exemplify the dynamic structure of MIPS concept.

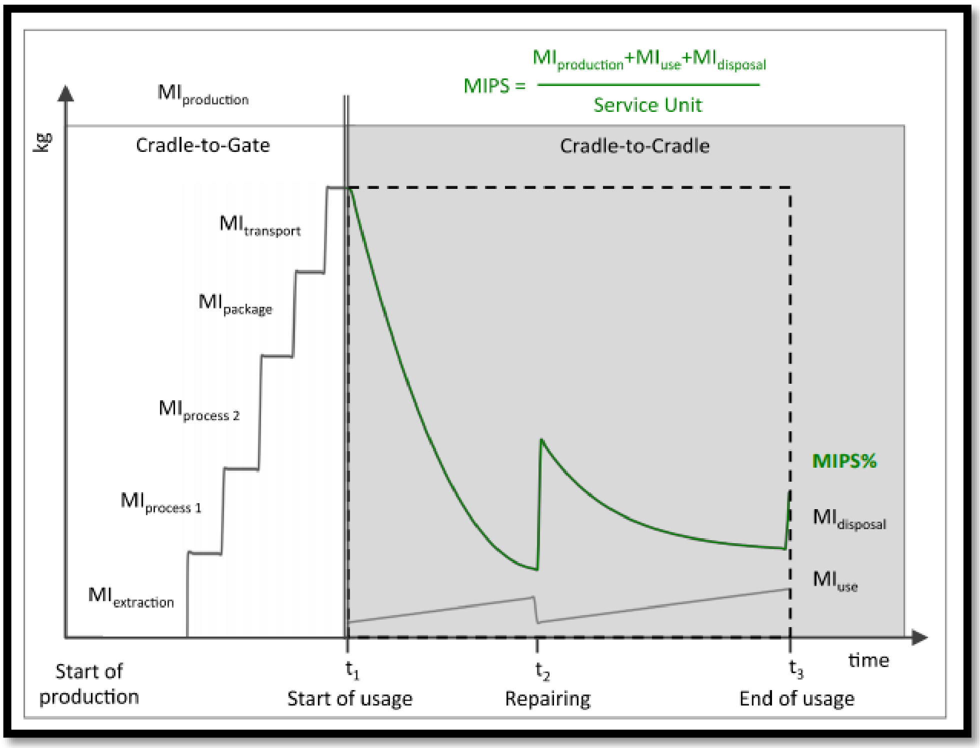

Figure 34 Time based MIPS approach [29]

This figure shows a general assumption displaying time on the x-axis against mass unit (e.g., kg) on the y-axis. On the left, the cradle-to-gate assessment accumulates the material input of production phase (including resource extraction, several processes, package, and transport). The MI is growing until start of usage (t_1). On the right, the cradle-to-cradle assessment illustrates MIPS, which equals the sum of $MI_{production}$ + MI_{use} + $MI_{disposal}$ per Service Unit at a specific assumed life time. The green graph shows that with a growing amount of services and a given MI, the MI/S (MIPS) diminishes. At point of repairing (t_2) MIPS increases due to necessary input but decreases due to prolonged life time (t_3). The grey graph illustrates MI_{use}. The longer the use phase the more MI is consumed (e.g., energy use). Repairing not only prolongs the life time but also reduces MI. [29]

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The difference between t_1 and t_3 is called time period defining the service life of a product/system. During the service life of an NBS like in green wall case study, there is a need of maintenance period which extends the "t_3 minus t_1" period. On the other hand, this maintenance activity will lead to a consumption of materials to be used for the reparation. The study of variations provides an insight into the frame of the subject with respect to the time and deviation in MI.

Environmental Assessment KPI's Calculations with Urban Metabolism Approach

Urban metabolism is a dynamic system exposed to a continuous alteration. In order to support and create long term solutions to the different environmental concerns related to cities, the dynamic structure of urban flows has to be evaluated by utilizing the different KPI studied under these sections. As this assessment methodology is based on time series concept, temporal resolutions allocated with each KPI selected in Chapter 4 including others from Deliverable 3.1 and 3.3 can be found in the following table. (Table 17) Following temporal resolutions were determined according to the unit describing the KPI respectively. Additionally, these resolutions are recommended, applied and available(data availability) in different context like monthly electricity bill or hourly CAQI value or per capita food production variability which are established,developed, standardized and used by relevant parties(e.g. government agencies, NGOs, private companies, relevant organizations and etc.). Furthermore, all of these temporal resolutions are describing the frequency of data acquisition period so it is crucial that the identified frequency has to be significant enough.

Table 17 Key Performance Indicators from D3.1 and D3.3 and their Time Resolution

Topics	Environmental KPI for Dynamic Assessment	Temporal Resolution
Climate	**Annual Carbon Sequestration**	Annually
		10 years
		50 years
		100 years
	Avoided GHG Emissions	Annually
	Peak Flow Variation	Annually
	Water Quality(WQ)	Daily
		Monthly
		Annually
	Total Runoff (TRU)	Annually or user/case defined
	Total Rainfall (TRA)	Daily
		Annually

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Topics	Environmental KPI for Dynamic Assessment	Temporal Resolution
		Seasonally
		Rainfall Event Based
	TRU/TRA	[Follow above statements]
Environment	Common Air Quality Index(CAQI) or Specific Pollutant Impact	Hourly
		Daily
		Annually
		Continuously
	Soil Quality	Monthly/Yearly (Optional: Before and After NBS Implementation)
Resource	**Energy Efficiency**	Hourly
		Daily
		Annually
	Per Capita Food Production Variability	Annually
	Buildings Energy Needs	Hourly
		Daily
		Annually
	Cumulative Energy Demand	Hourly
		Daily
		Annually
		Annually
	Water Scarcity	Daily
		Annually
	Raw Material Efficiency	Monthly
		Annually
	Specific Waste Generation	Daily
		Monthly
		Annually
	Efficiency of Valorisation as a Result of Recycling Processes	Annually
	MIPS	Depending on the service unit in concern (User defined period selection)
LCIA Indicators*	Climate Change	Annually
	Ozone Depletion	Annually
	Acidification	Annually
	Eutrophication	Annually
	Resource Depletion	Annually
	Photochemical Ozone Depletion	Annually
	Human Toxicity	Annually

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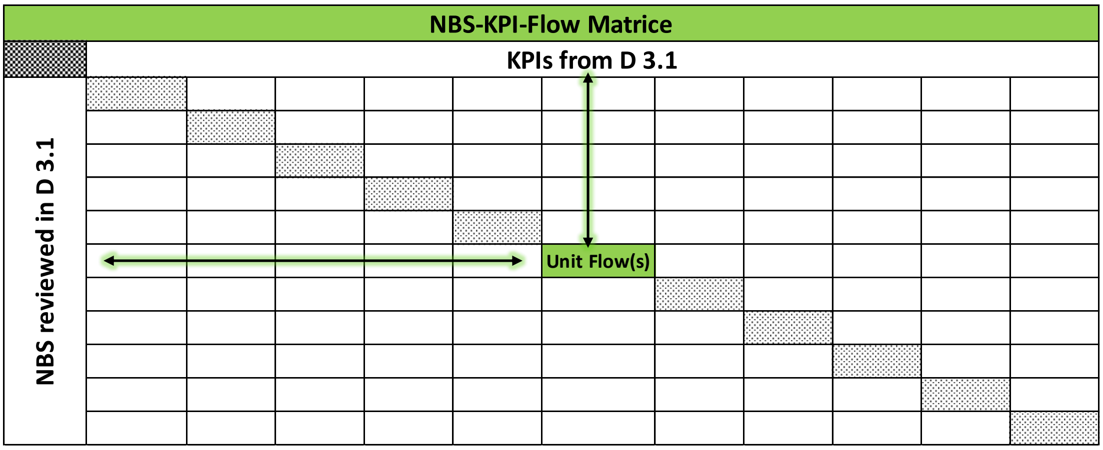
Topics	Environmental KPI for Dynamic Assessment	Temporal Resolution
	Ecotoxicity	Annually
	Ecosystem Damages	Annually
	Human Health Damages	Annually
	Natural Resource Damages	Annually

*It is suggested to make an annual LCA for to obtain healthy results. It is possible by evaluating every input and output flow in a yearly based manner which will show the dynamic alteration of every parameter that will affect the impact respectively. In this way, this will also give a chance to monitor the NBS implemented between different maintenance periods. However, it should be noted that temporal representativeness of LCI databases and their update status are significantly important factors to consider when selecting temporal resolution of an impact category.

Every NBS has its own system model consisting single or multi process. Therefore, when considering the KPI calculation it is necessary to make a link between NBS Urban Flow and the selected KPIs. The following table (Table 18) will serve as a template for the connection described above and filled-in version of this template is available in Annex B: NBS-KPI-FLOW ALLOCATION TABLE.

Table 18 Table(Template) for NBS-KPI-Flow Allocation



The dynamic nature of the urban metabolism approach refers to a broad range of quantitative methods that attempt to conceptualize urban areas with a time-based focus. Urban planning strategies should be nourished with trend analysis supporting sustainable urban planning decision via strong interpretation. However, before passing the interpretation stage, dynamic evaluation action of environmental impact assessment KPIs by using MFA and/or LCA method in N4C project

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should be achieved. In that respect, the project work package flow structure is well established to make a robust linkage between WP 2, WP 3 and eventually WP 6 then WP 7.

The tool(s)/module(s), which are still in development stages until the end of the project, within WP 6 will give the opportunity to monitor the time-based assessment of the environmental KPIs. At the end, N4C platform will be a dynamic decision support tool to support the urban re-naturing decision making and performance analyses. In this context, following tables show this direct connection between the tool and KPIs studied in this document. (Table 19 and Table 20)

Table 19 Tools/Service(s) and Urban Flow Indicators

Urban Flow Indicators	Tool(s) and Service(s)
Annual Carbon Sequestration	ET6 -GREENPASS /ET6bis-BOX3 Carbon/ET5-Inspection via Drones/ET7-EPESUS
Avoided GHG Emissions	ET7-EPESUS/ET8-Simplified LCA Tool
Energy Efficiency	ET7-EPESUS
Per Capita Food Production Variability	ET7-EPESUS
Cumulative Energy Demand	
Water Scarcity	ET7-EPESUS
Raw Material Efficiency	ET7-EPESUS
Specific Waste Generation	No module/tool allocated with this indicator in N4C project
Efficiency of Valorisation as a Result of Recycling Processes	ET7-EPESUS

Table 20 Tools and LCA Indicators

Life Cycle Indicators	Tool(s) and Module(s) from WP 2 and WP 6
Global Climate Change	ET8-Simplified LCA Tool
Ozone Depletion	
Acidification	
Eutrophication	
Resource Depletion	
Photochemical Ozone Depletion	
Human Toxicity	
Ecotoxicity	
Ecosystem Damages	
Human Health Damages	

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Natural Resource Damages	
MIPS	No module/tool allocated with this indicator in N4C project

Apart from these tools, the EMM toolbox, derived from the partners' expertise, will be integrated into the N4C platform as a database. This will serve as a background database delivering input data for calculations carried out in the SUA Tool module of N4C platform.

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Annex B: NBS-KPI-FLOW ALLOCATION TABLE

O=Object Scale   N=Neighbourhood Scale   C=City Scale

NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
Living wall systems Build or attached planter systems	Carbon sequestered (O, N)	GHG emissions avoided (O, N)	Energy demand for air treatment (O)	Food supply - of plant origin (C)	Energy demand for air treatment (O)	Water demand for irrigation (O)	Food supply - of plant origin (C)	-	-
	-	-	Energy demand for cooling (O)	-	Energy demand for cooling (O)	-	Fuel consumption avoided (O)	-	-
	-	-	Energy demand for heating (O)	-	Energy demand for heating (O)	-	Fertilizers – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Fertilizers – organic (O, N, C)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	-	Herbicides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Herbicides – organic (O, N, C)	-	-
	-	-	-	-	-	-	Insecticides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Insecticides – organic (O, N, C)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Pesticides – organic (O, N, C)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
Urban farms	Carbon sequestered (O, N)	GHG emissions avoided (O, N)	Energy demand for water supply (O, N	Food supply – of plant origin (O, N)	Fuel consumption avoided (O, N)	Water demand for irrigation (O, N)	Compost (O)	Waste generated (O)	-
	-	-	-	-	-	Water supply from alternative sources than supply system (O)	Food supply – of plant origin (O, N)	-	-
	-	-	-	-	-	-	Fuel consumption avoided (O, N)	-	-
	-	-	-	-	-	-	Herbicides-chemical (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	-	Other resource (O, N, C)	-	-
	-	-	-	-	-	-	Water demand for irrigation (O, N)	-	-
Quarry restoration	Carbon sequestered (O)	GHG emissions released (O)	Energy demand for construction (O)	-	Energy demand for construction (O)	Stormwater avoided into the sewer (O)	Chemicals used for water treatment (O)	-	-
	-	-	Energy demand for maintenance (O)	-	-	-	Construction materials required (O)	-	-
	-	-	Energy demand for water treatment (O)	-	-	-	Food supply – of plant origin (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	-	Fuel consumption for vehicles (O)	-	-
Bird friendly school gardens	Carbon sequestered (O, N)	-	Energy demand for maintenance (O, N)	-	-	Water for maintenance (O)	Compost (O)	Waste generated (O)	-
	-	-	-	-	-	-	Fertilizers-organic (O)	-	-
Large urban public parks	Carbon sequestered (O, N, C)	GHG emissions released (O, N, C)	Energy demand for cooling (O, N, C)	-	Energy demand for cooling (O, N, C)	Water for maintenance (O)	Chemicals used for water treatment (O)	-	-
	-	-	Energy demand for maintenance (O)	-	-	Water demand for irrigation(O)	Fuel consumption for vehicles (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for water supply (O, N, C)	-	-	-	Herbicides – chemical (O)	-	-
	-	-	Energy demand for water treatment (O, N, C)	-	-	-	Herbicides – organic (O)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O)	-	-
	-	-	-	-	-	-	Pesticides – organic (O)	-	-
	-	-	-	-	-	-	Water demand for irrigation (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	-	Water for maintenance (O)	-	-
Climber green walls	Carbon sequestered (O, N)	GHG emissions avoided (O, N)	Energy demand for cooling (O)	-	Energy demand for cooling (O)	Water demand for irrigation (O)	Water demand for irrigation (O)	-	-
	-	-	Energy demand for heating (O)	-	Energy demand for heating (O)	-	Compost (O)	-	-
	-	-	-	-	-	-	Fuel consumption avoided (O, N)	-	-
Botanical gardens	Carbon sequestered (O, N, C)	-	Energy demand for cooling (N, C)	-	Energy demand for cooling (N, C)	Water demand for irrigation (O, N, C)	Water demand for irrigation (O, N, C)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for maintenance (N,C)	-	-	Infiltration to groundwater (O, N, C)	-	-	-
	-	-	Energy demand for water supply (N, C)	-	-	-	-	-	-
Cemetery	Carbon sequestered (O, N, C)	GHG emissions released (O, N, C)	Energy demand for maintenance (O)	-	-	Water demand for irrigation (O)	Chemicals used for water treatment (O)	-	-
	-	-	Energy demand for water supply (O, N, C)	-	-	-	Fuel consumption for vehicles (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for water treatment (O, N, C)	-	-	-	Herbicides – chemical (O)	-	-
	-	-	-	-	-	-	Herbicides – organic (O)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O)	-	-
	-	-	-	-	-	-	Pesticides – organic (O)	-	-
	-	-	-	-	-	-	Water demand for irrigation (O)	-	-
Flower fields	Carbon sequestered (O, N, C)	-	-	-	-	Infiltration to groundwater (O, N)	Water demand for irrigation (O, N)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	Water demand for irrigation (O, N)	-	-	-
Hedge and planted fences	Carbon sequestered (O, N, C)	-	Energy demand for cooling (O, N)	-	Energy demand for cooling (O, N)	Water demand for irrigation (O)	Fertilizers – chemical (O, N)	-	-
	-	-	-	-	-	-	Fertilizers – organic (O, N)	-	-
	-	-	-	-	-	-	Herbicides – chemical (O, N)	-	-
	-	-	-	-	-	-	Herbicides – organic (O, N)	-	-
	-	-	-	-	-	-	Insecticides – chemical (O, N)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	-	Insecticides – organic (O, N)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O, N)	-	-
	-	-	-	-	-	-	Pesticides – organic (O, N)	-	-
	-	-	-	-	-	-	Water demand for irrigation (O)	-	-
Heritage gardens	Carbon sequestered (O, N, C)	-	Energy demand for cooling (N, C)	-	Energy demand for cooling (C)	Infiltration to groundwater (O, N, C)	Energy demand for maintenance (N, C)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	Water demand for irrigation (O, N, C)	Energy demand for water supply (N, C)	-	-
	-	-	-	-	-	-	Infiltration to groundwater (O, N, C)	-	-
Pocket gardens	Carbon sequestered (O)	GHG emissions released (O)	Energy demand for cooling (N)	-	Energy demand for cooling (N)	Water demand for irrigation (O, N, C)	Fuel consumption for vehicles (N)	-	-
	-	-	Energy demand for maintenance (N)	-	-	-	Water demand for irrigation (O, N, C)	-	-
Private gardens	Carbon sequestered (N)	GHG emissions released (O)	Energy demand	-	Energy demand	Water demand for	Fertilizer-chemical (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
			for cooling (O)		for cooling (O, N)	irrigation (O)			
	-	-	Energy demand for maintenance (O)	-	Energy demand for maintenance (O)	-	Fertilizer-organic (O)	-	-
	-	-	-	-	Energy demand for water supply (O)	-	Food supply – of plant origin (O, N)	-	-
	-	-	-	-	-	-	Water demand for irrigation (O)	-	-
Public urban green spaces Public	Carbon sequestered (O, N, C)	GHG emissions released (O, N, C)	Energy demand for cooling (O, N)	-	Energy demand for cooling (O, N)	Stormwater avoided into the sewer (O, N, C)	Chemicals used for water treatment (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
urban green spaces with specific uses Take into account the distribution of public green spaces through the city	-	-	Energy demand for maintenance (O)	-	-	Water demand for irrigation (O)	Fuel consumption for vehicles (O)	-	-
	-	-	Energy demand for water supply (O, N, C)	-	-	Water for maintenance (O)	Herbicides – chemical (O)	-	-
	-	-	Energy demand for water treatment (O, N, C)	-	-	-	Herbicides – organic (O)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O)	-	-
	-	-	-	-	-	-	Pesticides – organic (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	-	Water demand for irrigation (O)	-	-
	-	-	-	-	-	-	Water for maintenance (O)	-	-
Single trees	Carbon sequestered (N)	-	Energy demand for cooling (N)	-	Energy demand for cooling (N)	Water demand for irrigation (N)	Infiltration to groundwater (N)	-	-
	-	-	Energy demand for maintenance (N)	-	-	-	Water demand for irrigation (N)	-	-
	-	-	Energy demand for water supply (N)	-	-	-	-	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
Vegetated pergolas	Carbon sequestered (O)	GHG emissions avoided (O)	Energy demand for cooling (O)	Food supply – of plant origin (O)	Energy demand for cooling (O)	-	Food supply – of plant origin (O)	-	-
	-	-	-	-	-	-	Fuel consumption for vehicles (O)	-	-
Woods	Carbon sequestered (O, N)	GHG emissions avoided (O, N)	Energy demand for cooling (O, N)	-	Energy demand for cooling (O, N)	Infiltration to groundwater (O, N)	Infiltration to groundwater (O, N)	-	-
	-	-	-	-	-	Stormwater avoided into the sewer (O, N, C)	Herbicides – chemical (O)	-	-
	-	-	-	-	-	Surface runoff - not captured	Herbicides – organic (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
						by stormwater sewers (O, N)			
	-	-	-	-	-	-	Pesticides – chemical (O)	-	-
	-	-	-	-	-	-	Pesticides – organic (O)	-	-
	-	-	-	-	-	-	Stormwater avoided into the sewer (O, N, C)	-	-
	-	-	-	-	-	-	Surface runoff - not captured by stormwater sewers (O, N)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
Grass tram tracks	Carbon sequestered (O, N, C)	-	Energy demand for cooling (N, C)	-	Energy demand for cooling (N, C)	Water demand for irrigation (O, N)	Water demand for irrigation (O, N)	-	-
	-	-	Energy demand for water supply (N, C)	-	-	Stormwater avoided into the sewer (O, N)	-	-	-
Green strips	Carbon sequestered (O, N, C)	-	Energy demand for cooling (N, C)	-	Energy demand for cooling (N, C)	Water supply from alternative sources than supply system	Other resource (O, N, C)	-	Waste recycled (O)
	-	-	-	-	-	-	-	-	-

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Green waterfront city	Carbon sequestered (O, N, C)	-	Energy demand for constructio n (O)	-	Energy demand for cooling (C)	-	Water supply from alternative sources than supply system (O, N, C)	-	-
	-	-	Energy demand for cooling (C)	-	-	-	-	-	-
Planted car parks	Carbon sequestered (O, N, C)	-	Energy demand for constructio n (N, C)	-	Energy demand for cooling (N, C)	Water supply from alternativ e sources than supply system (O, N)	Water supply from alternative sources than supply system (O, N)	-	-
	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-

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Street trees	Carbon sequestered (O, N, C)	-	Energy demand for cooling (O, N, C)	-	Energy demand for cooling (O, N, C)	Stormwater avoided into the sewer (O, N, C)	Chemicals used for water treatment (O)	-	-
	-	-	Energy demand for water supply (O, N, C)	-	-	-	Herbicides – chemical (O)	-	-
	-	-	Energy demand for water treatment (O, N, C)	-	-	-	Herbicides – organic (O)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O)	-	-
	-	-	-	-	-	-	Pesticides – organic (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
Unsealed car parks	-	GHG emissions released (O, N)	Energy demand for water supply (O, N)	-	Energy demand for water supply (O, N)	Stormwater into sewer (O, N)	Energy demand for water treatment (O, N)	-	-
	-	-	-	-	Energy demand for water treatment (O, N)	Water supply from alternative sources than supply system (O, N)	Construction materials avoided (O)	-	-
Meadow	-	-	Carbon sequestered (O, N)	GHG emissions avoided (O, N)	Energy demand for maintenance (O, N)	Water demand for irrigation (O, N)	Fertilizers-chemical (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for maintenance (O, N)	-	-	-	Fertilizers-organic (O)	-	-
	-	-	-	-	-	-	Food supply – of plant origin (O, N)	-	-
	-	-	-	-	-	-	Fuel consumption for vehicles (O, N)	-	-
	-	-	-	-	-	-	Herbicides-chemical (O)	-	-
	-	-	-	-	-	-	Herbicides-organic (O)	-	-
	-	-	-	-	-	-	Insecticides-chemical (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	-	-	-	-	Insecticides-organic (O)	-	-
	-	-	-	-	-	-	Pesticides-chemical (O)	-	-
	-	-	-	-	-	-	Pesticides-organic (O)	-	-
	-	-	-	-	-	-	Water demand for irrigation (O, N)	-	-
Urban forests	Carbon sequestered (O, N, C)	GHG emissions released (O, N, C)	Energy demand for cooling (N)	-	Energy demand for cooling (N)	Stormwater avoided into the sewer (O, N, C)	Chemicals used for water treatment (O	-	-
	-	-	Energy demand for water supply (O, N, C)	-	-	-	Fuel consumption for vehicles (O)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for water treatment (O, N, C)	-	-	-	Herbicides – chemical (O)	-	-
	-	-	-	-	-	-	Herbicides – organic (O)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O)	-	-
	-	-	-	-	-	-	Pesticides – organic (O)	-	-
Urban orchards	Carbon sequestered (O, N)	-	Energy demand for cooling (O, N)	Food supply – of plant origin (O ,N, C)	Energy demand for cooling (O, N)	Water demand for irrigation (O, N)	Food supply – of plant origin (O ,N, C)	-	-
	-	-	Energy demand for	-	-	-	Fuel consumptio n for	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
			maintenance (O, N)				vehicles (O, N, C		
	-	-	Energy demand for water supply (O, N)	-	-	-	Water demand for irrigation (O, N)	-	-
Urban vineyard	Carbon sequestered (O, N,C)	-	Energy demand for cooling (O, N)	Food supply – of plant origin (C)	Energy demand for cooling (O, N)	Water demand for irrigation (O, N)	Fertilizer chemical (N, C)	-	-
	-	-	Energy demand for maintenance (O, N)	-	-	-	Fertilizer organic (N, C)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for water supply (O, N)	-	-	-	Food supply – of plant origin (N, C)	-	-
	-	-	-	-	-	-	Fuel consumption for vehicles (N, C)	-	-
	-	-	-	-	-	-	Pesticides chemical (N, C)	-	-
	-	-	-	-	-	-	Pesticides organic (N, C)	-	-
	-	-	-	-	-	-	Water demand for irrigation (N, C)	-	-

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Vegetable gardens	Carbon sequestered (O, N)	GHG emissions avoided (O, N)	Energy demand for maintenance (O, N)	Food supply – of plant origin (O, N)	-	Water demand for irrigation (O, N)	Compost (O)	-	-
	-	-	Energy generated by renewable resources (O, N)	-	-	Water for maintenance (O, N)	Food supply – of plant origin (O, N)	-	-
	-	-	-	-	-	-	Fuel consumption avoided(O)	-	-
	-	-	-	-	-	-	Herbicides – chemical (O)	-	-
	-	-	-	-	-	-	Water demand for irrigation (O, N)	-	-

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	-	-	-	-	-	-	Water for maintenance (O, N)	-	-
Phytoremediation Management of polluted areas by plants	-	-	Energy demand for soil treatment (O, N)	-	Energy demand for water supply (O, N)	-	Fertilizers-chemical (O, N)	-	-
	-	-	Energy demand for water supply (O, N)	-	Energy demand for water treatment (O, N)	-	Fertilizers - organic (O, N)	-	-
	-	-	Energy demand for water treatment (O, N)	-	-	-	Metals extracted from soil (O, N)	-	-
	-	-	-	-	-	-	Water demand for	-	-

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							irrigation (O, N)		
Quarry restoration	Carbon sequestered (O)	GHG emissions released (O)	Energy demand for construction (O)	-	Energy demand for construction (O)	Infiltration to groundwater (O)	Chemicals used for water treatment (O)	-	-
	-	-	Energy demand for maintenance (O)	-	Energy demand for maintenance (O)	Stormwater avoided into the sewer (O	Construction materials required (O)	-	-
	-	-	Energy demand for water treatment (O)	-	Energy demand for water treatment (O)	Water supply from alternative sources than supply system	Food supply – of plant origin (O)	-	-

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	-	-	Energy generated by renewable resources (O)	-	Energy generated by renewable resources (O)	-	Fuel consumption for vehicles (O)	-	-

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Rustic plants Horticultural but non-invasive plants Indigenous species Non-allergic species Diversity of plant species Plants with bio-filter features	Carbon sequestered (O, N, C)	-	-	-	-	-	-	-	-
Vegetation systems for slope erosion	-	-	-	-	Energy consumption avoided (C)	Infiltration to groundwa	Infiltration to groundwater (O, N, C)	-	-

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control Vegetation engineering systems for wind erosion control						ter (O, N, C)			
	-	-	-	-	Energy demand for construction (C)	-	-	-	-
Mulching	-	GHG emissions released (O)	-	-	-	-	Food supply – of plant origin (O, N)	-	Waste recycled (O, N, C)
	-	-	-	-	-	-	Fuel consumption for vehicles (N)	-	-
	-	-	-	-	-	-	Other resource (O, N)	-	-

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Soil amelioration/amendment/improvement Smart soils Reinforced /structural soil	-	-	Energy demand for water supply (O, N, C)	-	-	-	Food supply – of plant origin (O, N, C)	-	Waste recycled (O)
Excavation of new water bodies Infrastructure removed on rivers	Carbon sequestered (O, N)	GHG emissions released (O, N)	Energy demand for water supply (O, N)	-	Energy demand for water supply (O, N	Water demand from supply system - for human consumption (O, N)	Other resource (O, N, C)	-	-
	-	-	-	-	Energy demand for water	-	Chemicals used for water	-	-

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					treatment (O,N)		treatment (O, N)		
	-	-	-	-	Energy demand for water treatment (O, N)	-	Construction materials required (O, N)	-	-
	-	-	-	-	-	-	Fuel consumption for vehicles (O, N)	-	-
Gravity fountain	-	-	Energy demand for cooling (O, N)	-	-	Water demand for irrigation (O, N)	-	-	-

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	-	-	-	-	-	Water supply from alternative sources than supply system (O, N)	-	-	-
Reopened streams	-	GHG emissions released (N)	Energy demand for water supply (N)	-	-	Water demand from supply system – for human consumption (N)	Chemicals used for water treatment (N)	-	-

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	-	-	Energy demand for water treatment (N)	-	-	Water supply from alternative sources than supply system (N)	Construction materials required (N)	-	-
	-	-	-	-	-	-	Fuel consumption for vehicles (N)	-	-
	-	-	-	-	-	-	Water demand for irrigation (N)	-	-
	-	-	-	-	-	-	Water demand from supply system – for human	-	-

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							consumption (N)		
	-	-	-	-	-	-	Water supply from alternative sources than supply system (N)	-	-
Re-profiling river banks	-	-	Energy demand for cooling (O, N, C)	Food supply - of plant origin (O, N, C)	Energy demand for cooling (O, N, C)	-	Fertilizers – chemical (O, N, C)	-	-
	-	-	Energy demand for maintenance (N, C	-	-	-	Fertilizers – organic (O, N, C)	-	-

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	-	-	Energy demand for water supply (N, C)	-	-	-	Herbicides – chemical (O,N,C)	-	-
	-	-	-	-	-	-	Herbicides – organic (O, N, C)	-	-
	-	-	-	-	-	-	Insecticides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Insecticides – organic (O, N, C)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Pesticides – organic (O, N, C)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
Vegetation systems for riverbanks erosion control	-	-	-	-	Energy consumption avoided (O, N, C)	Water demand for irrigation (O)	Construction materials avoided (O, N, C)	-	-
	-	-	-	-	Energy demand for construction (O, N, C)	-	Fuel consumption for vehicles (O)	-	-
	-	-	-	-	-	-	Fertilizers – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Fertilizers – organic (O, N, C)	-	-
	-	-	-	-	-	-	Herbicides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Herbicides – organic (O, N, C)	-	-

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	-	-	-	-	-	-	Insecticides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Insecticides – organic (O, N, C)	-	-
	-	-	-	-	-	-	Pesticides – chemical (O, N, C)	-	-
	-	-	-	-	-	-	Pesticides – organic (O, N, C)	-	-
Constructed wetland for phytoremediation Constructed wetland for	-	-	Energy demand for water supply (O, N)	-	Energy demand for water supply (O, N)	Water supply from alternative sources than supply system	Metals extracted from soil (O, N)	-	Waste recycled (N)

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wastewater treatment	-	-	Energy demand for water treatment (O, N)	-	Energy demand for water treatment (O, N)	-	Water demand for irrigation (O, N)	-	-
De-sealed areas	-	GHG emissions avoided (N)	Energy demand for water treatment (N)	-	-	Water supply from alternative sources than supply system (N)	Other resource (N, C)	-	-
	-	-	-	-	-	-	Water supply from alternative sources than supply system (N)	-	-

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Rain/infiltration gardens	Carbon sequestered (O)	-	-	-	-	Water demand from supply system - for human consumption (O, N, C)	Food supply – of plant origin (O, N)	-	-
	-	-	-	-	-	Stormwater avoided into the sewer (O, N, C)	Water demand for irrigation (O, N, C)	-	-
Swales	-	-	Energy demand for water supply (O,N)	-	-	Water supply from alternative sources than supply	Food supply - of plant origin (if vegetated swales is applied) (O, N, C)	-	-

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						system (O, N)			
	-	-	-	-	-	-	-	-	-
Use of terraces	-	-	Energy demand for water supply (O, N, C)	Food supply – of plant origin (C)	-	Water demand from supply system - for human consumption (O, N, C)	Food supply – of plant origin (O, N, C)	-	-
	-	-	-	-	-	-	Water demand from supply system - for human	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
							consumption (O, N, C)		
Extensive green roofs	Carbon sequestered (O)	GHG emissions avoided (O)	Energy demand for cooling (O)	-	Energy demand for cooling (O)	Water demand for irrigation (O)	Fertilizers – chemical (O)	-	-
	-	-	Energy demand for heating (O)	-	Energy demand for heating (O)	-	Fertilizers – organic (O)	-	-
	-	-	Energy demand for maintenance (O)	-	-	-	Water demand for irrigation (O)	-	-
	-	-	Energy demand for water supply (O)	-	-	-	-	-	-

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Intensive green roofs Semi-intensive green roofs	Carbon sequestered (O)	GHG emissions avoided (O)	Energy demand for cooling (O)	Food supply – of plant origin (O)	Energy demand for cooling (O)	Stormwater avoided into the sewer (O)	Fertilizers – chemical (O)	-	-
	-	-	Energy demand for heating (O)	-	Energy demand for heating (O)	Water demand for irrigation (O)	Fertilizers – organic (O)	-	-
	-	-	Energy demand for maintenance (O)	-	-	Water supply from alternative sources than supply system (O)	Food supply – of plant origin (O)	-	-
	-	-	Energy demand for water supply (O)	-	-	-	Stormwater avoided into the sewer (O)	-	-

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	-	-	-	-	-	-	Water demand for irrigation (O)	-	-
	-	-	-	-	-	-	Water supply from alternative sources than supply system (O)	-	-
Roof ponds	Carbon sequestered (O, N, C)	GHG emissions avoided (O, N, C)	Energy demand for cooling (O, N, C)	-	Energy demand for cooling (O, N, C)	Water supply from alternativ e sources than supply system (O, N)	Water demand for irrigation (O, N)	-	-

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for heating (O,N,C)	-	Energy demand for heating (O,N,C)	-	Water supply from alternative sources than supply system (O, N)	-	-
As much as possible keeping old trees	Carbon sequestered (O, N, C)	GHG emissions avoided (O, N, C)	Energy demand for cooling (O, N)	-	Energy demand for cooling (O, N)	-	-	-	-
Compostin g	-	-	Energy demand for maintenan ce (O)	-	Compost (O, N)	Water for maintena nce (O)	Fertilizers avoided (N, C)	Waste generated (N, C)	Waste recycled (N, C)

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NBS	Annual CO2 Seq.	Avoided GHG Emissions	Energy Efficiency	Per Capita Food Production Variability	Cumulative Energy Demand	Water Scarcity	Raw Material Efficiency	Specific Waste Generation	Efficiency of Valorization as a Result of Recycling Processes
	-	-	Energy demand for processing of waste to be used as a resource (O)	-	Energy demand for processing of waste to be used as a resource (O)	-	Other resource (N, C)	-	-
	-	-	-	-	-	-	Pesticides avoided (N, C)	-	-
	-	-	-	-	-	-	Water for maintenance (O)	-	-
Conserving dead wood on the ground	-	-	Energy demand for processing of waste to be used as a resource (O)	-	-	-	Fuel consumption for vehicles (O, N, C)	Waste recycled (O, N, C)	-

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	-	-	-	-	-	-	Other resource (O, N, C)	-	-
Eco management plans No management Limited number of management interventions in time Specific positioning of management interventions in time	-	GHG emissions avoided (O, N, C)	-	-	Energy demand for maintenance (C)	-	Fertilizers avoided (O, N, C) Herbicides avoided (O, N, C)	-	-

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Mulching	-	GHG emissions released (O)	-	-	-	-	Food supply – of plant origin (O, N)	-	Waste recycled (O, N, C)
	-	-	-	-	-	-	Fuel consumption for vehicles (N)	-	-
	-	-	-	-	-	-	Other resource (O, N)	-	-
Reasoned or no use of chemical fertilizers (Sustainable use of fertilizer)	-	GHG emissions avoided (O)	-	Food supply – of plant origin (C)	Energy consumption avoided (O)	-	Fuel consumption avoided (C)	Waste generated (O)	-
	-	-	-	-	-	-	Fuel consumption for vehicles (C)	-	-
Reasoned use of organic fertilizer	-	GHG emissions released (O)	-	Food supply – of plant origin (C)	Energy consumption avoided (O	-	Fuel consumption avoided (C)	Waste generated (O)	Waste recycled (O)

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(Sustainable use of fertilizer)	-	-	-	-	-	-	Other resource (O, N)	-	-
Beehives	-	-	-	-	-	-	Food supply – of animal origin (O, N)	-	-
Insect hotels	-	-	-	-	-	-	Biomass (O)	-	-
Use of grazing animals	-	GHG emissions released (O,vN)	Energy demand for maintenance (O, N)	Food supply - of animal origin (O)	Energy demand for maintenance (O, N)	-	Food supply - of animal origin (O, N)	Waste generated (C)	-
	-	-	Energy demand for soil treatment (O, N)	-	Energy demand for soil treatment (O, N)	-	Fertilizers – chemical (O, N)	-	-
	-	-	-	-	-	-	Fertilizers – organic (O, N)	-	-

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	-	-	-	-	-	-	Herbicides – chemical (O, N)	-	-
	-	-	-	-	-	-	Herbicides – organic (O, N)	-	-
	-	-	-	-	-	-	Herbicides avoided (O, N)	-	-
Composting	-	-	Energy demand for maintenance (O)	-	Compost (O, N)	Water for maintenance (O)	Fertilizers avoided (N, C)	Waste generated (N, C)	Waste recycled (N, C)
	-	-	Energy demand for processing of waste to be used as a resource (O)	-	Energy demand for processing of waste to be used as a resource (O)	-	Other resource (N, C)	-	-

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	-	-	-	-	-	-	Pesticides avoided (N, C)	-	-
	-	-	-	-	-	-	Water for maintenance (O)	-	-
Limit or prevent some specific uses and practices	-	-	Energy demand for water supply (O, N, C)	-	-	Water demand from supply system – for human consumption (O, N , C)	Water demand from supply system – for human consumption (O, N , C)	-	-
Ensure continuity with	Carbon sequestered (O, N, C)	-	Energy demand for cooling (O, N, C)	-	-	-	-	-	-

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ecological network	-	-	Energy demand for water supply (O, N, C)	-	-	-	-	-	-
Integration in the flooding map	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-
Limit use of agricultural land	-	-	Energy demand for construction (O)	-	-	Water demand for irrigation (O)	Construction materials required (O)	Waste generated (O)	-
	-	-	Energy demand for maintenance (O)	-	-	-	-	-	-

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	-	-	Energy demand for water supply (O)	-	-	-	-	-	-

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