URBREATH [101139711]

Systemic Integration of Transformative Technical and Nature-based Solutions to Improve Climate Neutrality of European Cities and Regions and tackle Climate Change: the URBREATH Approach

URBREATH

D3.5 Numerical modelling for the NBSs - V2

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Document description	This document describes the models addressing NBS-specific physical phenomena and EU generic data and data requested in every front runner city to run the model. The data collected will address both local urban planning, built and natural environment information as well local atmospheric conditions and environmental data. This deliverable is linked to T3.4 and is an update of D3.4 and a last update is foreseen in M36 (December 2026).

Document Revision History

Version	Date	Modifications Introduced	
		Modification Reason	Modified by
0.1	1.9.2024	Table of contents	ICCS
0.2	15.11.2025	Overview of models to be discussed and links to other deliverables	VITO
0.3	03.12.2025	First draft for review	VITO
0.4	10.12.2025	Reviews and comments	EXUS
0.5	15.12.2025	Reviews and comments	Engineering
1.0	17.12.2025	Addressing all comments, finalizing deliverable	VITO
2.0	17.12.2025	Final quality check by the coordinator	The Lisbon Council
Final	18.12.2025	Version ready for submission to the EC Portal	The Lisbon Council

Disclaimer

The URBREATH project is co-funded by the European Union under grant agreement ID 101139711. The information and views set out in this document are those of the URBREATH Consortium only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

Executive Summary

Humans use a wide range of services and raw materials produced by ecosystems. These benefits are commonly known as 'ecosystem services' (ESS) or nature benefits and include both products (e.g. drinking water) and processes (e.g. waste decomposition). This deliverable presents the numerical models and frameworks that have been selected and are being configured to evaluate the impact of Nature-Based Solutions (NBS) on urban ecosystem services in URBREATH cities. It details the methodologies and the required data, and how these models address the requirements of the cities to support them in creating more climate robust neighbourhoods. The models address key urban metrics, including air quality, heat stress, biodiversity, recreation and water retention and infiltration.

During the first year of the URBREATH project the overview of the interests and requirements of the cities had been made to explore if and how a numerical approach can support them during the planning, implementation, and validation phase of the redesign of local neighbourhood plans integrating NBS. The wealth of available models and tools had been matched with these requirements to select the following models and frameworks.

Nature Value explorer: a pragmatic approach to value ecosystem services including producing, regulating and cultural services;
Urban climate modelling to evaluate impact of NBS on heat stress;
Air quality modelling to evaluate impact of NBS on air pollution;
3+30+300 to evaluate the availability of trees and vegetation;
Biotope Area Factor to screen the use of ecologically effective surfaces in urban developments.

For each model the necessary input data have been listed and matched with available datasets. This can be further refined with local data from the cities involved. During the second year of the project the models have been applied and updated for the URBREATH Cities. Additionally, the integration of the data using URBREATH’s Minio data repository has been foreseen and integration of the simulation models through reusable API’s has been demonstrated.

Future efforts in the third year of the project will focus on offering additional simulation components as re-usable APIs to enable further linking with local data and integration into the URBREATH platform and deploying visualizations to enhance accessibility and usability. Agentic AI is being explored as an option to enhance usability. These developments will support urban planners and policymakers in evaluating and implementing NBS interventions.

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List of Terms and Abbreviations

Abbreviation	Definition
3+30+300	Urban greenness rule: access to 3 visible trees, 30% tree canopy cover at neighbourhood level, and a public green space within 300 m
AC	Air Conditioning
API	Application Programming Interface
AQ	Air Quality
BAF	Biotope Area Factor
CAMS	Copernicus Atmosphere Monitoring Service
CMIP5	Coupled Model Intercomparison Project – Phase 5
CMIP6	Coupled Model Intercomparison Project – Phase 6
COPERT	Computer Programme to calculate Emissions from Road Transport
DEM	Digital Elevation Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
DUET	Digital Urban European Twins – Horizon project
ECMWF	European Centre for Medium-Range Weather Forecasts
ERA5	ECMWF Reanalysis version 5
ESS	Ecosystem Services

EU	European Union
FASTRACE	Traffic emission model developed by VITO
GIS	Geographic Information System
GeoJSON	Geographic JavaScript Object Notation
HWMI	Heat Wave Magnitude Index
LDT	Local Digital Twin
LOD	Level of Detail
LST	Land Surface Temperature
NBS	Nature-Based Solutions
NDVI	Normalized Difference Vegetation Index
NFR	Nomenclature for Reporting (emission sectors)
NO_2	Nitrogen Dioxide
NVE	Nature Value Explorer
OSM	OpenStreetMap
OSPM	Operational Street Pollution Model
PM_{10}	Particulate Matter with aerodynamic diameter ≤ 10 µm
$PM_{2.5}$	Particulate Matter with aerodynamic diameter ≤ 2.5 µm
QUARK	Quick Urban AiR quality using Kernels model developed by VITO
RIO	Regional Interpolation Model developed by VITO
SSP	Shared Socioeconomic Pathway
UHI	Urban Heat Island
VC	Virtual City
WBGT	Wet Bulb Globe Temperature
WP	Work Package

1 Introduction

The URBREATH project aims at addressing two main challenges within the fields of Urban Regeneration, Resilience, and Climate Neutrality:

- Gaps in the prevailing/conventional approach to revitalisation, regeneration, and greening planning about advanced integrated methods and concepts. The prevailing/conventional approach is often simplified to cost/profit criteria which do not often provide the necessary return on investment by failing to attract sustained funding, people, and businesses to regeneration areas.
- Lack of consideration of local communities' needs and hence often ending up with solutions (Nature-Based Solutions-NBSs or otherwise) that are imposed on the community, i.e. that are not socially acceptable (such often debated interplay between urban planning and mobility).

A detailed evaluation on NBS impacts helps to overcome both challenges. Within this deliverable we describe the numerical models that the URBREATH consortium aims to integrate into a digital solution to support cities. The ambition is to build a Local Digital Twin (LDT) and apply numerical (and other) models to evaluate the impact of NBSs. The concept of the LDT is presented in D4.1. Through this strategy we aim to achieve a more holistic approach for the evaluation of NBS, building on existing components and integration.

The evaluation of NBSs has a strong link with the concept of ecosystem services (ESS). Humans use a wide range of services and raw materials produced by ecosystems. These benefits are commonly known as "ecosystem services" or nature benefits and include both products (e.g. drinking water) and processes (e.g. waste decomposition)[1]. Along with the growth of the population, the demand for raw materials and services provided by ecosystems also grows. Many have long believed that ecosystem services are free, invulnerable and inexhaustible. But today the impact of human use and abuse is becoming more and more evident: e.g. air and water quality are threatened, oceans are overfished, pests and diseases are expanding beyond their historical limits, deforestation threatens natural protection against erosion, etc.

There is a growing awareness that the services provided by ecosystems are finite and under threat, and that short-term and long-term human interests should be investigated. The concept of considering nature and landscapes as producers of ecosystem services allows us to appreciate the benefits of nature and landscape and provides a framework to bring together and integrate the different social, economic and environmental aspects.

[1] Jacobs S, Vandewalle M, Connor D, Bidoglio G (2013). Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg

By integrating multiple numerical models into an LDT framework, URBREATH aims to provide helpful insights into these benefits offered by NBSs.

1.1 Purpose and Scope

This deliverable is linked to the activities in the task 3.4 focusing on the development and the implementation of numerical modelling for the nature-based solutions. In this deliverable we describe the numerical models that we aim to integrate and link to a unified digital solution offered to the URBREATH cities. With this integration we aim to create interoperable, reusable, and flexible components for digital twins targeting the impact of nature-based solutions (NBSs) and offer them in user friendly way.

1.2 Approach for Work Package and Relation to other Work Packages and Deliverables

Task 3.4 has strong links to other tasks and work packages. In the first year of the project, the needs and requirements from the cities have been gathered, discussed, and described in an iterative way involving all the partners in the consortium. This analysis has been led by WPs 2&5 with technical support from WP3&4.

The requirements of the cities have been discussed in depth and analysed for possible technical solutions. The needs of the cities are documented as use case in deliverable 2.4. Accordingly, this deliverable details the numerical models that can contribute to realizing the requirements of the described use cases.

Task 3.4 has strong links with other tasks offering model-based analysis and support in WP3:

- Task 3.1 offering AI-based algorithms and tools.
- Tasks 3.2 offering climate modelling, assessment of vulnerability to climate change.
- Task 3.3 offering short-term seasonal weather forecasting.
- Task 3.5 offering socioeconomic modelling support.

The data needs and data gaps are overseen in WP5. To create an integrated solution, the numerical models will be part of the local digital twin that is foreseen as outcome of WP4.

1.3 Methodology and Structure of the Deliverable

At the end of 2024, the needs and requirements of the cities had been analysed and matched with tools and models to support the cities. In 2025, the numerical models haven been applied to the URBREATH cities, as discussed in chapter 2. The integration of these models into Local Digital Twins (LDT) has been started and will continue in the next year. Each model relies on necessary input data. These data needs are described in chapter 3.

Lastly, an outlook to the next phase of the URBREATH project is given. This deliverable is foreseen to be updated at the end year 3. It will remain a live document during the project implementation.

2 Tool and model Descriptions

A list of numerical models has been selected to support the URBREATH cities to respond to their requirements linked to their use cases and KPIs.
The list of models described in this deliverable includes the numerical models. Next to these models, AI models are described in deliverable 3.1; the climate models and weather forecasts models are described in deliverable 3.2 and 3.3.

The data overview is given in the next chapter linking to on-going activities in WP4 and 5.

2.1 Detailed model descriptions

2.1.1 Nature Value Explorer

Ecosystem services are often not entirely appreciated in policy decisions because they are not fully captured in commercial markets nor adequately quantified in terms comparable with commercial services traded in markets. Ignoring the value of these ecosystem services may lead to overexploitation of ecosystems or unbalanced policy and investment decisions.

Because of the importance of these ecosystem services (ESS), the Environment Department of the Flemish has developed Nature Value Explorer (NVE) with VITO and the universities of Antwerp and Amsterdam to demonstrate the value of ESS in Flanders. The Walloon department DEMNA also started a platform on ecosystem services in Wallonia (WAL-ES). In 2020-2021, VITO and the university of Liège expanded the Flemish Nature explorer with data for Wallonia, so that the tool is now available for the entire country.

The tool is currently available as a stand-alone application for Belgium, presented in the figures below. The tool is freely available online including access to all literature, manuals, and documentation of the methodology to score the impact of NBSs for each ecosystem service[2].

The tool focuses on pragmatic methods to value ecosystem services. They help everyone (land managers, planners, national and local authorities, non-governmental organisations and active citizens) who wants to map the socio-economic importance of ecosystems. The list of indicator numbers and valuation functions was created based on literature review and empirical research. We refer to the manual for an underpinning of the results[3]. It describes all services included as well as the methodology for the qualitative and quantitative evaluation. The list of ecosystem services valued in this tool can be

[2] https://www.natuurwaardeverkenner.be/

[3] (https://www.natuurwaardeverkenner.be/docs/manual_EN/inleiding

further extended in the future, as it was not possible to derive quantification functions and a monetary value for all ecosystem services. The Nature value Explorer provides the initial valuation for each included service. If a specific ecosystem service proves to be very important or evokes discussions amongst stakeholders, it is advised to use more detailed ecological modelling or to use an economic valuation study specifically developed for the project.

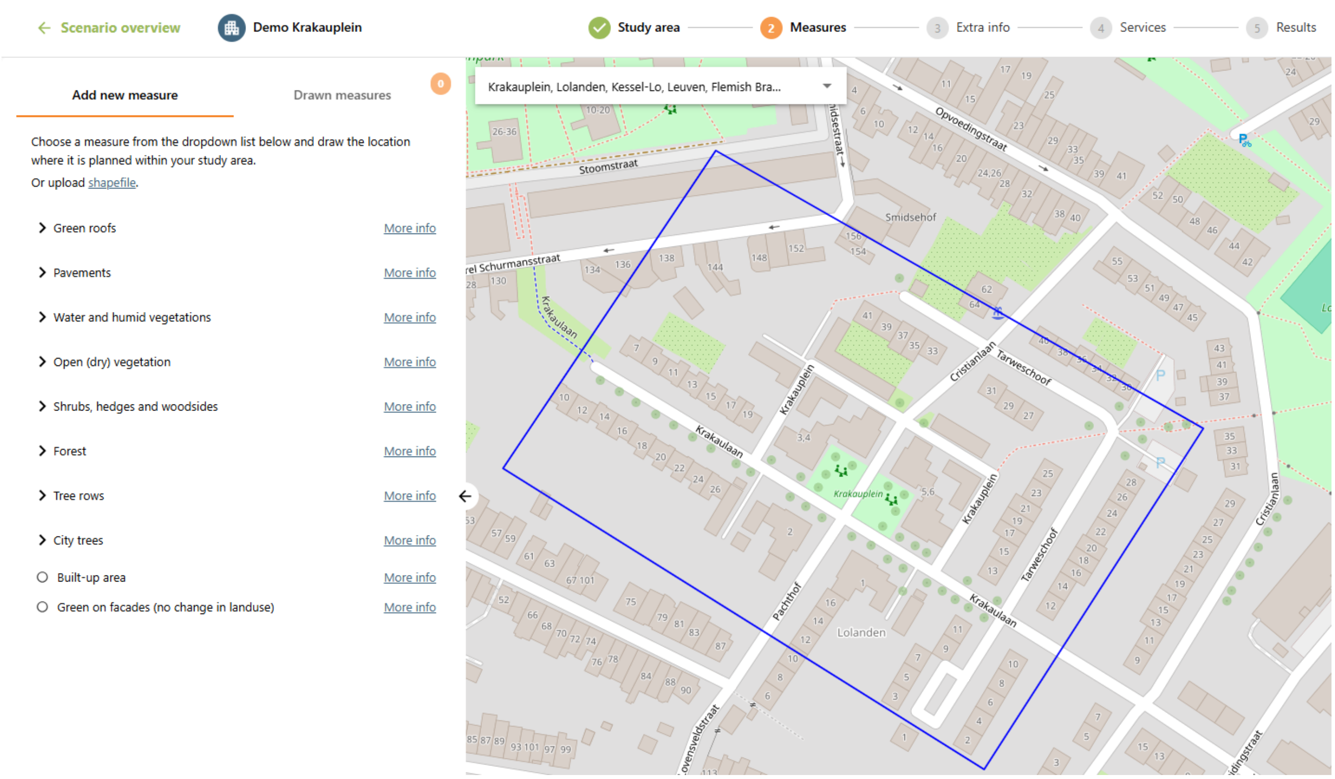

Figure 1: Example of an application of Nature Value Explorer for the Krakauplein case study in Leuven.

Ecosystem services are classically divided into four major groups: producing services, regulatory services, cultural services and support services. Producing services include the provision of products obtained from ecosystems such as genetic resources, food, fibre and raw materials. Regulatory services are those benefits that humans obtain as ecosystems help regulate certain processes such as climate and water quality. Cultural services are those that provide spiritual enrichment, cognitive development, recreation and aesthetic experience. Supporting services are those that are necessary for the provision of all the above services such as soil formation, photosynthesis and the food cycle.

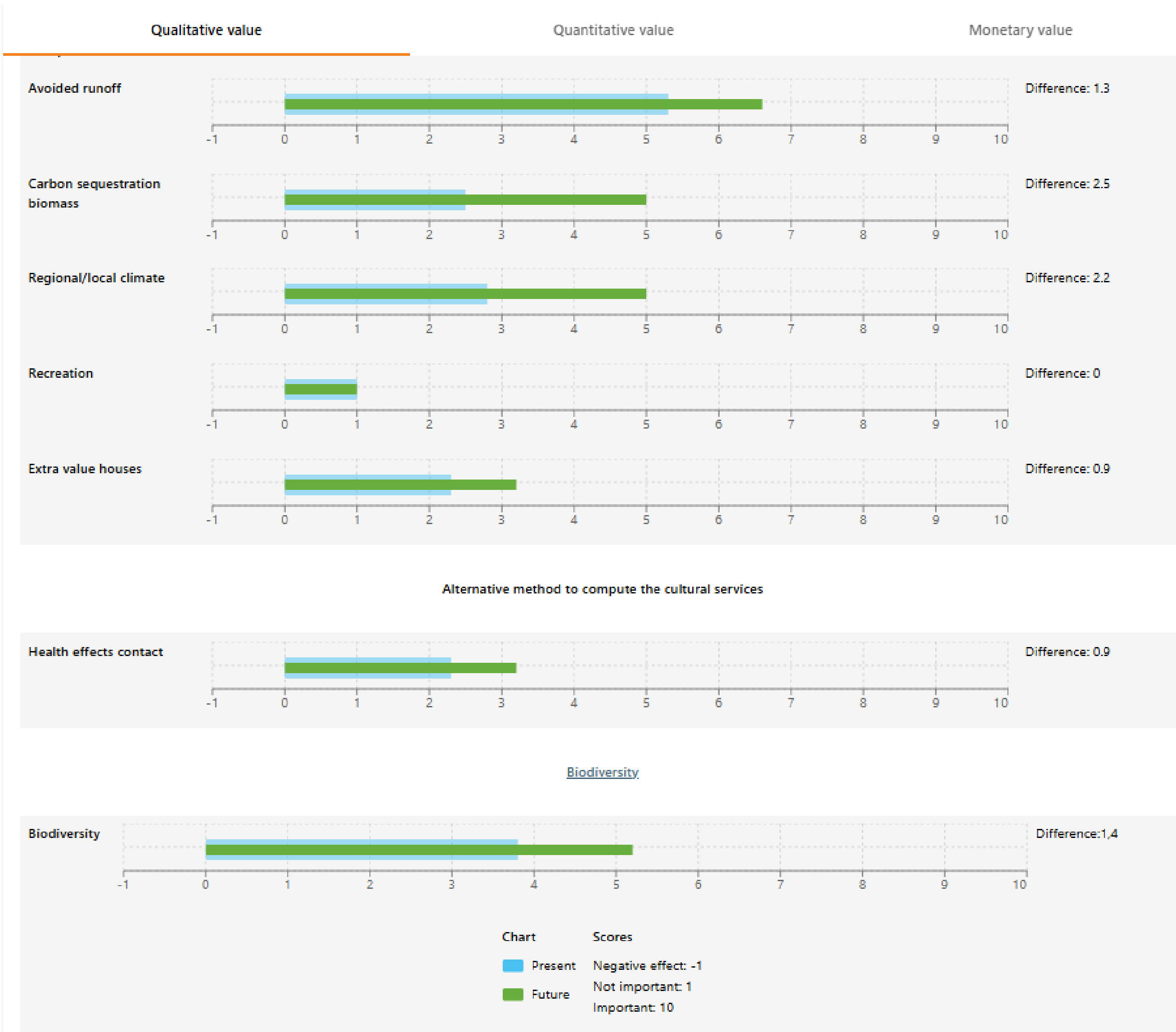

Figure 2: Overview of the evaluation of the qualitative value of nature-based solutions in an urban context using Nature Value Explorer.

Nature Value Explorer provides a step-by-step plan for estimating the effects on ecosystem services when expanding, downsizing or changing urban green spaces, and then depicting their welfare effects. For various ecosystem services, the manual indicates what exactly this service entails and how to value it qualitatively, quantitatively and/or monetarily. It indicates what the starting points are, what input data are needed and where one can find these data. Finally, each ecosystem service is illustrated with an example. These data are based on advancing insights on qualitative, quantitative and monetary valuation of ecosystem services.

The following services are currently included.

- Producing services
    - Food production
- Regulatory services
    - Air quality impacts
    - Noise impacts
    - Water retention
    - Carbon capture
    - Urban climate regulation
- Cultural services
    - Recreation
    - Added for real estate
    - Physical and mental health impacts
- Biodiversity

Currently, NVE is available as a web application. The VITO team, however, has a roadmap ready to integrate the different ecosystem services with an API to the URBREATH DT platform (more information on the integration is available in URBREATH deliverable D4.7). Instructions from the consumer side will be sent via API to an orchestrator, that will execute the ESS calculations. Output data will be sent back to the URBREATH DT platform. How this data needs to be packaged, will need to be cleared out with VCS. However, a first "off-line" connection between NVE and the VCS 3D viewer was already established, where results of the NVE were uploaded and viewable in the 3D viewer.

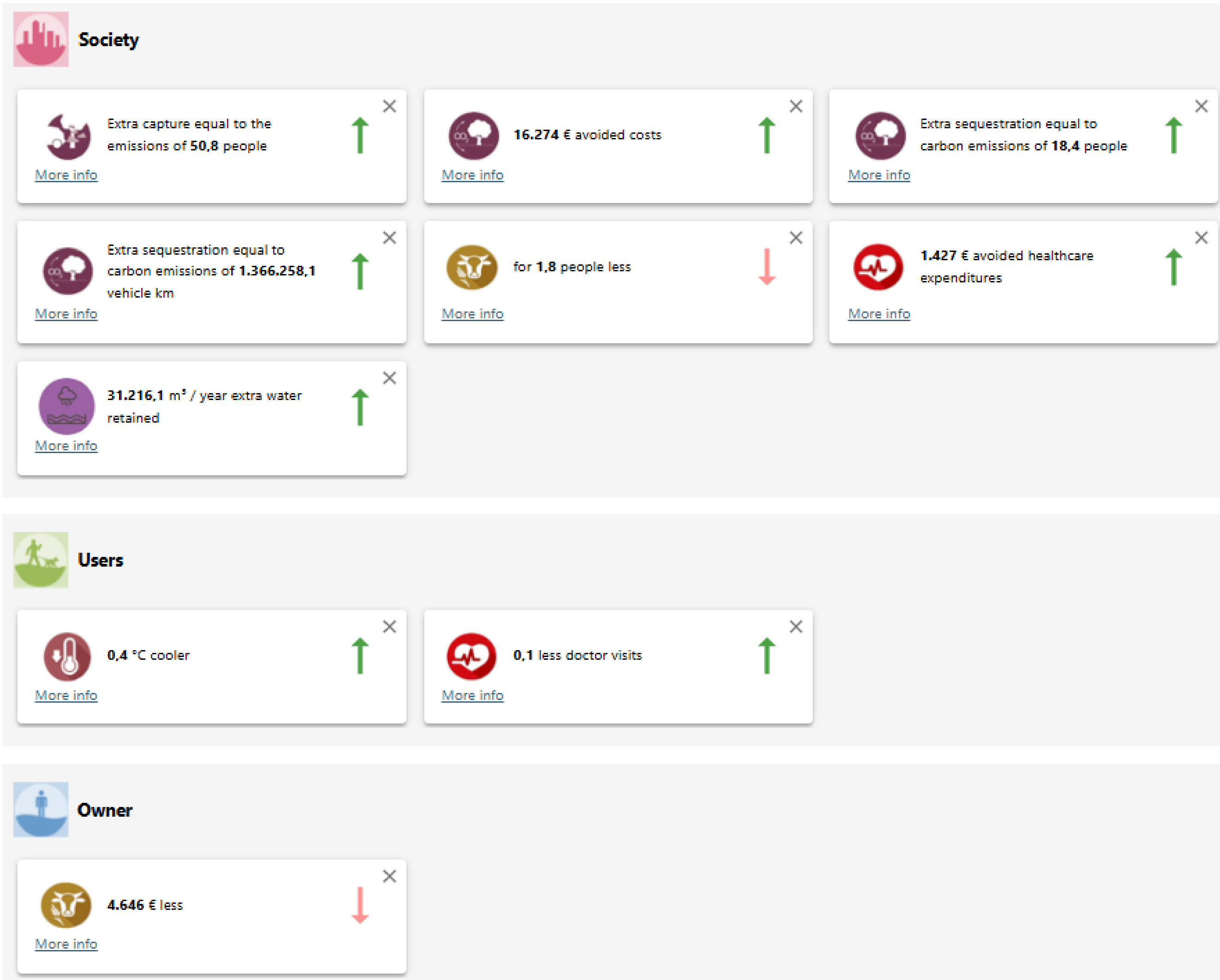

Figure 3: Dashboard presenting the change in ecosystem services for an urban project integrating new nature-based solutions.

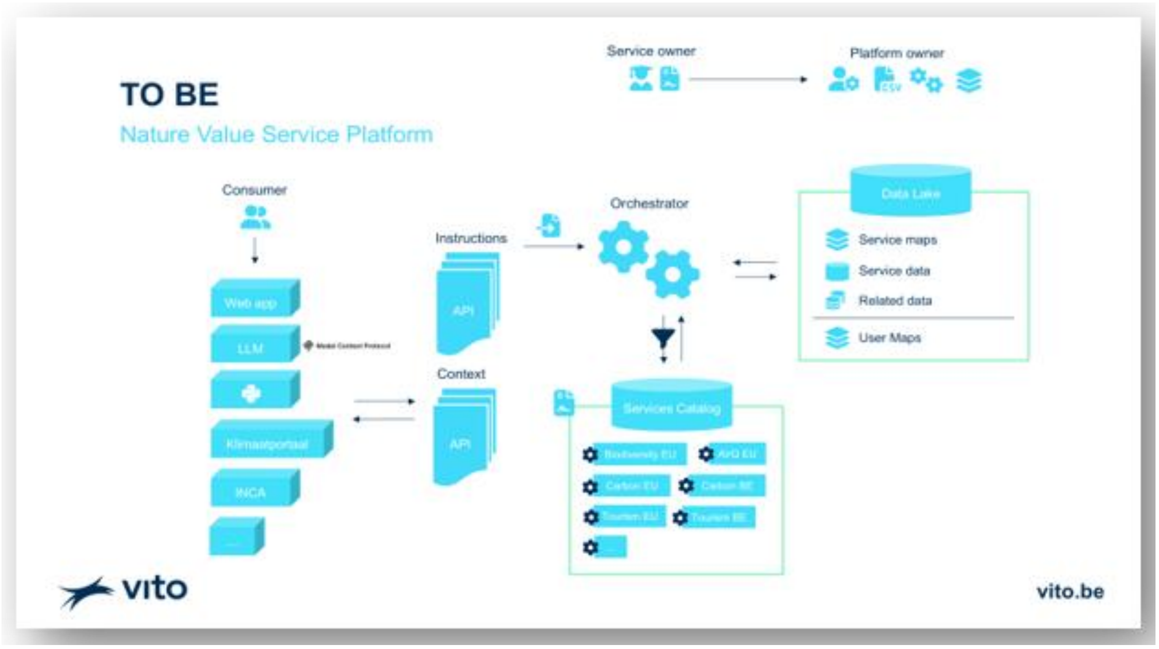

Figure 4: Architectural sketch of the NVE in URBREATH.

Almost all input data needed for the NVE are present in EU wide open datasets; however, it must be determined if the quality is sufficient for city level analysis. VITO is re-developing additional components of the NVE as reusable APIs. As we start form EU wide datasets, it is ensured that tools can be tested by all URBREATH cities and are easily transferable to other users.

3-30-300 and Biotope Area Factor had already identified as examples of these reusable components in the project (see sections 2.13 and 2.1.4). As next components the following topics have been identified based on the discussions with the cities and their preferences.

- Carbon sequestration in soil
- Infiltration
- Wood provision

input name	data type	unit	resolution (m)	thematic category	data source Belgium	remark	EU generic dataset	EU link	EU resolution
land use map	raster	categoric	10x10	General	Land use map 2019 VITO	as detailed as possible to see all the green types in the city; green map city	Urban Atlas Land Cover/Land Use 2018	https://land.copernic	0,25ha
PM10	raster	µg/m³	10x10	Air quality	pm10_anmean		Open Air Quality data	https://explore.opena	Point Data
PM2,5	raster	µg/m³	10x10	Air quality	pm2,5_anmean		Open Air Quality data	https://explore.opena	Point Data
Population	raster	number p	10x10	general	population density map	interpolation of a population map on 1 km	GHS layer	https://human-settler	100m
Rainfall	raster	mm/year	10x10	Water retention	Average yearly rainfall		EURADCLIM	https://dataplatform.k	1km
Topography (relief)	raster	score	100x100	Recreation	landschapskenmerkenkaart van het Agentschap Onroerend erfgoed	score based on the % of the area with a higher topography (in Northern part of Belgium not much relief so an important parameter)	EU-DEM	https://ec.europa.eu/	30m
LUT topography - recreation	LUT	score	100x100	Recreation	custom LUT Belgium		N/A	N/A	N/A
Heritage	raster	score	100x100	Recreation	Heritage maps (historic landscapes, monuments)	score based on % of heritage in total area	OSM historic buildings etc	https://wiki.openstree	Point Data
Visual detrusion	raster	score	100x100	Recreation	Maps of locations of wind turbines and high voltage lines	score based on presence of wind turbines or high voltage electrity in proximity and buffering by high green	OSM wind & HVL	https://wiki.openstree	Point Data
noise map	raster	score	100x100	Recreation	Noise contour maps roads, railways and airports	score based on presence of noise contours	Noise data reported under Environmental Noise Directive (END)	https://www.eea.euro	vector map
pathdensity	raster	score	100x100	Recreation	Open street map	score based on the presence, number of paths. Higher if it belongs to a network/indicated trail...	OSM paths	https://wiki.openstree	vector map
soil texture	raster	category	10x10	Water infiltration	Belgian Soil map (not available in cities)	WRB, but often in cities no knowledge on soil types, often disturbed.	N/A	N/A	N/A

Figure 5: Overview input data NVE & mapping to EU wide open datasets.

2.1.2 Urban climate modelling

UrbClim is VITO's high-resolution urban boundary layer climate model, designed to simulate urban climates at a typical spatial resolution of 100 metres[4]. The model consists of a land surface scheme built on the soil–vegetation–atmosphere transfer framework by De Ridder and Schayes[5] coupled with a 3D atmospheric boundary layer module. UrbClim enables detailed analysis of Urban Heat Island (UHI) effects and air temperature distributions and has been applied to and validated in over 10 cities

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[4] De Ridder K, Lauwaet D, Maiheu B. UrbClim: A fast urban boundary layer climate model. Urban Climate. 2015;12:21-48.

[5] De Ridder K, Schayes G. The IAGL Land Surface Model. J Appl Meteorol. 1997;36:167–182.

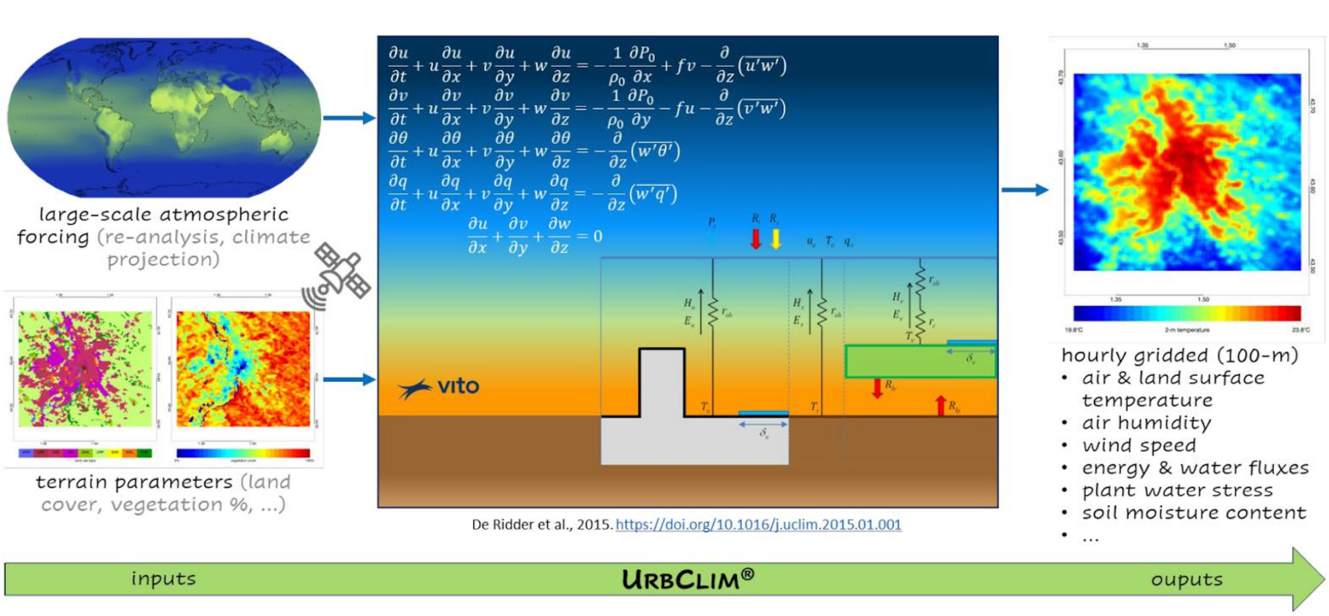

Figure 6: Schematic representation of the UrbClim model.

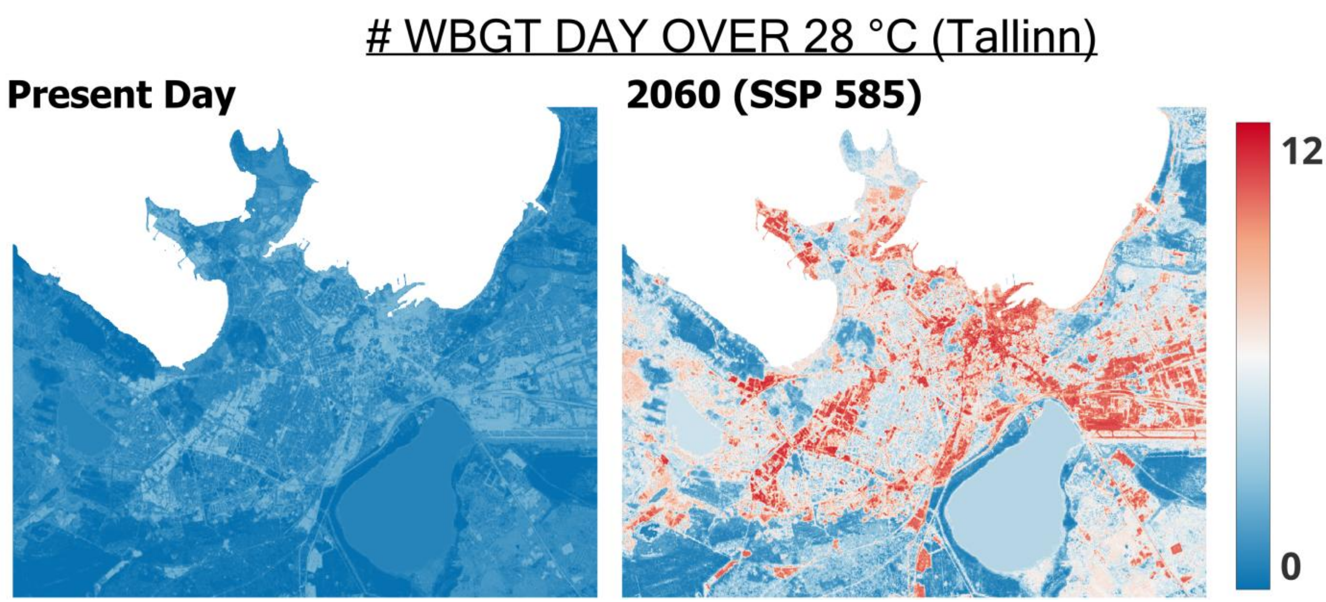

Figure 7: Example of a high-resolution WBGT map for the city of Tallinn, showing and comparing the mean number of days per year with WBGT above 28 °C for the present climate and for a future scenario in 2060.

UrbClim outputs provide valuable spatial data on urban air temperatures and the UHI effect, which are relatively stable over short distances. However, air temperature alone is insufficient to fully quantify heat stress. Factors such as radiation load (shortwave and longwave), humidity, and wind speed play a critical role in human thermal comfort. To address this, VITO has developed a methodology to calculate the Wet Bulb Globe Temperature (WBGT), a comprehensive heat stress indicator by combining UrbClim outputs with detailed radiation calculations using 3D data on buildings and vegetation[6]. This enables the computation of several heat stress indicators, such as - among others - the number of heatwave days, exceedances of health threshold values, heat-related mortality and lost working hours. These capabilities make UrbClim an ideal tool for heat stress analysis, offering clear and impactful results for identifying vulnerable urban areas. More information on the urban climate modelling can be found at https://climasys.vito.be/en.

A lot of input data have been processed and combined to initiate the modelling for all the URBREATH cities.

- 2D surface data (ERA5 data)
  - Surface pressure
  - Downwelling shortwave radiation
  - Downwelling longwave radiation
  - Precipitation
  - Geopotential
  - Sea surface temperature (if sea is present in model domain)
  - Soil moisture (ideally a vertical profile) (only for model initialization)
  - Soil temperature (ideally a vertical profile) (only for model initialization)
- 3D profiles (up to 3 km height, from ERA5 as well)
  - Air temperature
  - Humidity
  - U and V wind components
- Climate change projection (CMIP6):
  - Delta matrix for selected variables
- Land cover: defines a set of input parameters for each land cover class (albedo, emissivity, roughness length, stomatal resistance, root distribution)
- Vegetation cover fraction (monthly for seasonal change)
- Digital Elevation Model (terrain height)
- Soil sealing fraction
- Anthropogenic heat flux
- Soil texture

Within the URBREATH project, the Urbclim model is applied to model the urban climate for the URBREATH cities. The urban climate has been modelled in high resolution for all the cities for both the current as well as the future climate. The modelling provides information on a variety of parameters

[6] Lauwaet D, Maiheu B, De Ridder K, Boënne W, Hooyberghs H, Demuzere M, Verdonck ML. A new method to assess fine-scale outdoor thermal comfort for urban agglomerations. Climate. 2020;8(1):6. doi:10.3390/cli8010006.

including air temperature, wind speed, humidity and radiation load to generate advanced relevant indicators. The following indicators are available to analyse the local situation.

- Mean daily Temperature and Average yearly 2m air temperature)
- Daily Mean Max/Min temperature and Average daily max/min temps
- UHI_day / UHI_night (Urban Heat Island intensities)
- Days above 25°C / 30°C / 35°C (Frequency of hot days)
- Nights above 20°C / 25°C / 28°C (Frequency of tropical nights)
- Heatwave Days (Days exceeding 90th percentile of temperature for ≥3 days)
- Heat Wave Magnitude Index (HWMI), quantifies severity & duration of heatwaves
- Mean Temperature of Warmest Month
- Mean Temperature of Coldest Month
- Cooling Degree Hours (Hours above 25°C, weighted by intensity)
- Wet bulb globe temperature (WBGT)
  - WBGT_dayover25/28/29.5/31: Days with WBGT above thresholds
  - WBGT_nightover25/28: Nights with high heat stress
  - WBGT_hourover25/28/29.5/31: Cumulative hours of heat exposure
  - WBGT_JJA / WBGT_DJF: Summer vs. Winter WBGT averages

These indicators offer options to assess general climate and UHI effects in urban areas, identify temperature extremes and heat risk (temporal and spatial analysis), characterize thermal seasonality & energy demand (AC use), assess outdoor thermal comfort and health stress.
The indicators can be combined with population data and health data to analyse the heat stress impacts.

2.1.3 3+30+300

The Nature based solutions institute (https://nbsi.eu/) has introduced the 3+30+300 rule a few years ago as a concept for developing urban forests and creating greener and healthier cities. The rule states that all residents should be able to see 3 large trees from their home, live in a neighbourhood with at least 30% tree canopy (or vegetation) cover, and be no more than 300 metres from the nearest public green space that allows for multiple recreational activities. Konijnendijk published a paper presenting this approach and the scientific basis[7].

In the urban paragraph of the deal on the EU Nature Restoration Law, it reads that member states shall achieve an increasing trend in the total national area of urban green space till a satisfactory level is reached. Green standards can help to define this satisfactory level. The 3+30+300 rule is one of these

[7] Konijnendijk, C.C. Evidence-based guidelines for greener, healthier, more resilient neighbourhoods: Introducing the 3–30–300 rule. J. For. Res. 34, 821–830 (2023). https://doi.org/10.1007/s11676-022-01523-z

standards. The 3+30+300 rule emerges as a transformative concept, emphasizing the essential role of green spaces in human lives, particularly for mental well-being. Moving forward, it is crucial to consider not only the quantity but also the quality and use of green spaces to maximize their benefits[8].

Currently many cities and regions look at implementing this rule as new indicator or standard for urban green, such as Flanders[9]. Therefore, the indicators have been calculated for all URBREATH cities. Several versions have been finalized in 2025. A first version includes only trees as a strict interpretation of the concept. Based on the discussions with the cities, versions including contributions from low vegetation have been provided as well.
To provide data for all cities, the maps have been generated starting from EU generic data. Integration of local data is achieved through coupling with VC planner (API based communication).

The '3' indicator refers to at least 3 visible trees. This indicator has been implemented using a viewshed analysis starting from a digital terrain model, digital surface model and tree canopy layer. Based on discussions with the cities, the indicator has been updated by integrating low vegetation as well. Low vegetation receives half the weight of trees. The indicator quantifies the proportion of visible green elements from any given point, capturing the visual experience of greenery from residential locations. The construction of the indicator ensures that it can be broader applied than the check on a minimum of 3 visible trees.

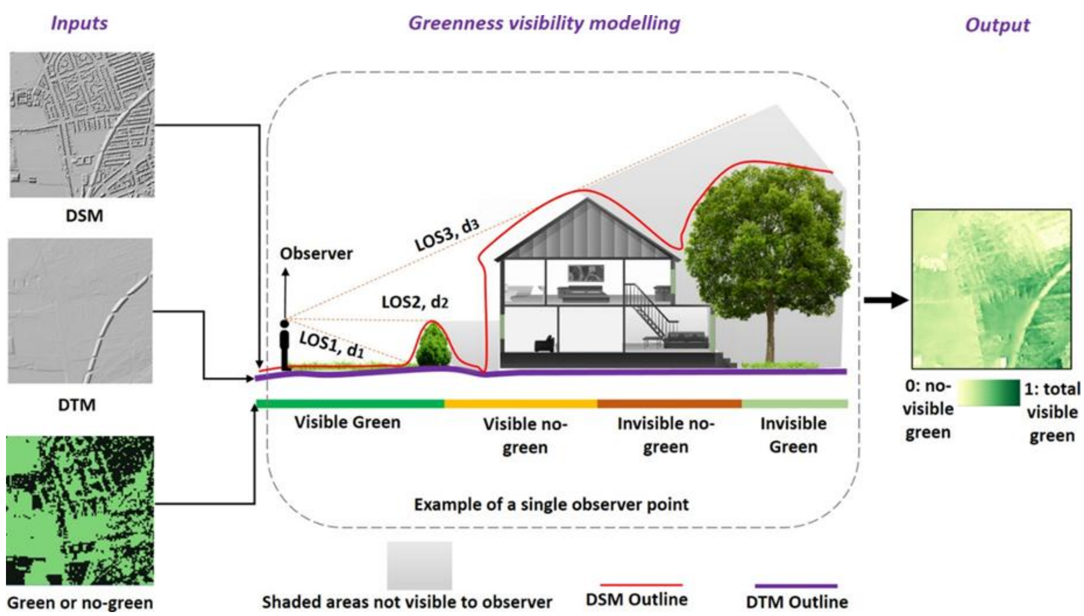

Figure 8: Schematic overview of the Greenness Visibility Index (reproduced from Labib et al., 2021).

8 https://platformurbangreening.eu/inspiration/beyond-concrete-the-transformative-impact-of-the-3-30-300-rule-on-urban-living/

9 https://www.natuurenbos.be/groennormen

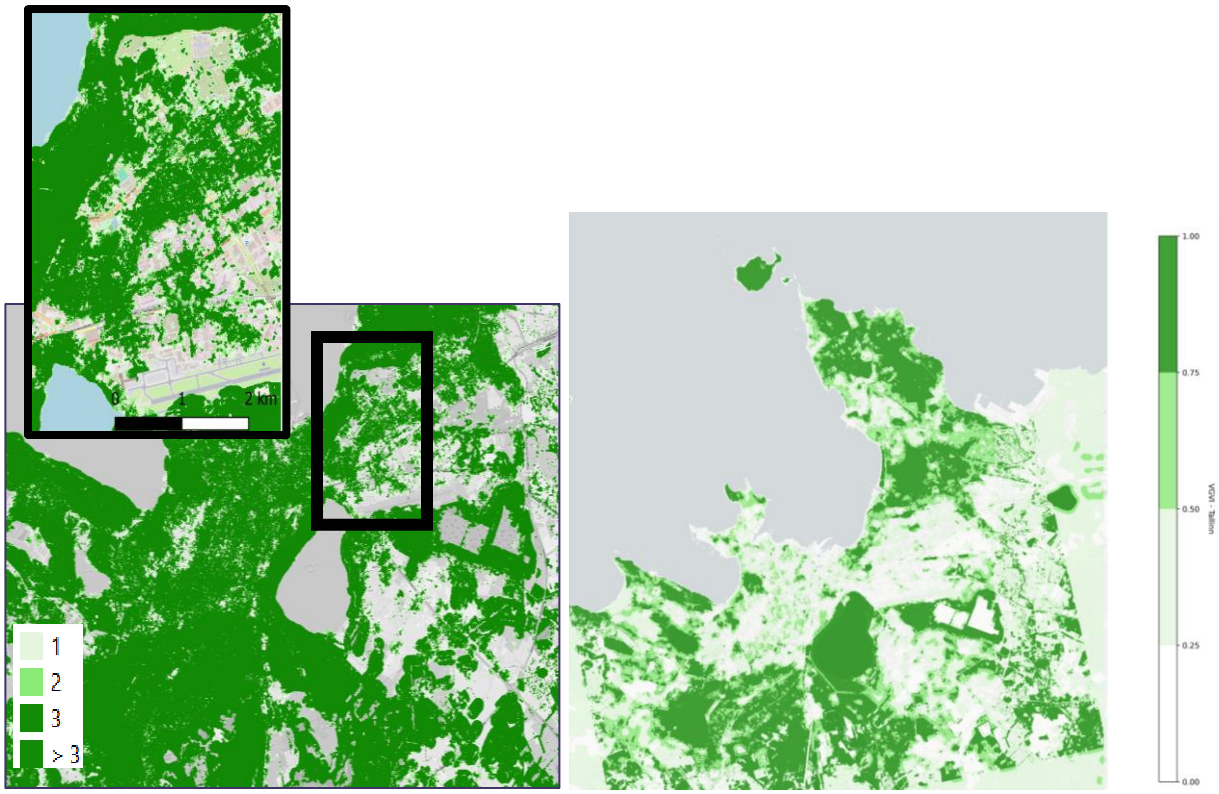

Figure 9: Examples of the check on 3 visible trees (left) and the Greenness Visibility Index for Tallinn.

Secondly, an evaluation of 30% tree cover at neighbourhood level is made. This indicator can be calculated for all cities starting from Copernicus Tree Cover density data. For this indicator, a version including contributions from low vegetation at half the weight of trees has been made and lastly a version including contributions from low vegetation and water as well. Both low vegetation and water add to a more climate adaptative and natural environment. An important parameter in this analysis is the definition of 'neighbourhood'. Different buffer radius distances have been used 200 m, 300 m and 500 m.

Figure 10: Comparison of the '30' indicator for Leuven using 10 m resolution EU generic data and trees only (left) with a version using 1 m resolution data and combining trees and low vegetation.

Lastly, the 300 indicator evaluates the accessibility of green within a 300 m (walking) distance. This indicator can be calculated for all EU cities using OpenStreetMap data for the road network and all green areas. A minimum of 0.5 ha is used for the green areas.

The criteria and choices for the indicators have been evaluated with the cities, and several versions have been provided as the choices can differ based on the context.

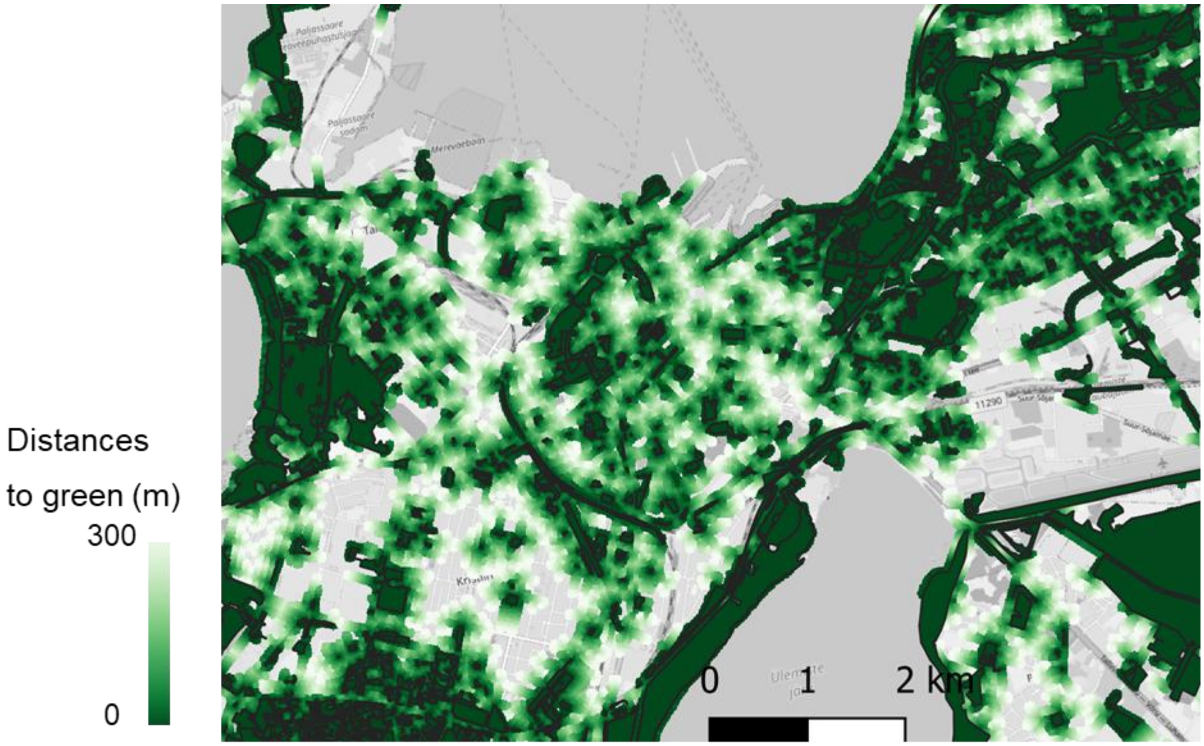

Figure 11: 300 indicator for Tallinn showing access to green areas within a 300 m distance along the road network.

The resulting indicators have been integrated into the LDT as layers that can be visualised. The API is presently in development and is expected to be available at the start of 2026. Following its release, integration into the LDT environment will take place, which will facilitate scenario analysis and the exploration of What-If scenarios using local data.

Figure 12: Visualisation of the 3-30-300 results in the LDT for the case area in Leuven (Krakauplein).

2.1.4 Biotope Area Factor (BAF)

The Biotope Area Factor (BAF)[10] is a tool used to measure the absorbent properties of a surface. It has been initiated by Berlin and other cities in and outside the EU. The concepts of the BAF have been clearly described for the application in an urban context by the urban development department of Berlin[11] and its application in Canada:

"*To calculate this BAF indicator, one need only determine the relationship between the ecologically effective surface area and the total surface area of a lot. Over the last three decades, this factor has been incorporated into the urban planning practices of several cities so that under-used spaces such as walls and roofs can be better integrated into greening policies. The BAF is particularly valued because it offers a flexible approach to reconciling densification and greening policies. Given the problem of heat islands, which affect the health of the most vulnerable, this innovative measure provides a way to improve air quality and increase access to cooler spaces in the city. With regard to the built environment, it helps solve the problem of urban flooding by lowering the degree of soil sealing*." (reproduced from departement of Berlin's website[15]).

[10] https://ugl.sg/wp-content/uploads/2021/01/20191002_biotope_area_factor.pdf

[11] https://www.berlin.de/sen/uvk/natur-und-gruen/landschaftsplanung/bff-biotopflaechenfaktor/

The calculation can be performed in different cities using essentially the same formula:

$$BAF = \sum_{i=1}^{N} \frac{active\ surface_i \times value\ factor_i}{Total\ surface}$$

In the formula, the summation is made of each area of active surface, weighted with a value resembling its ecological value, over the total area of the site of interest.

The example below demonstrates the flexibility of the model. In this calculation, the individual parts of a plot of land are weighted according to their “ecological value”.

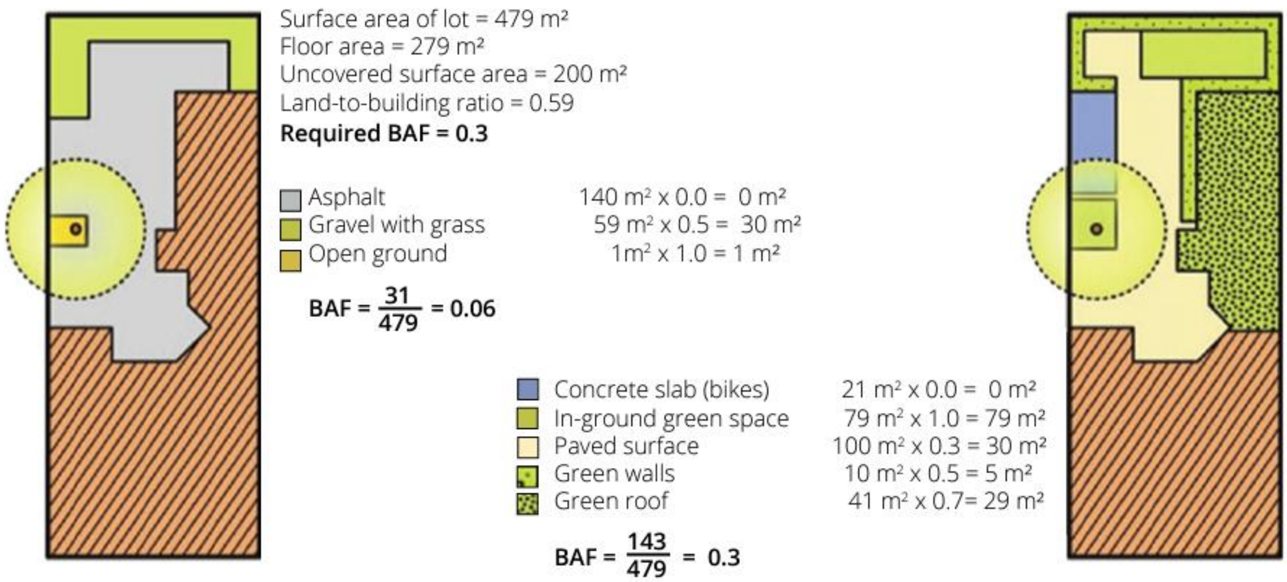

Figure 13: Example of the application of BAF, reproduced from *Co-designing the active city – participatoryplanning.ca*[10].

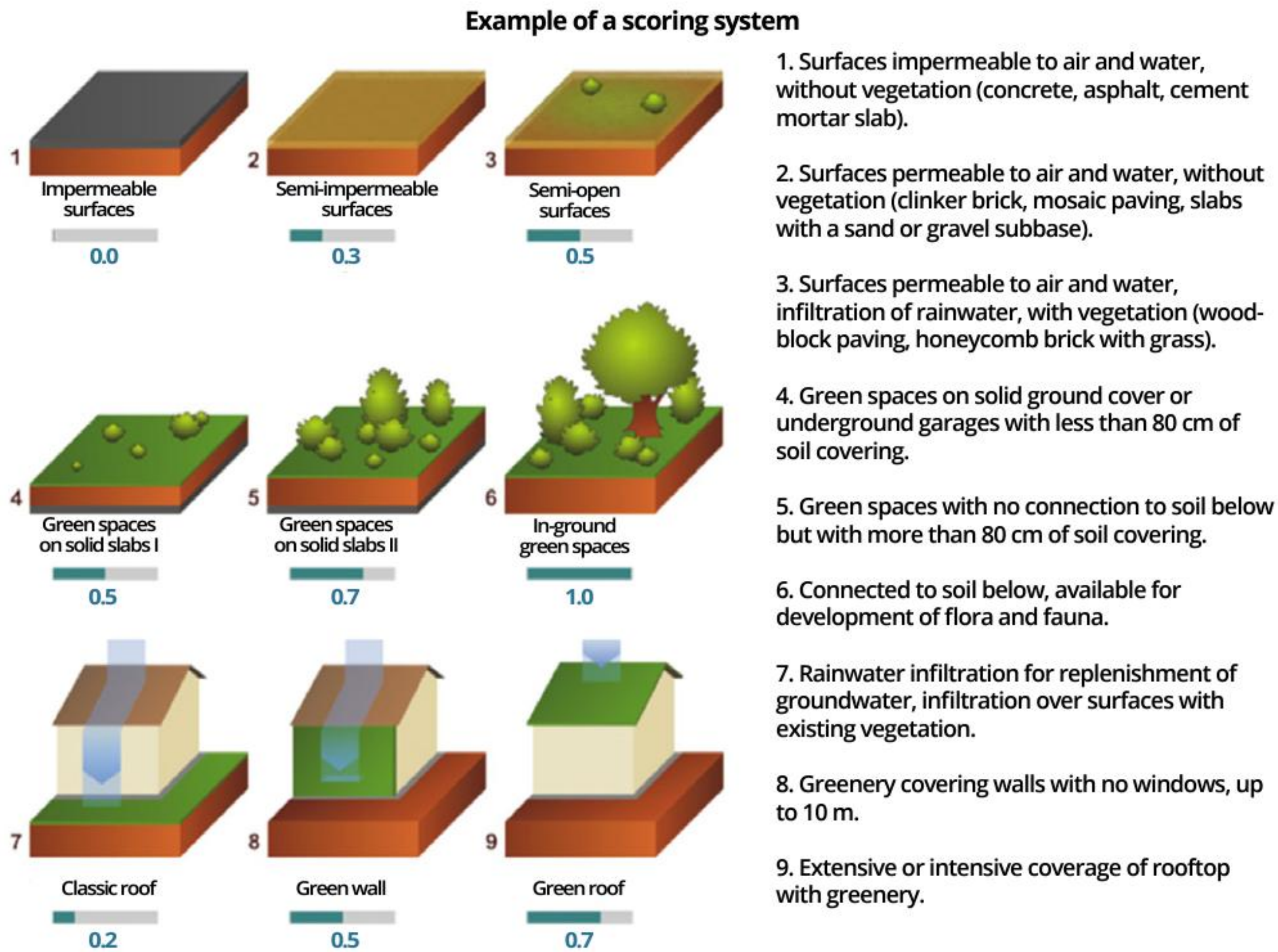

Figure 14: Overview of the BAF scoring system, reproduced from *Co-designing the active city – participatoryplanning.ca*[10].

2.1.5 Air quality modelling

Several air quality (AQ) models can be applied to assess or forecast air pollution levels in EU cities. To respond to the air quality interests of the URBREATH cities, we plan to build on existing AQ models and applications.

As part of the proof-of-concept digital twin solutions offered by the Horizon project DUET[12], air quality models have been integrated into a digital twin architecture. URBREATH will build on this previous integration to make steps towards a more robust model coupling and integration with other models to evaluate the impact of NBSs. VITO integrated the FASTRACE traffic emission model and the QUARK air

[12] https://www.digitalurbantwins.com/

quality model to evaluate mobility choices for air quality impact. The models have been described by Degraeuwe et al.[13] and applied to build stand-alone tools to evaluate road traffic contributions to NO_2 (nitrogen dioxide) concentration in Europe. This application[14] can also be applied for a first screening of the air quality situation in the URBREATH cities and check the contribution of different sectors including road transport and NFR (Nomenclature for reporting) sectors. The figure below shows an overview for Cluj-Napoca.

The QUARK and FASTRACE models can be coupled to a digital twin architecture. An overview of the current model coupling is given in the figure below. The next step is a more robust model coupling avoiding direct links but have a full integration of each component. More insides in the models and existing applications are available on https://atmosys.vito.be/en.

VITO's QUARK model (Quick Urban AiR quality using Kernels) is a kernel-based model derived from a Gaussian plume model[15]. A kernel is the annual average pollutant concentration around a road segment. Such kernels can be calculated for different orientations of the road (from North-South to East-West in steps of for example 15°) and for meteorological conditions across the EU. A database of these kernels can be used to quickly model local traffic contributions to air pollution levels. Similarly, it can be applied for other sectors.

[13] Degraeuwe B. et al., A source apportionment and air quality planning methodology for NO2 pollution from traffic and other sources, Environmental Modelling & Software, 176 (2024), 106032, https://doi.org/10.1016/j.envsoft.2024.106032

[14] https://no2sourceapportionment.concawe.eu/

[15] Lefebvre W. et al. Modeling the effects of a speed limit reduction on traffic-related elemental carbon (EC) concentrations and population exposure to EC, Atmospheric Environment, 45/1 (2011), 197-207, https://doi.org/10.1016/j.atmosenv.2010.09.026

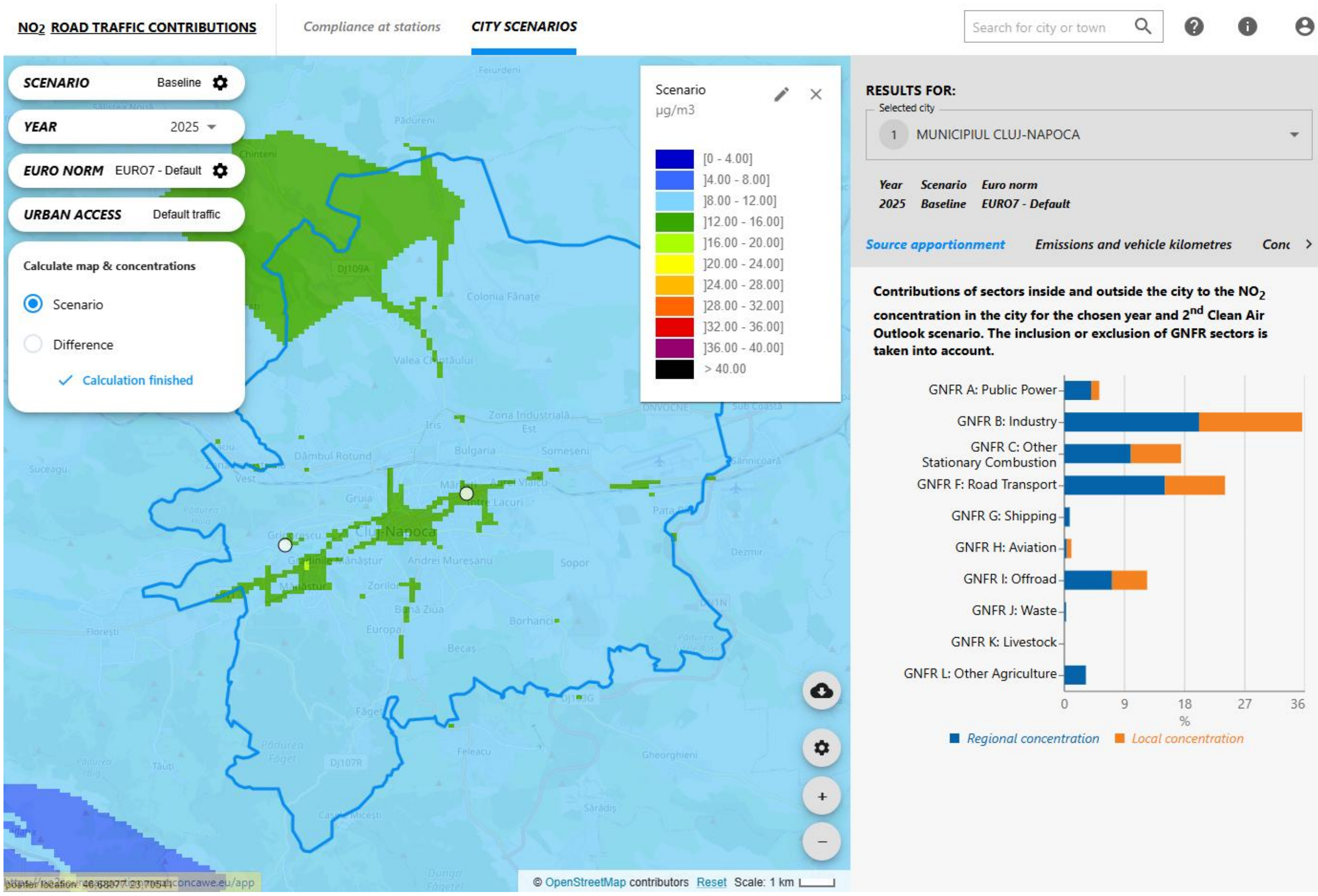

Figure 15: Analysis of air quality situation for Cluj-Napoca using using NO_2 source apportionment viewer yielding insights per sector and split between local and regional contributions.

FASTRACE (Hooyberghs et al., 2022)[16] is a software tool developed by VITO to calculate spatially disaggregated emissions from road transport, starting from country specific vehicle fleet data, COPERT emission factors (Ntziachristos et al., 2020)[17] and traffic intensities at the street level. FASTRACE calculates the emission per vehicle type and per road segment.

[16] Hooyberghs H. et al., Validation and optimization of the ATMO-Street air quality model chain by means of a large-scale citizen-science dataset, Atmospheric Environment, 272 (2022), 118946, https://doi.org/10.1016/j.atmosenv.2022.118946.

[17] Ntziachristos, L., and Z. Samaras. "EMEP/EEA air pollutant emission inventory guidebook 2019: 1. A. 3. bi-iv road transport 2019." Luxembourg: European Environment Agency (2019).

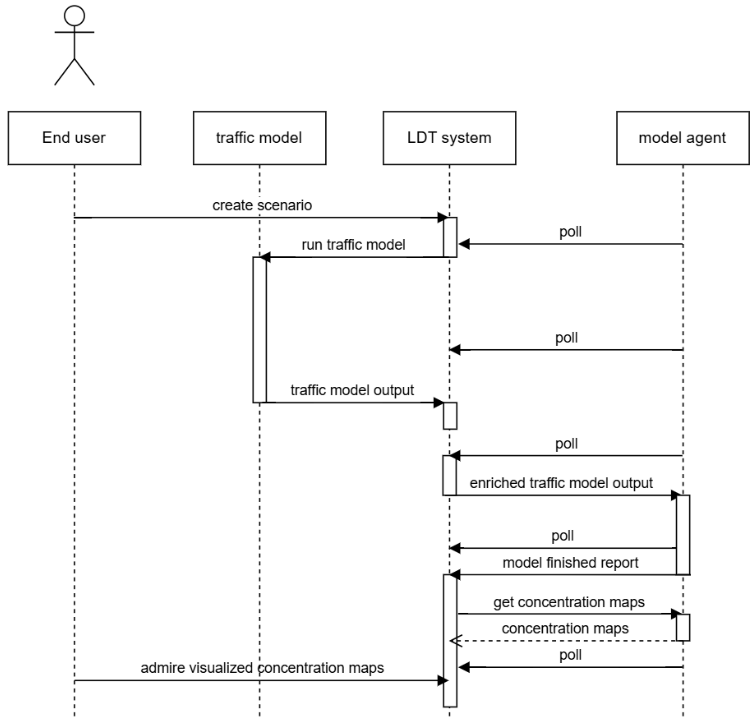

Figure 16: Schematic overview of air quality model integration in LDT flow scheme.

2.1.6 Impact of NBS on Heat Stress

Heat stress mitigation is one of the key expected benefits of Nature-Based Solutions (NBS). To assess these effects at local scale, a high-resolution, intervention-specific modelling approach is applied to evaluate how planned NBS scenarios influence Land Surface Temperature (LST). This modelling framework simulates how modifications to the urban environment (such as adding trees or installing cool roofs) change surface thermal behaviour.

The method uses a GeoJSON masterplan describing the proposed interventions and generates synthetic satellite imagery that represents the projected post-intervention state of the area. From this synthetic representation, LST and other derived environmental variables are recomputed, enabling a quantitative assessment of the expected heat-mitigation effects of different scenarios.

2.1.6.1 Methodology

The methodology follows a sequence of steps that translate planned NBS interventions into projected thermal outcomes. First, the proposed modifications to the urban environment—such as tree planting, the creation of green corridors, shading structures, cool roofs, or new vegetation patches—are encoded in a GeoJSON masterplan. This spatial representation forms the basis for generating a synthetic depiction of the future landscape. Using a dedicated simulation engine, synthetic post-intervention satellite imagery is produced, reflecting how the area would appear once the planned interventions are in place.

From this synthetic imagery, a set of environmental variables is recalculated to capture expected changes in surface and vegetation characteristics. These include Land Surface Temperature (LST), vegetation indices such as NDVI (Normalized Difference Vegetation Index, a measure to derive vegetation information from satellite images), variations in imperviousness and surface albedo, and the presence of shadows or canopy-driven cooling effects. By comparing these recalculated layers with the corresponding baseline conditions, the approach enables a quantitative assessment of several heat-related outcomes. These include local reductions in surface temperature, the spatial extent and distribution of cooling effects, potential synergies between combined interventions (for example, trees and cool roofs), and the identification of zones where NBS measures generate the greatest impact.

2.1.6.2 Use Case Alignment

This modelling approach aligns closely with several needs identified in the URBREATH use cases. It supports cities in examining how specific urban design choices influence local heat stress, offering a means to assess the thermal implications of alternative layouts and configurations of NBS within relatively small or targeted intervention areas. The high spatial resolution of the outputs provides the level of detail required in planning processes that rely on precise, evidence-based microclimate information. In doing so, the model also contributes to the comparative evaluation and scoring of different NBS strategies, enabling cities to prioritise those interventions that offer the strongest potential for improving climate resilience and mitigating heat-related risks.

2.2 Current Development Status and next steps

For each of the numerical models the next steps are described in the table below.

Table 1: Overview of selected numerical models and their respective status of use in the project and planned next steps.

Tool	Status	Next Steps
Nature Value Explorer	The approach to evaluate ecosystem services of NBSs is fully developed and applied in a stand-alone application for Belgium. To enable EU wide use, components of NVE are offered as stand-alone components integrated in the URBREATH toolbox using APIs. 3-30-300 and BAF can be seen as first examples.	• Develop next components linking to the interest of the cities: carbon sequestration in soil, infiltration, wood provision • Integrate the APIs
Urban climate modelling	VITO has modelled the urban climate for all cities for both the current as well as the future climate.	• Options to link with population and health data

Air quality modelling	On-hold as none of the cities has interest to look into air quality modelling in the URBREATH project.	• On hold
3+30+300	Several versions of the indicators have been developed and are provided to the cities using generic EU data. Calculation using local (user) data is being finalized trough coupling with VC planner.	• Finalize integration as re-usable model into LDT (API development)
Biotope Area Factor	Well known concept that can easily be applied for back-of-the-envelope calculations, integrated in VC Planner	• Offer in LDT toolbox besides VC Planner
Impact of NBS on Heat Stress	Several cities have expressed interest in applying this modelling approach, and discussions are ongoing to run tailored simulations for their specific intervention areas.	• Integrate the APIs

Of the selected numerical models, we do not foresee an integration of the urban climate model. This proofs too complex given the model complexity and computational demands.

Additionally, Oto the next steps for the numerical models, increased usability of the model results using agentic AI will be explored in 2026.

3 Data Needs and Data Analysis

3.1 Data requirements and analysis for Nature Value Explorer

The following data are needed to set up Nature Value Explorer for an urban environment. The tool relies on raster data at a sufficiently high-resolution to differentiate in an urban context. The concept can work with any resolution, but the quality of the analysis improves with availability of higher resolution data. The current version used in Flanders relies mainly on 10x10 m^2 raster data. Processing of data from other data formats can be included.

The following maps are the strict minimum to configure the tool.

- Land use map
- Vegetation map / Urban green inventory
- Air quality maps: annual average particulate matter concentrations (PM_{10} and $PM_{2.5}$)
- Population density map / number of inhabitants
- Annual average rainfall data

Possibly soil texture information can be added, but due to soil disturbance often less relevant in an urban context.

Additional data requirements need to be addressed if we want to value the impact of NBSs on recreation.

- Presence of heritage or cultural / historical landscapes
- Visual pollution
    - Presence of wind turbines or high-voltage network lines
    - Analysis of buffering of visual pollution by trees (can be added on demand)
- Noise levels
- Trail network and trail density
    - This is based on open street maps but can be refined with local data if available

For each dataset, an EU generic dataset or remote sensing database is proposed if local data proof to be unavailable or not suited.

3.2 Data requirements Urban Climate modelling

To operate UrbClim, the following meteorological and terrain datasets are applied:

- ERA5 Reanalysis Data: Provides meteorological inputs for conducting historical reference simulations, typically a recent 10-year period, allowing for statistically robust heat stress indicator maps.

- Future climate projections: usually coming from IPCC global climate model ensembles under different SSP scenarios, provided in collaboration with URBREATH Task 3.2 Climate Modelling and Assessment of vulnerability to climate change
- Imperviousness and Building Height: from local sources or Copernicus datasets
- Land Cover Data: from local sources or Copernicus datasets
- Monthly Vegetation Cover: Sentinel-2 data or other local datasets
- GLO-30 Copernicus Digital Elevation Model: A global DEM with a 30-metre resolution is included to account for terrain effects

The urban climate modelling has been initiated with these datasets.

3.3 Data requirements Air quality modelling

The scheme below shows the overview of the data and models used to create high resolution maps for the region of Flanders. This combines the impact of local emissions from traffic, other local emissions such as industry, emissions outside the modelling domain via the background concentrations, meteorology and the local built environment.

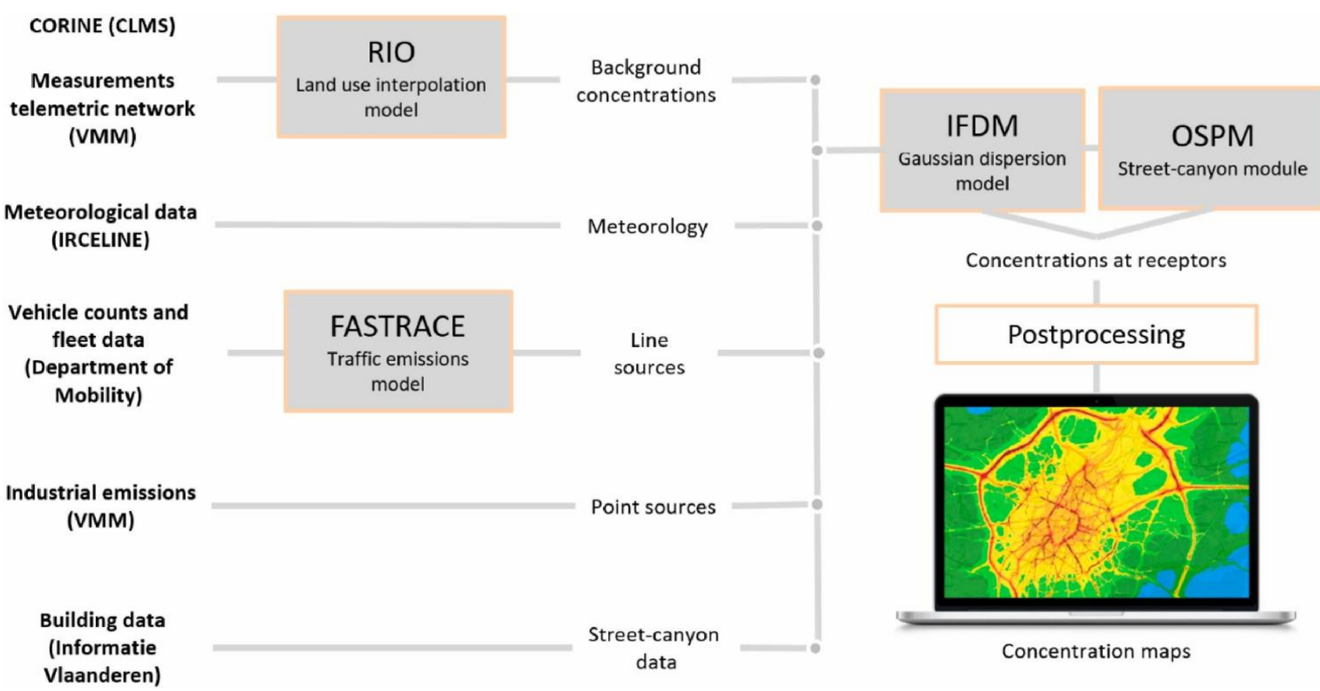

Figure 17: Flow chart of the ATMO-Street model chain used to create high-resolution air quality maps for the Flemish region (reproduced from Hooyberghs et al.)[18]

[18] Hooyberghs H., De Craemer S., Lefebvre W., Vranckx S., Maiheu B., Trimpeneers E., Vanpoucke C., Janssen S., Meysman F., Fierens F., 2022, Atmospheric Environment 272, 118946

- Background concentrations can be provided from a local model (such as the RIO model applied in Belgium) or CAMS reanalysis map for the EU provided by ECMWF.[19]
- Meteorology can be provided by a local meteo provider providing assimilated meteo model data or meteo measurements or ERA5 reanalysis meteo.
- To evaluate the impact of road traffic and road traffic scenarios, traffic intensities on the road network are needed as either annual totals or peak hour traffic intensities. EU generic data can only give a rough first estimate. EU Traffic Data Mapper is given such EU wide estimates (Degraeuwe et al. 2024)[13]. Local mobility data can further refine the air pollution maps.
- Fleet data are combined with traffic intensities to calculate traffic emissions. COPERT provides for the EU27 detailed vehicle fleet data as well as necessary emission factors[20].
- To include the local impact of the built environment, a street canyon module like OSPM can be applied[21]. It relies of the combination of the traffic network and building data to process the necessary parameters to describe street canyons. Deliverable 4.1 includes the full overview of all the available data to describe and visualize the buildings in all URBREATH cities and the available level of detail (LOD1/2/3).

3.4 Data requirements 3+30+300

The 3+30+300 evaluation scheme requests the calculation and aggregation of the 3 underlying indicators. For each indicator necessary input data need to be provided.

- To calculate indicator '3' at least a dataset with all trees in a city is needed. Either point locations of trees in an inventory or remote sensing data providing an overview of trees or tree crowns can be applied. A first estimate can be made by directly calculating the number of trees in a buffer area. A more refined analysis applies a viewshed analysis considering the presence of buildings and other objects. This can be achieved considering a Digital Terrain Model (DTM) containing the terrain elevation and a digital surface model (DSM) providing surface heights including natural and built features. The following datasets are requested.
    - A map indicating the location of trees (vegetated) areas
    - A Digital Terrain Model (DTM)
    - A Digital Surface Model (DSM)
- To calculate indicator '30' a 30% tree canopy cover needs to be evaluated. This requests a tree canopy map. The same data as for indicator '3' can be applied.

[19] https://ads.atmosphere.copernicus.eu/datasets/cams-europe-air-quality-reanalyses?tab=overview

[20] https://copert.emisia.com/

[21] https://envs.au.dk/en/research-areas/air-pollution-emissions-and-effects/the-monitoring-program/air-pollution-models/ospm/description-of-the-ospm-model

- To calculate indicator '300' an overview of publicly accessible green needs to be available. Either this is available, or an accessibility analysis can be made using for example the OpenStreetMap network. Using such a network, the distance to public green can be calculated as distance over the network.
    - Public green space
    - Road network including soft mobility, either OpenStreetMap or other local data.

3.5 Data requirements Biotope Area factor

The biotope area factor aims to inform users on the permeability and absorbent properties of a current or future plan for an urban domain. These calculations rely on the availability of sufficiently high-resolution land cover and land use information datasets as a starting point. Users either need to upload this information themselves, or this can be provided for a city or region.

The necessary land use and land cover information is identical to Nature Value Explorer. Typically, these 2D datasets don't inform on greening at building level such as type of green roof or vertical greenery. Users should refine the information starting from an available overview from public datasets.

3.6 Data requirements for Impact of NBS on heat stress

The data requirements for this modelling approach are centred on accurately representing both the existing urban environment and the planned interventions. A key input is a GeoJSON masterplan that specifies the locations, geometries, and types of NBS measures to be assessed, such as new tree plantings, vegetated areas, and cool roofs. This information is essential for generating a realistic depiction of the post-intervention landscape. In addition, baseline spatial datasets (such as recent satellite imagery, land cover information, vegetation layers, and surface characteristics) are needed to ensure that the synthetic imagery and the recalculated environmental variables reflect local conditions. Together, these datasets allow the model to quantify the expected thermal effects of the proposed interventions by comparing the simulated scenario against the existing baseline.

4 Conclusions

This deliverable outlines the progress made in the selection and configuration of numerical models to evaluate the impact of Nature-Based Solutions (NBS) on the urban environment and local ecosystem services including heat stress, air quality, water retention and infiltration, recreation and ecological impact. The initial phase of the project included the matching of available tools and models to the requirements of the cities and has been largely completed in 2024. For each selected model and tool, an overview of necessary input data was documented starting from mostly available EU wide generic data and further refined with local data.

In the second year of the project, the urban climate modelling and the work on the greenness indicators has largely been completed and the resulting data are available for use. The integration of APIs to calculate the 3-30-300 indicators using local / scenario data is on-going. Next components of the Nature Value Explorer are identified to be developed as robust standalone components that will be added to the URBREATH toolbox.

In parallel with advancing the numerical models for Nature-Based Solutions, we aim to improve usability and expanding the adoption of the results among practitioners. During 2026, VITO's team see initial experimentation with agentic AI to support a broader and more intuitive uptake of modelling tools and outputs. This exploratory work aims to allow users to interact with complex models through natural-language or task-oriented prompts, thereby reducing technical barriers and improving operational accessibility. As a first milestone in this direction, WP3 will work toward enabling AI-assisted geospatial data processing, allowing an AI agent to guide users through dataset preparation, spatial analysis steps, and model configuration workflows. This will set the foundation for more advanced forms of AI-supported modelling in future iterations.
Overall, special focus will be given on integration, visualization, and deployment, during future phases of the project. This will ensure the models are accessible, practical, and relevant to urban planning and decision-making processes.

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