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D3.4 – REPORT ON THE CLIMATE RESILIENCE ASSESSMENT METHODOLOGY AND CLIMATIC TREND ANALYSIS

Organisation name of lead contractor for this deliverable: TECNALIA		
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5	07/02/2019	TEC, NBK	Second version of the deliverable
6	11/02/2019	CER	Revision of the second draft
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8	27/02/2019	NBK	Revision of the consolidated version
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Executive Summary

Task 3.4 aims to bring closer urban climate resilience assessment to the municipalities. This task was born from the need of helping the municipalities in the decision making processes related to NBS implementation. A lot of options arise in this kind of assessments and depending on the interest of the cities, different tools and methods could provide a certain answer to city needs. Decision support guideline for climate resilience cities and NBS created in task 3.4 helps the municipalities in this selection through the completion of a questionnaire. The questionnaire contains simplified questions related, for example, to the kind of strategies that they want to implement and/or the budget that they have. As a result, the municipalities obtain a selection of methods and tools that cover their interests together with a description of each of them. Therefore, recommendations about the most suitable tools are provided and municipalities can take more informed decisions.

The guidelines are going to be implemented in Nature4Cities platform and municipalities will be able to make the assessment for free. Thanks to this, existing tools and methods to assist the urban re-naturing design process in the field of climate resilience is facilitated and, together with it, the consideration of nature based solutions as part of sustainable urban planning is supported.

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1 Introduction

1.1 Purpose

The main objective of the task has been to address the impact of climate change at the urban level and assess the benefits of the NBS to improve climate resilience of the cities.

The following objectives have been pursued:

- To adapt to N4C the urban climate change assessment methodology in order to understand how the NBS can improve the climate resilience of the cities
- To develop an integrated method between climate change assessment method and urban metabolism approach
- To validate the approach by applying it in a well-known case study.
- To define assessment scenarios and to assess them in the case studies
- To bring closer the urban climate change assessment and NBS effectiveness to the municipalities.
- To integrate the outcomes into N4C platform

The main result of the task is a guideline to support the municipalities in understanding existing methods and tools that address:

1) the impact of climate change at urban level
2) adaptation and mitigation strategies
3) NBS benefits to improve climate resilience of cities

The guideline will be implemented in N4C platform and municipalities will be able to use it to select the most suitable methods according to their specific needs.

1.2 Contribution of partners

To help the organization and development of the task, 4 main subtasks have been defined:

3.4.1 Analysis of the existing methods for climate change models
3.4.2 Establishment of the climate change assessment methodology
3.4.3 Evaluation of the scenarios
3.4.4 Integration of methodologies in N4C platform

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Following these subtasks, table 1 summarizes the main contributions made by partners involved in the task:

- CER: Cerema
- EKO: Ekodenge
- NBK: Nobatek
- RINA
- SZTE: University of Szeged
- TEC: Tecnalia Research & Innovation

Table 1: Contributions made by partners

Partner	3.4.1	3.4.2	3.4.3	3.4.4	Report
CER					First and second version revision
EKO	19 articles, 8 projects and 6 tools review and analysis	RACER of 6 tools, Y/N matrix of 3 tools and 6 forms development, Guidelines validation	Alcalá de Henares case study development	Contributions to the guideline	Chapter 5.2 development, first and second version revision
NBK		RACER of 9 tools (together with RINA), Y/N matrix of 7 tools and 5 forms development, Guidelines validation	NEST real case study in Donosti	Contributions to the guideline	Chapter 5.1.6 development Consolidated version revision
RINA	20 articles, 7 projects and 8 tools review and analysis	Helped NBK with the RACER, and the Y/N matrix of 15 tools and 4 forms development, Guidelines validation	Szeged case study development	Contributions to the guideline	Chapter 5.3 development
SZTE			Contributions and review of Szeged case study	Contributions to the guideline	Chapter 5.3 contributions and review
TEC	20 articles, 12 projects and 17 tools review and analysis	Methodology development RACER of 15 tools, Y/N matrix of 15 tools and 8 forms development, Guidelines validation	HAVURI, CityCAT, EnviMET and ENERKAD real case study in Donosti. Integration	Guideline structure development	Deliverable 3.4 development
	Coordination between partners				

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1.3 Structure of the deliverable

Deliverable 3.4 has been structured according to the main result obtained in the task. Therefore, all the chapters aim to present developed guideline to support the municipalities in decision making process. The chapters go through all the steps given from the begging of the task and until the final result validation.

After presenting the relationship with other tasks of the project, chapters related to task developments go from chapter 3 to chapter 6. Chapter 3 explains the procedure followed for the guideline construction. This procedure goes from a state of the art revision of scientific articles, projects and tools in the field of climate resilience and ends with the main result validation. In between, a RACER assessment has been made to classify the information collected during the state of the art revision.

Before developing the guidelines, some intermediate results have been obtained. These results are explained in chapter 4 and are the basis over the guideline has been built. Therefore, the state of the art revision had as a result the climate resilience information update. With this information, the methodology to be implemented in the guidelines has been defined. The different methods and tools that exist to support developed methodology has been classify according to the RACER assessment explained in chapter 3.

Chapter 5 explain the main result of the task: decision support guideline for climate resilience and NBS. The guideline has 3 main parts, (1) a questionnaire that collects the interest of the cities in the field that applies. This is the data entry of the guideline and connects the repository with the municipality interests. (2) A Yes/No matrix that connects the questionnaire with the results. This represents the engine of the guideline and has been created according to the information analyse during the state of the art revision. (3) A collection of forms that include information about the methods and tools that are suggested as a result of the guideline application.

Chapter 6 explains how the guidelines have been validated through the performance of 3 case studies. Some conclusions are given in chapter 7.

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2 Relation with other tasks of the project

2.1 WP2. NBS Urban performance assessment

Nature4Cities WP2 aims to create an “expert modelling toolbox” to address performance indicators that could provide a detailed assessment of both urban challenges and nature based solutions. With this purpose in mind, task 2.1 has defined urban performance indicators interesting for the assessment of NBS projects. Among others, these indicators include the climate and the energy point of view.

After the definition of the urban indicators in task 2.1, Task 2.2 has compiled an expert modelling toolbox. Moreover, an evaluation and a benchmarking of the models and methods that allow assessing previously identified indicators has been done in task 2.2. WP2 indicators, models and methods related to climate resilience assessment has been considered in the context of task 3.4. In a summarized way, the common parts are:

Table 2: Relationship between WP2 and T.3.4

Common parts	Consideration in WP2	Consideration in Task 3.4
Climate mitigation **Climate adaptation**	Urban sub-challenge	Climate strategies considered
Flood	Urban sub-challenge flood management	Climate threat/impact considered as part of the methodology
Envi-MET **GreenPass** **RayMan** **i-Tree Eco** **SOLWEIG** **TEB**	Tools analysed for the Toolbox	Tools included in the guideline

Some information collected in task 2.2 was useful to develop the tools forms presented later in this deliverable. However, as the objective of the studies are different, in task 3.4 it was necessary to go in deep to understand further to which extent these tools allow assessing climate resilience of cities and NBS effectiveness over them.

2.2 T.3.1. Urban metabolism

The urban metabolism models developed under T3.1 of Nature4Cities project cover the operating and investment cycles of cities through analysis of material and energy balance within the system boundaries on a dynamic basis [N4C D.3.1]. Therefore, the urban metabolism models, comprised of urban flows between metabolic processes and associated with operating and investment cycles, will be quantitatively assessed through setting up material and energy balances where quantification of these flows will be the basis of indicator-based environmental assessment under T3.3. This approach also will

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support the assessment of the effectiveness of NBS to improve the climate resiliency of cities. For instance, an NBS can help in minimizing the UHI effect and therefore, the energy entering the system for cooling will be minimize and, consequently, the Global Warming Potential will be reduced too. Task 3.5 will put all these links together in the so-called Dynamic assessment methodology.

The climate change influences over and is influenced by the urban flows. For example, we expect that the weather conditions will be more extreme. Therefore, we expect colder winters and warmer summers, that means that the energy demand for heating and cooling will be higher. Thus, the climate will have an influence over the urban energy flow that will be measure under urban metabolism basis.

Being more specific, from the indicators considered in the urban metabolism approach, the following are common to the indicators considered in climate resilience assessment:

- Carbon sequestration
- Global warming potential
- Runoff
- Indicators related to energy

In brief, urban metabolism water, energy and carbon dioxide flows are crucial to understand the climate resilience of cities. How NBS can have a positive influence in those flows and therefore, in the improvement of cities resiliency is one of the main objectives of studying further these nexuses in task 3.5.

2.3 T.3.3. Development of the N4C Environmental Assessment Methodology

Task 3.3 considers a Life Cycle oriented approach to deliver the N4C environmental assessment methodology. LCA based methodologies are useful to understand, for instance, to which extent a NBS can contribute to mitigate the climate change. Going into detail, several LCA indicators allows assessing the primary energy needs reduction due to the implementation of NBS. The solutions that have as a result a reduction of primary energy needs are considered as climate mitigation strategies. This is because the dependency of fossil based fuels is reduced and the global warming potential gases associated are reduced too.

In the context of T3.4, together with adaptation strategies, climate mitigation strategies have been considered as part of urban climate resilience assessment methodology. Therefore, T3.4 created guidelines include LCA based assessment criteria following a similar approach to T3.3. Table 3 summarizes this relationship.

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Table 3: Relationship between T.3.3 and T.3.4

Pontetial commont parts	T3.3 (LCA)	T3.4 (Climate resilience)
Goal of the study	- To identify climate change hotspots of NBS and their opportunities for improvement. - To compare the climate change impacts of different NBS options meeting the same urban challenges.	- To guide the municipalities in the selection of the most suitable methods and tools according to their interest in the field of climate resilience
Mitigation or adaptation to climate change	Mitigation	Adaptation and Mitigation
Perspective	Life Cycle perspective	Multiple perspectives
Scale of assessment	Object / Neighbourhood scale	Object / Neighbourhood / City scale (even up to the city too)
Indicators	Climate change (kg CO_2-eq) Damage to Human Health due to Climate change (DALY) Damage to Ecosystems due to Climate change (species.yr)	Runoff reduction, building cooling and heating energy demands, primary energy demand reduction, external air temperature reduction, carbon sequestration, global warming potential reduction,
Tools	LCA software (simplified or not)	24 different methods and tools (generalist and specific)

2.4 WP6. Nature4Cities tools and platform development

The work done and presented in this deliverable is going to be integrated in N4C Platform.

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3 Procedure followed for guidelines construction

The procedure followed to construct the guidelines for climate resilient cities and NBS can be summarized in 3 consecutive steps:

- State of the art revision to understand existing information, documentation, methods and tools available for the purpose of the task.
- Analysis of the models and tools Identified in the state of the art through RACER method.
- Validation of previous collected information through the performance of Case studies.

Following chapters summarize each of these steps.

3.1 State of the art revision

The state of the art revision has been divided into 2 main parts. The starting point of the work consisted in identifying and reviewing related articles.

In order to facilitate the interchange of information between the three partners involved in the state of the art revision, a repository in google drive has been created. This repository has been structured according to the information that it was interesting to extract from the documentation. In case of the scientific articles, the following information has been considered:

Table 4: Information collected during the Articles revision

Reference Title, author, year	**Type of document** Scientific article, project deliverable, book, publication	**Who is including the information?** RINA, EKODENGE, TECNALIA	**Interest for the purpose of the task** High, medium, low, with interest to other task and/or to make links between tasks
Main objective	**Scale** City, District, Building, ...	**Target of the measures** Adaptation, mitigation, resilience	**Type of NBS** According to project list
Type of interventions Other than NBS	**Datasets used** Type of info and Data sources	**Case studies**	**Actuation areas** Drainage, water supply, solid waste management,

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Climate issues Model, scenarios and trends, components (inside/outside temperatures, rain, humidity,…), extreme conditions (flood, drought, heat stress,…)	Assessment methodology and tools	Indicators	Links with other tasks Task 3.1 Urban metabolism, task 3.2 urban agents, task 3.3 LCA, …

Thanks to the articles revision, a deep view of the urban resilience, adaptation and mitigation, NBS effectiveness and climate trends have been obtained. The articles revision had as a result the identification of projects of interest and models and tools that can allow the assessment of different parts of climate resilience and NBS effectiveness. Therefore, the second part of the state of the art revision was focused on the analysis of identified projects, models and tools.

Table 5: Information collected during the projects revision

Full name of the project	**Short name**	**Dates** Beggining-Ending	**Who is including the information?** RINA, EKODENGE, TECNALIA
Main objective	**Climate issues** Model, scenarios and trends, components (inside/outside temperatures, rain, humidity,…), extreme conditions (flood, drought, heat stress,…)	**Other issues of interest for the purpose of the task** NBS, urban climate resiliency, urban climate risks and challenges, CC mitigation, CC adaptation, related indicators, smart city, …	**Tasks and/or deliverables of interest** Reference, public or private?
Assessment methodology and/or model Name, brief description of the method and/or model, existing or developed within the project?	**Tool** Name, brief description of the functionalities, existing tool or developed within the project?	**Datasets used** Type of info and Data sources. Ex: Climatic data from EnviMET	Indicators considered
NBS considered	Case studies	**Privacy** Public, private, opened but without access to the database and the methodology,…	**Comments** Own perception about the interest of this project for the task
Links with other tasks Task 3.1 Urban metabolism, task 3.2 urban agents, task 3.3 LCA, …			

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Table 6: Information collected during the models and tools revision

Reference Title, author, year	**Developer** Main developer first, others	**Type** Tool, model, certification	**Who is including the information?** RINA, EKODENGE, TECNALIA
Main functionalities	**Climate issues** Model, scenarios and trends, components (inside/outside temperatures, rain, humidity,…), extreme conditions (flood, drought, heat stress,…)	**Other issues of interest for the purpose of the task** NBS, urban climate resiliency, urban climate risks and challenges, CC mitigation, CC adaptation, related indicators, smart city, …	Scale Object, Neighbourhood, City and/or range of cell size, other: region,…
Privacy Public, private, opened but without access to the database and the methodology, available at cost (specify the price)…	**Code** SQL, Pyton, MongoDB, Fortran,	**Assessment methodology and/or model** Name, brief description of the method and/or model, existing or developed within the project?	**Datasets used** Type of info and Data sources. Ex: Climatic data from Envimet
Indicators considered	**NBS considered**	**Case studies**	**Comments** Own perception about the interest of this tool for the task
Links with other tasks Task 3.1 Urban metabolism, task 3.2 urban agents, task 3.3 LCA, …			

Mentioned information has been collected for each of the following documentation:

- 60 Scientific articles.
- 25 projects.
- 30 models or tools.

The state of the art revision establishes the basis of this task developments. On the one hand, the climate resilient information has been updated and organized. On the other hand, the information has been used to develop the methodology that connects the different parts of the climate resilience and NBS effectiveness perspectives. One of the main challenges of the task has been organizing all this information in a useful way. This challenge has been transformed into the guidelines for municipalities, which is the main result of the task.

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3.2 RACER assessment

This section describes the method that has been developed to classify the methods and tools according to their suitability for the urban climate resilience and NBS methodology application. The approach is based on the RACER method, an evaluation framework design by the European Commission to assess the value of scientific tools for use in policy making [EU, 2005 and 2009]. RACER stands for Relevant, Accepted, Credible, Easy and Robust:

- Relevant – e.g. closely linked to the objectives to be reached.
- Accepted – e.g. by staff and stakeholders.
- Credible for non-experts, unambiguous and easy to interpret.
- Easy to monitor – e.g. data collection should be possible at low cost.
- Robust – e.g. against manipulation.

This generic approach has been adapted in order to fit to the purpose of Nature4Cities. In practice, RACER method has been adapted to consider the dimensions needed to address the impact of climate change at urban level and assess the benefits of NBS to improve climate resilience of the cities. Therefore, the different methods identified during the state of the art have been characterized as follows:

- **Assessing urban climate issues**: methods that take into account issues related to climate, (such as temperatures, rainfall, air quality) are considered relevant for the purpose of the methodology.
- **Consideration of different scales**: methods that cover object, neighborhood and city scales are needed in order to fully characterize the NBS effectiveness over the climate resilience of the city.
- **Analyzing all the stages**: from identification of threats to the analysis of NBS effectiveness. Methods that allow assessing the whole process are presented as suitable for the purpose of the methodology. However, according to the specific characteristics that this methodology wants to fulfill, it was considered challenging finding a method that could assess the whole process.
- **Assessing NBS**: as Nature Based Solutions are the focus of the project, methods that consider several NBS are included as relevant.
- **Feasibility to apply the method**: data, tools and information availability for the application of the methods by the municipalities, it was considered interesting too.

These dimensions have been considered as the main criteria to appraise the climate resilience of the cities and NBS.

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In operational terms, the RACER assessment relied on the elaboration of a number of “evaluation matrices”. Each of those matrices focused on one component of the RACER method (namely Relevance, Acceptance, Credibility, Easy to monitor and Robustness). During the assessment procedure each criterion included in the evaluation matrices was classified as “fully achieved”, “partly achieved” or “not achieved” considering the criteria established in tables 7 to 11.

Table 7: Evaluation matrix for the RELEVANT category

RELEVANT - i.e. closely linked to the objectives to be reached				
Assessment category	Climate resilience oriented	Scales covered	Scope	Potential to assess NBS
Criteria	Climate resilience issues covered	Scales for which could be applied	Usefulness to assess the whole process	Usefulness to assess NBS
Fully achieved	It provides a deep view of urban climate resilience issues (UHI, rainoff, pollution,...)	It covers all the relevant scales (at least from city to object, positively considered added scales)	It allows assessing the whole process: from climate risks to implementation measures and effectivity of the measures	It allows assessing NBS (Green and blue infrastructures positively considered)
Partly achieved	It covers several or at least the most relevant urban climate resilience issues and/or supports the calculation of any of them	It covers several relevant scales and/or is very meanigfull for one of them	It allows assessing several parts of the process or only one part but is very relevant for it.	It allows assessing several NBS and/or can be included in the assessment (Green and blue infrastructures optional)
Not achieved	Focused on limited parts of climate resilience	It covers only one/ not very detailed scale	It is focused in one part of the process or in several of them but is not very relevant.	It is not related to NBS

Table 8: Evaluation matrix for the ACCEPTED category

ACCEPTED - e.g. by staff and stakeholders			
Assessment category	Scientific Status	Acceptance by the municipalities	Administrative institutions (e.g. EC)
Criteria	Use by the scientific community	Decision making	Acceptance by the politicians
Fully achieved	Its use is widespread in the scientific community with positive results	Frequently used by the municipalities for decision-making	Approved and recommended by politicians/public administration agents
Partly achieved	Known and accepted by scientifc community but not very used / Promising method	Municipalities are starting to take it into account and/or is very useful for decision making	Positively considered by politicians/public administration agents
Not achieved	Its use is not widespread and it doesn´t seem as promising	Not used for decision making, difficult to use for this purpose	Not recognized by politicians/public administration agents

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Table 9: Evaluation matrix for the CREDIBLE category

CREDIBLE for non-experts, unambiguous and easy to interpret			
Assessment category	Unambiguous	Transparency	Consensus
Criteria	Results interpretation	Traceability	Standardization
Fully achieved	The meaning of the results given is clearly defined. Results are useful without the need of extensive explanations	Data collection and treatment processes are clearly defined and is possible to trace them	Standardized /Certified by externals
Partly achieved	The meaning of the results given is defined but explanations are needed to interpret it correctly	Data collection and treatment processes are defined	In process to be standardized or several parts can be certified
Not achieved	The meaning of the results is not clearly defined causing an open interpretation	Data collection and treatment processes are not detailed	Not standardized

Table 10: Evaluation matrix for the EASY TO MONITOR category

EASY TO MONITOR - e.g. data collection should be possible at low cost			
Assessment category	Support for its application		
Criteria	Tools availability (for municipalities)	Data availability and treatment (other than the specific for the city)	Municipalities dependency
Fully achieved	It is implemented in free tools that make easier the application	Data is accessible and in a good quality	Municipalities are autonomous in the application of the whole process
Partly achieved	Tools needed are available at cost or are available only for project partners	Data needed for the application has to be collected and treat	Municipalities can make the application of the whole process but deep knowledge is needed
Not achieved	No tools are available at the moment	Strong efforts are needed to collect the data in a good quality	Municipalities depend on external services to make the assessment

Table 11: Evaluation matrix for the ROBUST category

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ROBUST – e.g. against manipulation			
Assessment category	Reliability	Comparability	Reliability
Criteria	Calibration	Usefulness to making comparisons	Consistency
Fully achieved	The model allows calibration for each case study (by using real data instead simulated or database info, etc.)	Obtained results can be compared to other cities/districs/neighbourhoods	Obtained results are of good precision with little error and a consistency check is possible.
Partly achieved	Several parts of the model can be calibrated	Several normalization changes are needed in order to make the results comparables	Obtained results are of good precision with little error but a consistency check is not possible.
Not achieved	Calibration is not allowed	Comparisons are not allowed	The precision of the results is not validated

RACER assessment presented, allowed comparing the methods considering the same criteria. As a result of the RACER assessment, the 30 methods identified during the state of the art have been analyzed and classified according to their suitability for the urban climate resilience analysis. This analysis has been done according to the information that is available online. Chapter 4.3 Includes the results of the assessment. The assessment was useful to understand better methods´ characteristics and needs too.

3.3 Validation

All the information collected during the state of the art revision and the RACER assessment has been organized in the so-called guidelines for climate resilient cities and NBS, which is the main result of the task.

As it is explained later in the deliverable (see chapter 5), the guideline consists on a questionnaire which is supported by a yes/no matrix. According to the answers given to the questionnaire, the guidelines filter the information basing on yes/no matrix and giving suggestions to the users about the methods that can be used to assess the issues of their interest. To provide these results, the Yes/No matrix contains basic information of the models and tools that can be answered in terms of yes/no. This kind of organization of the information allows the quick identification of the models of interest for a municipality. Once the method selection is made, forms with basic information of the selected methods is provided.

In order to validate the guidelines, three case studies have been performed. The case studies were useful to validate the information introduced in the yes/no matrix, the

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questionnaire to be made to make the methods selection and to develop the forms that are obtained as a result of the guidelines application.

Chapter 6 is dedicated to the case studies, which in a summarized way consists in:

- Donostia/San Sebastián city (Spain): for Donostia/San Sebastián a full case study has been performed. This means that the questionnaire was filled by the municipality and the methods obtained as a result have been applied in a practical way. Numerical results have been obtained.
- Alcalá de Henares (Spain): the questionnaire was filled by the city and selected methods have been analyzed in order to understand better if they really answer to city's interests
- Szeged (Hungary): same approach to Alcalá de Henares has been applied.

Thanks to the case studies performance, the most promising methods considered in the guidelines have been analysed and the information about them has been validated.

4 Intermediate results: basis of the guidelines for climate resilient cities and NBS

Thanks to the work done and described in chapter 2, several intermediate results have been obtained. These intermediate results conformed the basis of the guidelines for climate resilient cities and NBS.

First of all, the climate resilient information has been updated and a completed repository has been created. Thanks to this information, the different steps of the urban climate resilience and NBS methodology has been defined. Considering these steps, the methods have been characterized according to the steps of the method that they covered and the relevance of them has been assessed in terms of RACER. These 3 intermediate results are described in the following chapters.

4.1 Climate resilient information update

This chapter summarizes the findings of the state of the art made. These findings stablish the bases of the issues that the urban climate resilience and NBS methodology has to consider to provide a detailed view on how the NBS can be part of climate adaptation and mitigation strategies for cities.

Most of studied articles are focus on resilience (18/61) or consider both mitigation and adaptation strategies (17/61). However, when making the NBS effectiveness assessment, only few methods (2/30) allow considering both strategies. Moreover, these

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2 methods do not consider both strategies with the same scope and are focused in one of them, providing only some information about the other. Specific articles for adaptation (11/61) and mitigation (5/61) have been analysed too giving a more detailed view of each of the strategies.

Around the half of studied articles (28/91) consider nature based solutions as a key element that can help to improve urban climate resilience. These nature based solutions include specific solutions such as permeable pavements (2/61) or green building NBS (2/61) and more general solutions such as green and blue infrastructures (10/61), NBS in general (7/61) and green public spaces (7/61). It is important to note that NBS appear regularly in scientific articles search for climate resilience, climate adaptation and climate mitigation (24/61). This statement suggests that the interest of introducing nature based solutions in the cities to improve climate resilience is growing (most of studied articles are less than 3 years old). Considered methods and tools are aligned with the articles and most of them (20/23) allow assessing the NBS effectiveness over climate adaptation and/or mitigation of the city.

When talking about the scale, most of studied articles work at city level (42/61). From these articles, more than the half take into account specific climate issues of the city (22/42). Extreme rainfall connected with floods and air temperature linked with heat island effect are the most repetitive climate concerns that appear in scientific articles that work at city level (16/22). Some of the studied articles consider the district scale (6/61) and only few of them are focused on object level (2/61). In case of the districts, the floods (2/6) and the surface temperatures (2/6) have been studied. On the other hand, several regional scale articles have been studied too (10/61).

Regarding climate issues, more than the half of the studied articles consider them somehow (34/61). From them, most are focused on the risks caused by the climate such as flooding (12/34) and heat waves (8/34). Several articles consider the air and the soil quality too (5/34). In the specific field of climate trends, the work done by the Intergovernmental Panel on Climate Change (IPCC) is the most relevant and consolidated. IPCC is the United Nations body for assessing the science related to climate change[1].

As this is the most robust source in this context, this deliverable uses the definition given by the IPCC for the following Key terms [IPCC annex II 2014]:

- Resilience: the capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation.

[1] https://www.ipcc.ch/

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- Adaptation: the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.
- Mitigation: a human intervention to reduce the sources or enhance the sinks of greenhouses (GHGs).

On the other hand, when analysing the kind of indicators considered in the articles, almost none of them appear more than two times. This reflects the lack of agreement on how to consider or how are defined the indicators related to climate resilience. Groups of indicators can be made according to the climate fields that they allow to analyse. For example, indicators related to air temperature are considered in several articles (9/61) in completely different terms like "Physiologically Equivalent Temperature" or "Annual heat-related mortality (number of deaths)". Indicators related to runoff (5/61) are defined as surface runoff, flood management or flood risk among others.

As it can be perceived, most of the articles that include indicators are related to climate adaptation (28/61). Nevertheless, only few studied articles include climate mitigation indicators (5/61). This is because it is no very common to analyse climate mitigation strategies considering urban climate resilience approach. Much more articles on climate mitigation are found when energy consumption and/or emissions savings approaches are followed. In order to cover robustly this part of the assessment, methods and tools search has been included considering this different approach. Thanks to this extension on the search scope, methods and tools useful to analyse NBS effectiveness for climate mitigation are well covered in the guidelines (8/23).

The result of the climate resilient information update was the definition of the steps and the content that the methodology should have for understanding how the climate change can affect the cities and how the NBS can improve the resilience of them.

4.2 Methodology: from Climate trends to NBS effectiveness

The ambition of defined methodology was trying to consider all the issues that are related to climate trends and NBS. This means that the result of the methodology definition is the identification and organization of all the potential issues of interest for the municipalities regarding the climate change and NBS fields. This approach has been defined while making the state of the art revision and realising that the multiple climate related perspectives cannot be covered by a single method (see chapter 4.1). For example, none of the methods analyse the NBS effectiveness on climate mitigation and adaptation together with the same scope. However, the trend driven by the Covenant of

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Mayors for Climate and Energy (CoM)[2] is to *include both climate and mitigation aspects* [CoM, 2018]. This is aligned with IPCC approach which considers that *Adaptation and mitigation are complementary strategies for reducing and managing the risks of climate change* [IPCC Urban areas, 2014].

Therefore, the objectives considered while collecting all the issues of interest for the methodology have been:

- It must allow understanding how the climate trends can affect the cities.
- It must consider how to assess the climate hazards that could affect the cities.
- It must allow assessing mitigation and/or adaptation strategies.
- It must include how to assess the effectiveness of the NBS to improve city resilience.

As a result, all the issues of interest to be considered in the whole process from climate trends analysis till NBS effectiveness have been identified and organized within 5 fields (figure 1):

1) Climate trends: air temperature, Rainfall/precipitation, air quality
2) Climate threats/impacts/hazards: Colder winters and warmer summers, Urban heat Island effect (UHI), runoff, air pollution, water quality, wind field.
3) Strategies: Mitigation and adaptation
4) Indicators to assess urban vulnerability and risks: Building cooling and/or heating energy demand reduction, global warming potential reduction, primary energy demand reduction, runoff reduction, carbon sequestration, external air temperature reduction.
5) NBS effectiveness (according to N4C project list): parks and gardens, structures associated to urban networks, structures characterized by food and resources production, natural and semi-natural water bodies and hydrographic networks, constructed wetlands and built structures for water management, green roofs, urban planning strategies, works on soil, vertical structures (green walls and façades), direct human interventions.

[2] https://www.covenantofmayors.eu/

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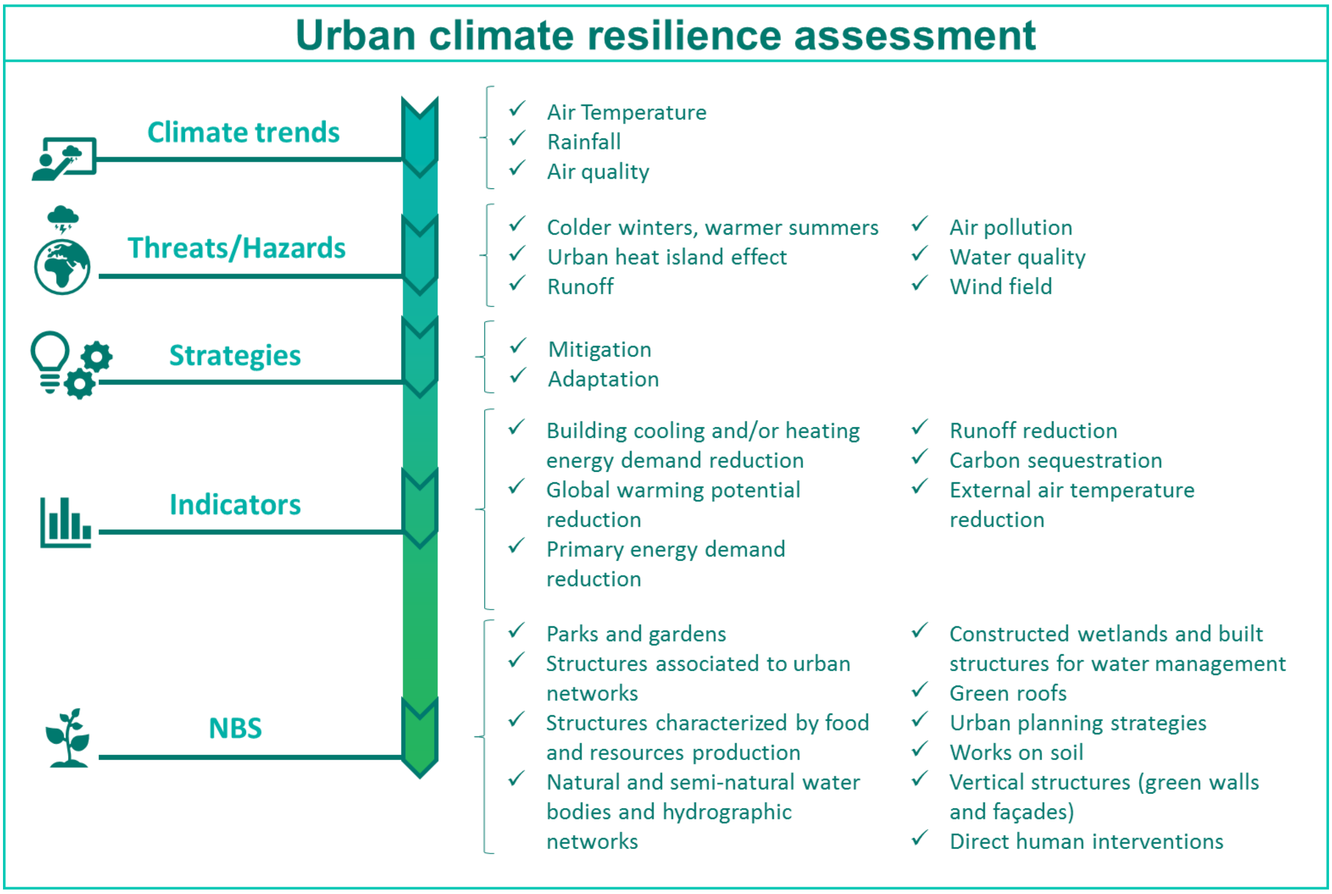

Figure 1: Issues covered by the urban climate resilience assessment methodology

The main challenge in the methodology development has been managing the lack of connections between the different parts that the methodology must cover. This is translated in one of the suggestions to improve the work done in this field.

Therefore, in the context of this task, when we are talking about the methodology we are referring to all the information that can be part of this kind of analysis. If a specific assessment wants to be made, the method to be applied will be the one included in the tool (or method) selected thanks to the guideline application.

It is important to note that after identifying all the potential issues of interest for the municipalities regarding the climate change and NBS fields, several expectations have been defined to be answered by the method (or methods in plural):

- understanding current situation (climate threats currently affecting the municipality),
- identifying potential future impacts due to the climate change if there is no intervention (BAU),
- building NBS scenarios to try to minimize the potential impacts,
- assessing the scenarios and
- selecting the most suitable NBS solutions according to their effectiveness

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Following this approach, the case study of Donosti/San Sebastian has been defined and performed (see chapter 6.1).

Next chapters (4.2.1 – 4.2.5) explain the information related to climate change and NBS according to the 5 fields of interest identified.

4.2.1 Climate trend analysis

The key document for the task 3.4 Urban Climate resilience, is the "Urban areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability" [IPCC, 2014], developed by the IPCC and published in 2014.

To understand better how the trends could affect the climate, the IPCC defines several scenarios named: historical, RCP 4.5, RCP 8.5. Within these scenarios, how the air temperature, the Rainfall / precipitation and the Air quality are going to evolve are explained.

Data sources about this include: [Adaptecca][3]. Among others, it contains data related to the maximum and the minimum diary temperature for the 3 IPCC scenarios for the following periods:

- Historical: 1950-2005
- RCP 4.5 and 8.5: 2006-2100

This information is based on [Eurocordex][4] information. Adaptecca has data for Spain, same data can be found for Europe in [Copernicus][5]. The problem with this data is that it is daily data and most of the methods need hourly data to perform their assessments. This is one of the conclusions of the case studies.

4.2.2 Climate threats / impacts

According to the expected climate trends, six threats that could affect the cities have been included as part of the potential issues of interest for the municipalities:

- Colder winters, warmer summers (extreme temperatures): Projections of climate change show increasing frequency and severity of extreme weather events, such as heatwaves. More extreme temperatures will cause an incrementation of the energy demand for cooling and/or heating.

[3] http://escenarios.adaptecca.es/#model
[4] https://www.euro-cordex.net/
[5] https://cds.climate.copernicus.eu/#!/home

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- Urban Heat Island (UHI) effect: The temperature in an urban area is usually higher than in the surrounding countryside. The magnitude or intensity of this UHI phenomena depends on various factors, such as the size and morphology of the city. The primary factors are the increased absorption of heat caused by changes in land cover, the trapping of heat by buildings due to their mass and canyon-like geometry, and the reduction in vegetation.
- Runoff: the hard, often paved, surfaces in urban areas influence the runoff patterns and may, if poorly designed and maintained, be the direct reason for the disastrous effects of flooding. Rainwater must be drained away in a controlled manner in order to avoid flooding, erosion, and landslides. Urban areas may cause considerable intensification of rain, hail, and thunderstorms, especially «downwind» from the major sources of rain triggering nuclei. The peak runoff is reached more rapidly and is higher than if the city were not there.
- Water quality: going beyond the need of the cities to protect their citizens against the water-related disasters (e.g. droughts and floods), it is needed to guarantee water availability and high-quality groundwater, surface water and drinking water.
- Air pollution: Urbanization is associated with pollution of both water and air in many different ways. In addition to the direct effects that the various pollutants have on health, they also have an impact on climate. The evolution of urban air pollution in and around large cities results in a new mixture of contaminants which do not only pose serious health hazards and deteriorate the quality of life, but can also destabilize the urban atmospheric chemistry, thus creating different end products that have a long life-span and can spread well beyond the boundaries of the normal sphere of influence.
- Wind field: When the large-scale winds are light or calm, the UHI can generate its own wind system. What is sometimes called the "city wind" develops in a fashion that is similar to that of the sea breeze; in coastal areas, the two wind systems may combine into intense and complex circulations. The surface in an urban area is normally rougher than in the surrounding countryside causing the urban boundary layer to be both deeper and more turbulent.

These threats and impacts can be minimized through the implementation of NBS in the city. Different kinds of strategies could be considered depending on the aim of this implementation.

4.2.3 Climate related strategies

Once the climate threats and/or impacts that could affect the urban environments have been defined, the municipality can decide between implementing mitigation strategies to try to avoid them and/or adaptation strategies to be better prepared to the potential climate changes.

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- Adaptation: the process of adjustment to actual or expected climate and its effects.
- Mitigation: a human intervention to reduce the sources or enhance the sinks of greenhouses (GHGs).

The idea in N4C project is to understand to which extend the nature based solutions can help to adapt the cities to climate change and/or to mitigate this phenomena. However, other kind of solutions can be implemented both to mitigate and adapt the city to climate change.

4.2.4 Climate threats and NBS effectiveness related indicators

NBS indicators have been identified and analysed in several tasks of N4C project. In task 3.4, selected indicators are related to identified climate threats and strategies:

- Building heating and cooling energy demand reduction: mitigation strategies include, for example, the implementation of green facades to better isolate the buildings. This will cause a reduction of the energy needs for heating and cooling that can be monitored through these indicators.
- Primary energy demand reduction: this indicator is related to the energy consumed in the city. Considering it in terms of primary energy (renewable and no-renewable) is interesting, for instance, to relate it to greenhouse emissions.
- Global warming potential reduction: greenhouse gas emissions are very related to energy consumption by source. Moreover, air quality will depend on this kind of emissions. Nature based solutions could help to improve both aspects.
- Carbon sequestration: Carbon is stored in living and dear organic matter above and below the ground. Changes in ecosystems as a result of climate change, can contribute to changes in carbon storage, which in turn can affect the climate system through the release of greenhouse gases such as carbon dioxide. This indicator will be positively affected by the nature based solutions, whose will have a positive impact over the air quality.
- Runoff reduction: the nature based solutions (soils and plants) can help to adapt the cities to increasingly precipitations. This indicator has been included to understand the effectiveness of NBS in this context.
- External air temperature reduction: this indicator will allow to monitor urban heat island effect.

4.2.5 Nature Based Solutions that allow to mitigate and/or to adapt cities to climate change

Nature based solutions considered in this part of the method have been the ones included in the N4C list:

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- Parks and Gardens
- Structures associated to urban networks
- Structures characterized by food and resources production
- Natural and semi-natural water bodies and hydrographic networks
- Constructed wetlands and built structures for water management
- Green roofs
- Urban planning strategies
- Works on soil
- Vertical structures (Green walls and facades)
- Direct human interventions

The potential of the methods to assess the effectiveness of these NBS to mitigate or adapt the city to climate change, is included in the guideline.

After collecting all the issues that a climate change related methodology has to cover, identified methods and tools that exist in this field have been analysed and classified according to the RACER method that was explained in chapter 3.2 and which results are presented in chapter 4.3.

4.3 Results from the RACER assessment: methods and tools classification

The RACER assessment has been used to make a ranking between identified in the state of the art methods and tools. This ranking will provide more information to the municipalities when two or more methods are selected, and they want to understand further their potentialities to better chose between them. The analysis has been done according to the scoring system explained in chapter 3.2.

From the 30 methods initially identified, 20 were selected to be included in the guidelines because of the RACER. The other 10 methods were not considered of interest for the methodology.

Table 12: RACER assessment results

	RACER results					
	RACER	Relevant	Accepted	Credible	Easy	Robust
Envi-MET	**25**	6	6	5	3	5
Library of Adaptation Option	**24**	6	3	3	6	6
Design Builder	**23**	4	4	6	3	6
EPA Storm Water Management Model (SWMM)	**23**	6	4	4	4	5
Enerkad	**23**	6	3	5	3	6

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Green Pass	**21**	8	3	3	3	4
HAVURI	**20**	6	3	5	4	2
NEST	**19**	3	2	5	5	4
CITY-CAT	**19**	7	3	2	1	6
Soil and Water Assessment Tool (SWAT)	**19**	5	4	3	3	4
Climate-ADAPT web platform	**19**	5	6	2	4	2
Rayman	**18**	4	2	4	3	5
Fault tree analysis (FTA)	**18**	8	4	4	2	0
SIRVA	**18**	5	3	3	3	4
Simile	**18**	6	3	2	2	5
URB-CLIM	**17**	5	2	3	1	6
EPESUS	**17**	2	2	5	2	6
Enviro-HIRLAM	**15**	4	3	4	3	1
PLINIVS models	**15**	5	3	2	1	4
IVAVIA	**13**	4	3	3	1	2

The following methods were considered out of the scope of this part of the task: Transition handbook, ANOVA, WRF, E-guide, CityCanopy, Flood Risk Management (FRM) practices with model-based assessments, SUA, IPCC projections of Future Changes in Climate, PDE Toolbook for Matlab (v.2015, Mathworks, Natick, MA, USA), Ecosystem-based adaptation in cities (EbA).

While working together with WP2 partners it was decided to include 3 more methods: TEB, i-tree eko and Solweig whose scored over the media, according to the evaluation criteria defined in task 2.2 [N4C, D2.2].

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5 Decision support guidelines for climate resilient cities and NBS

Decision support guidelines have been created with the aim of helping the municipalities in identifying and deciding between all the existing methods and tools that exist to analyze the climate resiliency of cities and the nature based solutions.

The guidelines have been created to be publicly available in the N4C platform. Therefore, the efforts done in task 3.4 in collecting and organizing the huge amount of information that exists in the field of climate adaptation and mitigation and NBS, will be extended to all the interested stakeholders.

This chapter explains how the guidelines work, from information selection to results obtained:

- Express the issues of interest of the user: the user has to identify the parts of the climate resilient cities and NBS, he/she is interested in. As it was explained in the methodology chapter, a wide variety of issues is related to this field and there is no a single method or tool that covers all these issues. Thus, it is needed to focus the assessment by expressing which are the interests and excluding no related methods. This expression of interest is made through the completion of a questionnaire (see chapter 5.1).
- Engine of the guideline: according to the user´s expressions of interest, the guideline selects and makes suggestions about which kind of methods covers the user´s issues of interest. This is done according to the information that is included in the yes/no matrix which is explained in chapter 5.2.
- Results: in the Excel version, while the questionnaire is being filled, the user can see the number of methods that could answer to the issues of its interest. After finishing the completion of the questionnaire, forms with completed information about selected methods are given. The explanation of the content included in the forms is explained in chapter 5.3 and the forms for the 24 methods will be included in the N4C platform.

Next chapters explain these issues with more detail.

5.1 Questionnaire

The questionnaire of the guidelines aims to understand the interests of the cities in the context of climate resilience and Nature Based Solutions.

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Before the questionnaire is implemented in the platform, it works by clicking in the small boxes considering the following:

- ☐ municipality is not interested in considering this issue
- ☒ municipality is interested in working with this issue

The questionnaire has the following functionalities:

- Multiple choice is possible.
- Is not needed to select a box in each question. Therefore, if the user is not interested in one part of the assessment is possible not answering to this question.

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1.

Do you want to assess climate trends that could affect your city?

Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.[12] This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns https://www.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-understanding-and.html

☐ Air Temperature

☐ Rainfall

☐ Air Quality

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2. Which kind of threats/impacts do you want to consider?

The main weather and climate hazards with the potential to affect European cities and urban areas are flooding, sea level rise, high temperatures and water scarcity and drought.

☐ Colder winters, warmer summers	☐ Urban Heat Island	☐ Flooding/Runoff
☐ Air Pollution	☐ Water Quality	☐ Wind field

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3.

Which strategy do you want to implement?

Strategies related to climate are generally divided in 2

☐ **Adaptation**

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

☐ **Mitigation**

A human intervention to reduce the sources or enhance the sinks of greenhouses (GHGs).

4.

Which kind of outputs do you want to obtain?

☐ **Quantitative assessment**

☐ **Qualitative assessment**

☐ **Decision support**

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5. Which indicators do you want to take into account?

- ☐ Building cooling energy demand reduction
- ☐ Building heating energy demand reduction
- ☐ GWP reduction
- ☒ Primary energy demand reduction
- ☐ Runoff reduction
- ☐ Carbon sequestration
- ☐ External air temperature reduction

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6.

At what scale do you want to work?

☐ Object	☐ District or Neighborhood	☐ City	☐ Up to the city

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7.

Are you interested in specific NBS?

☒ Parks and gardens

☐ Structures associated to urban networks

☐ Structures characterized by food and resources

☒ Natural and semi-natural water bodies and hydrographic

☐ Constructed wetlands and built structures for water

☐ Green roofs

☐ Urban planning

☐ Works on soil

☐ Vertical structures

☐ Direct human interventions

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8. Availability

Some of the methods and tools are available for users. Depending on the level of expertise required by each method, some could be applied without the need of a deep knowledge and municipality technicians could be in charge of applying the methods. Please, specify the interest on how performing the assessment:

- ☐ **License of the tool**
  Thus, the user can perform all the
- ☐ **Experts Service**
  Thus, the service is subcontracted
- ☐ **Documentation**
  Thus, information is available

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9.

Budget

For subcontracting the service or for downloading the tool (depending on the selection in question 8). Free tools need different level of knowledge to be applied.

☐ Up to 30000	☐ From 10.000 to 30.000	☐ From 250 to 10.000	☐ Free

Once the user has selected the issues of interest, the filter is applied and the methods are selected according to the yes/no matrix.

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5.2 Information classification: Yes/No matrix

The yes/No matrix is the repository that contains the information needed by the guideline to make the methods selection.

The 24 methods are organized in rows and the columns contain the issues of the methodology considered of interest for climate resilient cities and NBS. In this sense, 42 criteria have been defined and the methods have been characterized with a yes, if they cover that issue, or a no, if the issue is out of the scope of the method. The engine of the platform will read this yes/no matrix and will select the methods according to it and to the questionnaire filled by the user.

5.3 Methods and tools for climate resilience forms

The methods and tools for climate resilience forms are the result of the guidelines application. When a method is filtered, the form of it is given to the user. In total 21 forms have been created, one for each method and tool. Figure 2 summarizes the information included in the form, which aims to guide to the user of the platform in the selection of the methods to use in its case study.

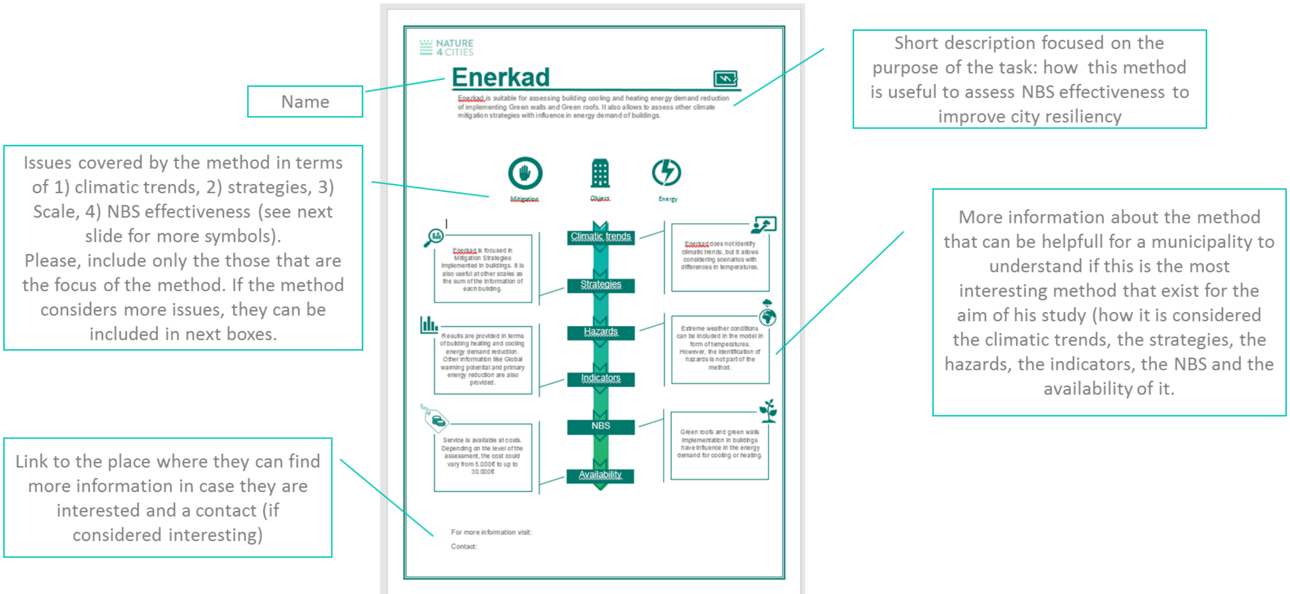

Figure 2: Example of the forms obtained as a result of method selection

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6 Case studies: Guideline validation

Case studies have been performed with the aim of understanding better to which extend the methods identified in the state of the art cover the different parts of the urban climate resilience methodology. The case studies were useful to validate the questionnaire too.

6.1 Txomin Enea neighbourhood of Donostia/San Sebastián city (north of Spain)

Donostia/San Sebastian is a coastal city located in the north of Spain. According to the questionnaire filled by the municipality, the procedure defined in figure 3 has been followed and the methods mentioned have been applied.

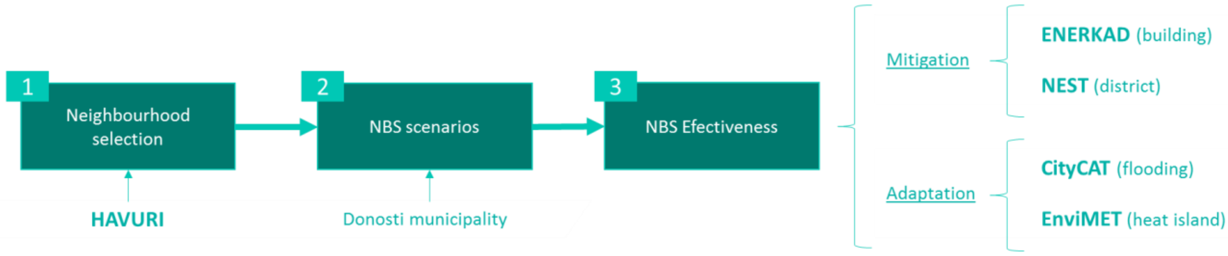

Figure 3: general scheme of Donosti/San Sebastian case study

This procedure responds to the expectations defined to be answered by the methods in chapter 4:

- understanding current situation (climate threats currently affecting the municipality) → already identified by the city.
- identify potential future impacts due to the climate change if there is no intervention (BAU) → Made with HAVURI methods.
- built NBS scenarios to try to minimize the potential impacts → developed together with the municipality.
- assess the scenarios → According to ENERKAD, NEST, CityCAT and EnviMET methods.
- select the most suitable NBS solutions according to their effectiveness → according to the results given by the previous methods.

6.1.1 HAVURI: Neighbourhood selection to focus the strategies

HAVURI method was selected because it allows assessing any climatic trend for any climatic scenario. Havuri performs a comparative risk and vulnerability analysis among

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the spatial units of the selected system and for any climatic hazard. The assessment is carried out for impact chains considering the effects of a certain hazard in a receptor (humans, buildings, infrastructures, etc.). As a result of the application of this method, the most vulnerable to a certain climatic hazard neighbourhoods will be identified.

In the case of Donostia/San Sebastian the analysis was performed for the impact chains of i) rainfall flooding on the urban environment and ii) impact of temperature and heat waves on the human health. For “rainfall flooding” impact chain, the following information was used for the exposure indicator: surface exposed to a maximum rainfall of two hours expected for the period of 2071-2100, with a return period of 25 years and under the most extreme scenario of IPCC (RCP 8.5). Regarding the “increase of temperature” impact chain, the whole city was considered exposed to this threat. The temperature future trends were generated under both IPCC scenarios RCP 4.5 and 8.5. (see chapter 4.2.1).

The analysis unit selected for the case study is the “minor unit” that is a local classification of the city used by the city council. The city of Donostia/San Sebastian is distributed in 109 minor units. As appreciated in figures 4 and 5, a comparison of risk among the minor units of the city is obtained, as a percentile values.

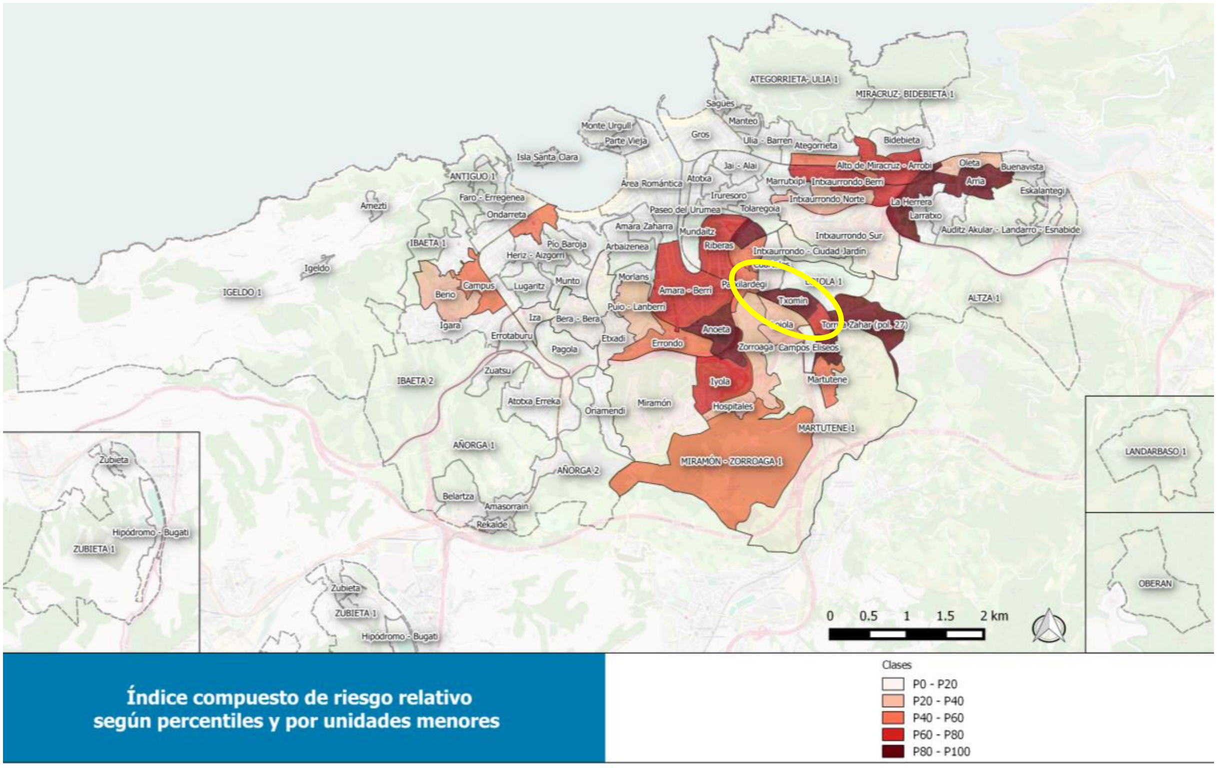

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Figure 4: Risk index for the impact chain: rainfall flooding caused on the urban environment

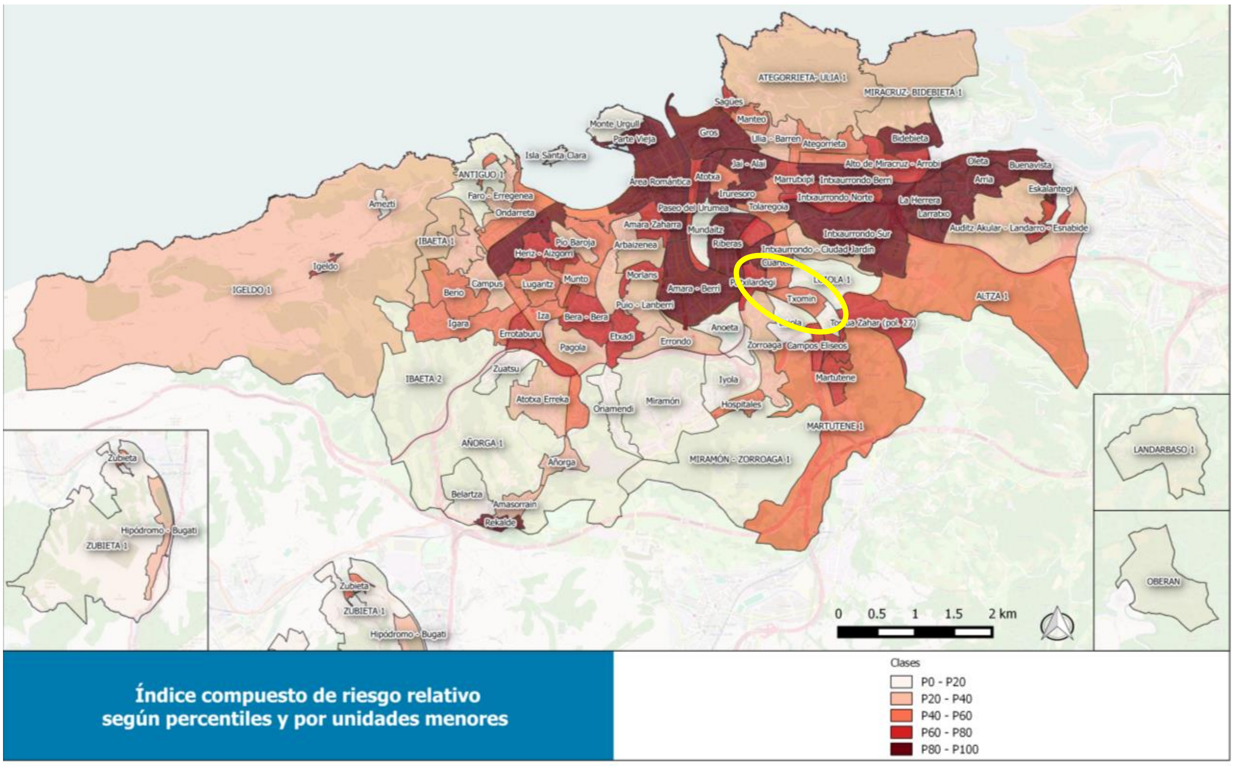

Figure 5: Risk index for the impact chain: increase of temperature and heat waves on the human health.

Risk indexes are built from exposure and vulnerably indexes that, in turn, are built from sensitivity and adaptive capacity. Indexes are ranked from 0 at the minimum to 2 at the maximum.

Attending to the risk results it can be concluded that “Txomin Enea” is one of the areas of the city with high risk indexes for all the impact chains analysed. The area of Txomin Enea is indicated with a yellow mark in figures 4 and 5.
The following table shows all these indexes for Txomin Enea Area for the impact chains:

Table 13: Indexes of Txomin Enea for the analised impact chains.

					RISK
			VULNERABILITY		
IMPACT CHAIN	SENSIBILITY	ADAPTIVE CAPACITY		EXPOSURE	
Rainfall flooding	1.000	1.632	1.090	2.000	2.000
Human health	1.719	1.365	1.535	1.020	1.217

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HAVURI results show that Txomin Enea area is highly exposed to flooding with a high risk on the built environment. Regarding the increase of temperature, the area is not very exposed, but human health sensibility to temperatures and heat waves is high. Therefore, medium-high risk indexes have been obtained for this area.

As appreciated, the results obtained by HAVURI are very detailed and allow a comparative analysis in order to help in the decision-making process to prioritize certain areas or to planning interventions. However, HAVURI needs a huge amount of information of the city in order to create the indexes shown in table 13. Once the information is gathered the analysis is easy to perform and the outcomes are very useful and are presented in form of indexes, maps and graphics which make easier the understanding and interpretation of them. However, the analysis must be carried out by an expert supported by stakeholders of the institution implied.

6.1.2 TXOMIN ENEA CASE STUDY

As a conclusion of the analysis performed by HAVURI, Txomin Enea area from Donostia/San Sebastian was selected for the NBS study and implementation. Besides, it is important to note that the area is in process of urban regeneration and the NBS can be incorporated from the early stages of the area design.

Once the area has been selected, next step in the case study is to develop NBS scenarios to be implemented in Txomin Enea. The objective of NBS implementation is to improve city adaptation to climate change and to mitigate its effects. Considering that Txomin Enea is exposed to high risk of fluvial flooding and high temperatures, the effectiveness of certain NBS in the reduction of these impacts wants to be understood.

For this effectiveness assessment two scenarios are designed with different types and configurations of NBS. The name given to these scenarios responds to the feasibility of the intervention. Therefore, the “feasible” scenario considers the installation of NBS in public spaces and public buildings according to the city council criteria. The “ideal” scenario considers, apart from the “feasible” NBSs, the implementation of NBS in private areas too. The list of NBS considered in both scenarios are summarized in figure 6 and figures 7 and 8 reflect the distribution of the NBS along the neighbourhood.

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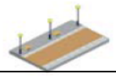
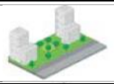
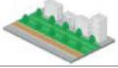
	"Feasible Scenario" NBS	"Feasible Scenario" NBS Surface (Ha)	"Ideal Scenario" NBS	"Ideal Scenario" NBS Surface (Ha)
	199 units of Woody species	0.08	116 woody species more	0.09
	Green roofs in public buildings	1.07	Green roofs in public and private buildings	2.80
	Permeable pavements in some places	0.60	Permeable pavements in all the sidewalks	0.60
	Urban gardens	0.08	Urban gardens	0.08
	herbaceous vegetation in public places.	0.70	Herbaceus vegetation in public places	2.20
	Installing 7 fountains of 7 meters of height	-	Installing 7 fountains of 7 meters of heigh	-
		-	Installing grass car parks	0.27

Figure 6: NBS-scenarios designed for Txomin-Enea case study.

Figure 7: Location of different types on NBS on Txomin Enea. "Feasible scenario"

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Figure 8: Location of different types on NBS on Txomin Enea. “Ideal scenario”

These two scenarios have been modelled and assessed by different methods and purposes:

- Envi-met has been used to understand the effectiveness of the NBS to adapt the neighborhood to the expected temperatures increase.
- CityCAT, on the other hand, has been used to understand the NBS effectiveness to run-off reduction.
- ENERKAD has been used to understand the mitigation effects of the NBS in the energy demand of the buildings.
- NEST has been used to understand the NBS effectiveness to reduce the climate impacts at the neighborhood scale.

The following chapters describe the case studies results of each method.

6.1.3 CityCAT

CityCAT method was selected because it allows to calculate quantitatively the effectiveness of any type of Nature Based Solution regarding runoff reduction, at any scale.

CityCAT needs, on the one hand, a wide amount of cartography information of the study site such as: buildings, soil cover, soil type, terrain and vegetation and; on the other hand, it needs meteorological information representative of the study site. The model runs for a certain rainfall conditions that the user must introduce into the model. In Txomin Enea case study, a typical day of rainfall obtained from a close meteorological station to

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Txomin Enea was used for a return period of 10 years. Climate trends could be included to analyse their effect on urban hydrodynamics.

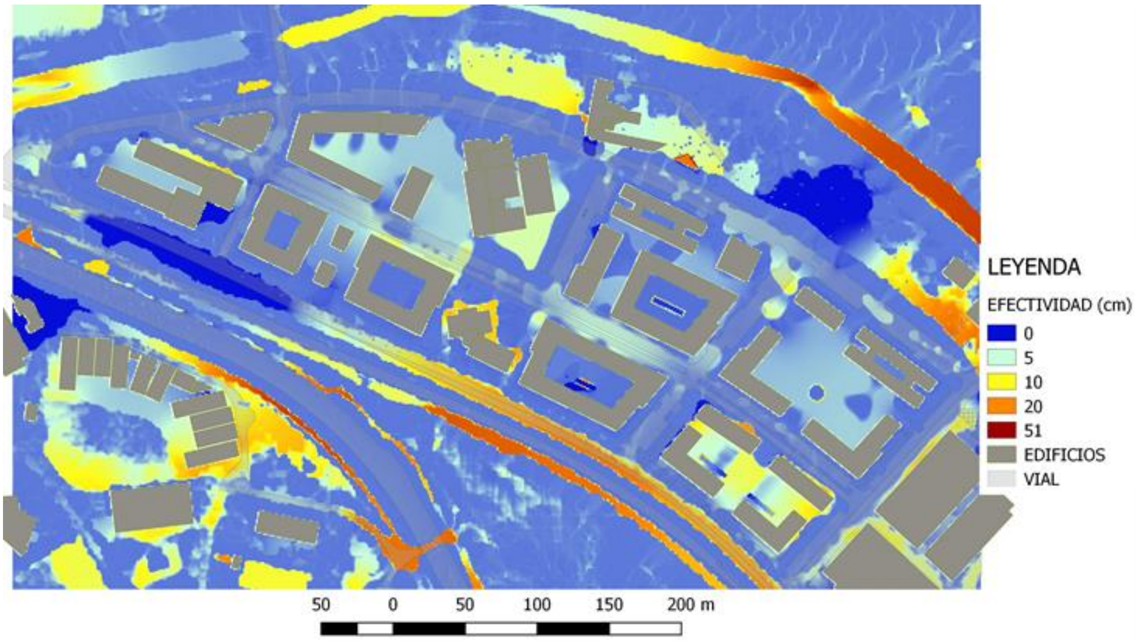

Figure 9: runoff reduction in the “ideal scenario” comparing with the current configuration in Txomin ENEA without NBS. (“feasible scenario” has not been modelled in CityCAT).

CityCAT allows the visualization of the results given as a reduction of a high of the sheet of water and as runoff reduction in centimetres. As appreciated in figure 9 the maximum reduction in the “ideal scenario” comparing with a no NBS configuration is 51 cm. The normal reduction in rest of the study site is between 5 and 20 cm due to the effect of NBS. Results seem to be easy to interpret.

The main disadvantage of the model is that a pre-processing of the cartography is required in order to run it. This pre-processing can be very time-consuming. However, as an advantage, once this pre-processing of the inputs is done, the simulation of different scenarios with different NBS configurations or different meteorological conditions, is very easy to perform.

In this sense, ENVI-met model, also selected for this case study (see chapter 6.1.4), needs very similar inputs to the ones required for CityCAT. Therefore, the information can be shared for both models.

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6.1.4 EnviMET

ENVI-met method was selected because it allows to calculate quantitatively the effectiveness of any type of Nature Based Solution regarding temperature reduction, at neighbourhood scale.

As it was mentioned in the description of CityCAT, ENVI-met also needs a wide amount of cartography information of the study site such as: buildings, soil cover, soil type, terrain and vegetation. On the other hand, it needs meteorological information representative of the study site that matches with the information of CityCAT.

It should be note that ENVI-met does not identify climatic trends, but it allows considering them as inputs to the model. This is because the model runs for a specific weather conditions (air temperature, humidity, wind speed and wind direction) of a certain day that the user must introduce. In Txomin Enea case study, a typical hot day of summer has been simulated, and the data have been obtained from a meteorological station close to Txomin Enea. Results of the model are given in figures 10 and 11.

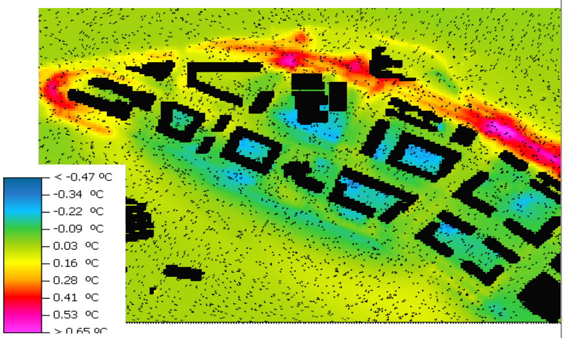
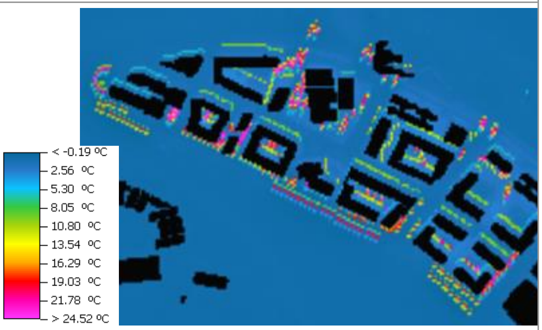
IDEAL SCENARIO	
Temperatures reduction (Tª)	**Mean radiant temperature reduction (Tmrt)**
	

Figure 10: thermal variables reduction in the “ideal scenario” compared with the current configuration in Txomin ENEA without NBS. The results are given at 14.00 pm and at 1.5 m of height. Temperature reduction (left) and Tmrt reduction (right).

FEASIBLE SCENARIO	
Temperatures reduction (Tª)	**Mean radiant temperature reduction (Tmrt)**

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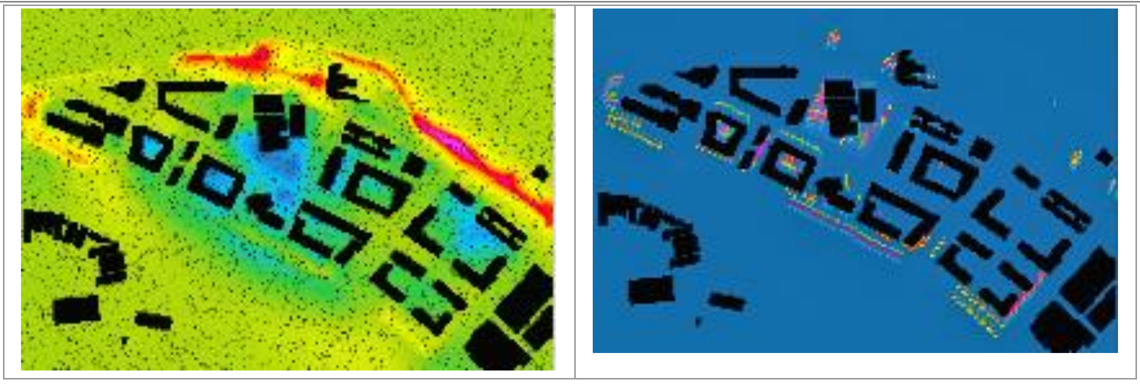

Figure 11: thermal variables reduction in the "feasible scenario" compared with the current configuration in Txomin ENEA without NBS. The results are given at 14.00 pm and at 1.5 m of height. Temperature reduction (left) and Tmrt reduction (right).

The maximum temperature reduction in the ideal scenario (left picture in figure 10), compared with the current situation is 0.78 ºC that matches with the combination of permeable pavement and vegetation surface. The effect of vegetation in the public spaces and private yards are also noticeable, with a reduction of air temperature around 0.1 and 0.3 ºC.

Regarding mean radiant temperature (Tmrt)[6] the reduction is more perceptible because this parameter depends on the shadow projected by urban elements (right picture in figure 11) but also because vegetation keep at lower surface temperature then mineral surfaces that can reach 70ºC. In this case, as appreciated in figure 10, the most reduction is 27.7 ºC matches with the presence of a tree in the ideal scenario versus nothing in the current situation.

The same effects and conclusions are obtained in the comparison between feasible scenario and the current situation with no NBS. As the surface occupied by NBS in feasible scenario is smaller than in the ideal one, the effects of air temperature and Tmrt reduction is also minor and located in the areas of the study site where NBS are located.

The bigger the shadow projected by urban elements the bigger the Tmrt reduction, therefore the higher trees the higher the Trmt reduction.

[6] The **mean radiant temperature** (Tmrt) is defined as the uniform surface temperature of an virtual environment in which the radiant heat transfer with the human body is equal to the radiant heat transfer in the actual environment. It is an area weighted mean temperature of all the objects surrounding the body.

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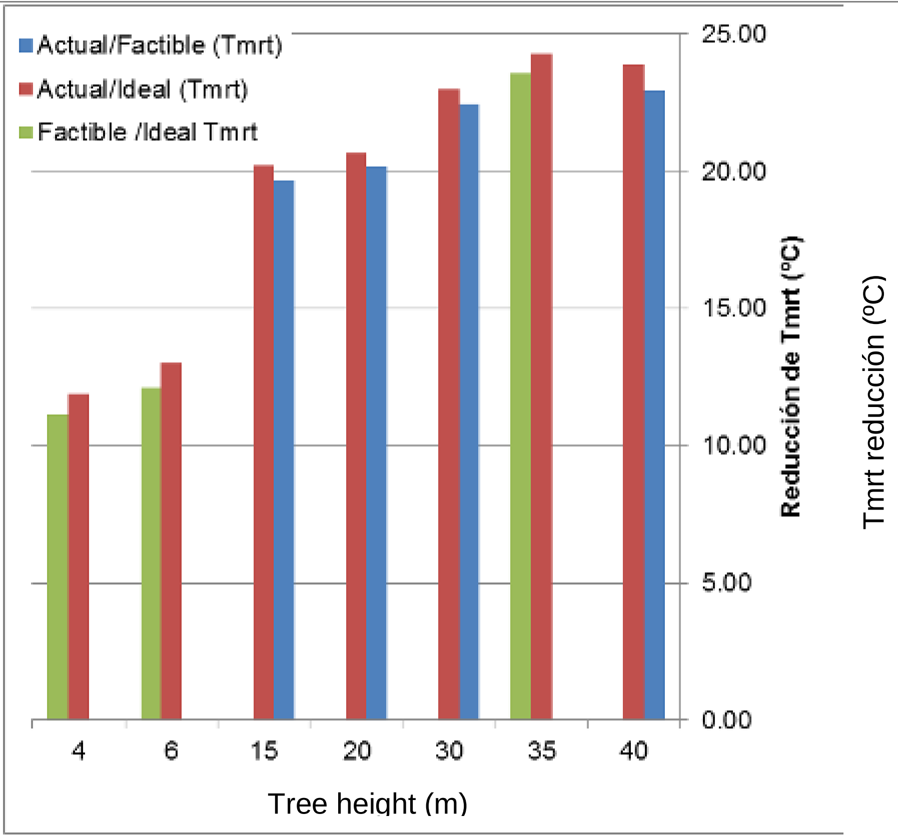

Figure 12: Tmrt reduction depending on the height of trees (at 14.00pm)

It should be note that the effectiveness of NBS temperature reduction varies depending on the selected moment of the day and according to the solar radiation. Moreover, there are different variables that can be assessed, such as air temperature, mean radiant temperature and surface temperature, among others. This variability in the way of express effectiveness is a disadvantage, as far as comparing with other NBS studies. Unfortunately, there is a lack of consensus on how is the better way of measuring the thermal effectiveness of adaptation measures. The scientific community is working on standardising thermal effectiveness related process that is, the way of measure the thermal variable and the metrics to express the effectiveness[7].

6.1.5 ENERKAD

Enerkad method has been selected in order to understand the NBS effectiveness to reduce the energy demand of the buildings. In this sense, the implementation of NBS it is considered a mitigation strategy. This is because the aim is to reduce the consumption

[7] http://www.resin-cities.eu/home/

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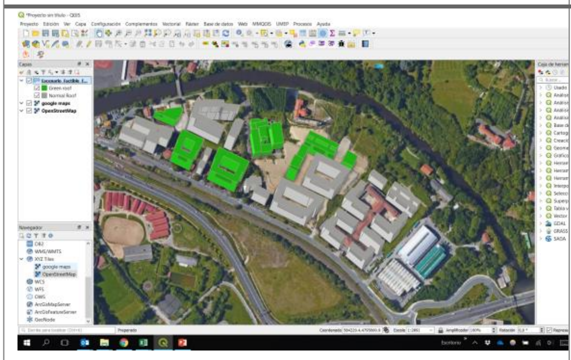
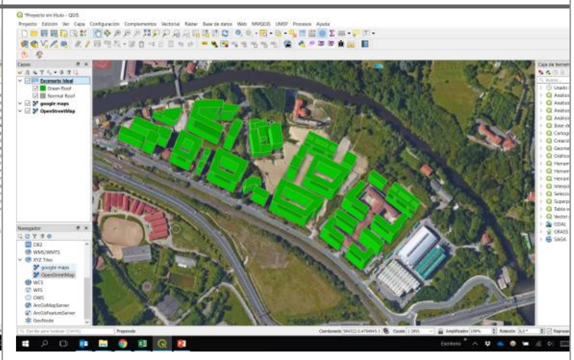
of energy and, as a consequence, to minimize the environmental impacts due to energy consumption.

For the model application, Enerkad needs data regarding the buildings geometry of the neighbourhood and the use of it (thus, results depend on the use given to the building). This information must be easy to find and treat because it is included in the city cadastre. Therefore, data obtaining process shouldn't be time consuming, unless the data from the cadastre has mistakes. In such a case errors have to be identified and corrected.

On the other hand, Enerkad needs the external air temperature as an input variable. This information is included in the model as hourly temperatures of a reference year. In this sense, an analysis of the potential use of ENVI-met results has been done. Considering that ENVI-met provides temperature variation results for a specific hour of a specific day, the analysis requires a huge number of ENVI-met simulations in order to provide all the data demanded by Enerkad. Therefore, this data has been obtained from the EnergyPlus building energy simulation model[8].

In a summarized way, the application of the method is easy to make when the input information is well presented. Regarding the information needed from the NBS, data related to the thermal transmittance of the green roofs NBS had to be included. This data has been obtained from design builder model (see chapter 6.3.1). Other NBS such as green façades, can be assessed by the model too, but the thermal transmittance of them has to be included.

Figure 13 includes pictures of the NBS modelled by Enerkad and table 14 summarizes the green roofs surface considered in the assessment and the number of buildings where these green roofs have been implemented.

Feasible scenario	**Ideal scenario**
	

[8] https://energyplus.net/

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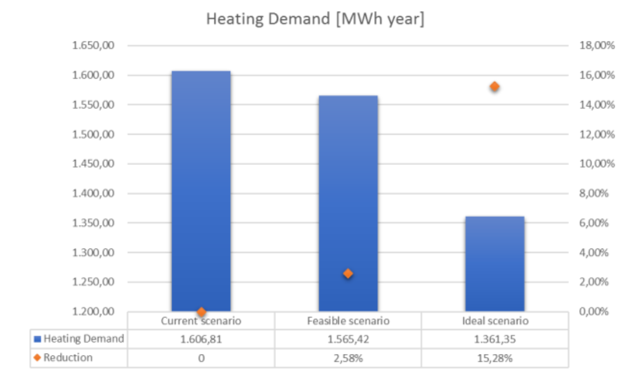
Figure 13: NBS feasible and ideal scenario modelled with Enerkad

Table 14: NBS surface and number of buildings modelled with Enerkad

Scenario	Installed Green roof [m2]	Number of buildings where GF is applied
Current scenario	-	0
Feasible scenario	10.092,87	16
Ideal scenario	28.057,03	38

The results of Enerkad are expressed in terms of MWh of energy demand reduction. This information can be provided per square meter of heated/cooled area too (see figure 14).

Heating demand of the neighbourhood	Heating demand of the buildings where the NBS were implemented
(chart)	(chart)



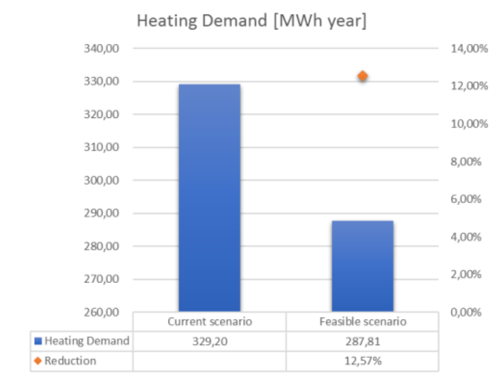


Figure 14: Results provided by Enerkad

Enerkad results shows that green roofs implementation reduces the energy demand of the building in percentages that vary from 2,58% in the feasible scenario to 15,28% in the ideal scenario.

As a conclusion, Enerkad is a method easy to apply when cadastre information is well provided. Information from other methods such as energyPlus and design builder can be easily included to complete the assessment. Enerkad can be also linked with ENVI-met, but strong efforts are needed to obtain the whole hourly temperatures of a year with this approach, other urban climate tools like UWG would be more adapted[9] as it directly provides local climate temperature in a district in function of a temperature from close rural meteo station, depending on the district land use. It also can be use with weather projection to add the local NBS effect. Regarding the NBS, it must be note that Enerkad

[9] http://urbanmicroclimate.scripts.mit.edu/uwg.php

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is focused on buildings and, as a consequence, only NBS that can be implemented in buildings, such as green roofs and green façades, are going to have remarkable effects on the results. The interpretation of the results is easy to make and non-experts can easily understand them.

6.1.6 NEST

NEST tool has been selected in order to understand the NBS effectiveness to reduce the climate impacts at the neighbourhood scale. In this sense, the implementation of NBS it is considered a mitigation strategy.

NEST (Neighbourhood Evaluation for Sustainable Territories) is a tool developed by Nobatek to assess the sustainability of a district building project (analysis of environmental, economic and social impacts).

In its current version, NEST is a plugin for the 3D design software Sketch Up, and therefore the design and modelling of eco-districts is made in 3D. The analysed impacts are based on an LCA approach with various indicators: environmental (primary energy consumption, climate change, waste, water, air pollution), social (user satisfaction on various criteria) and economic (cost of construction and use). It uses a database designed from well-known international databases (mainly ecoinvent) and completed with data, based on the compilation of various national and international benchmark studies (for example the HQE Performance test in France). Some data are specific to France, others are international.

To carry out the modelling with NEST, general elements of the neighbourhood (location, buildings, public spaces, green spaces, infrastructures, etc.), programmatic data and geometric elements (building structure, energy performance of buildings, etc.) are introduced by the user. Because of its polymorphic nature, the neighbourhood is a complex entity to be defined. Therefore, and for simplification purposes, NEST considers the neighbourhood as the aggregation of buildings and infrastructures (roads, parking, public lighting, etc.). The duration of the analysis considered in NEST is fixed (50 years) and in accordance with existing standards for Life Cycle Assessment of buildings.

Regarding the information needed from the NBS, data related to the type and location of the NBS in the neighbourhood has to be included.

Because the aim of the study is to understand to which extend NEST can assess the NBS effectiveness to reduce the climate impacts at the neighbourhood scale, Nobatek first analysed which NBS could be assess with NEST (feasibility study for NEST), and

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produced a matrix NBS type – Indicators (Table 15), based on the tool characteristics and on the WP2 matrix which links NBS types to relevant indicators.

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Table 15: Matrix NBS type - Indicators (feasibility study for NEST)

Indicators / NBS type	1 - Building cooling energy demand reduction	2 - Building heating energy demand reduction	3 - GWP ~~reduction~~	4 - Primary energy demand ~~reduction~~	5 - Runoff reduction	6 - Carbon seques-tration	7 -External air temperature reduction	8 - Biodiversity	9 - Air quality
Urban challenge > USC	Resource efficiency > Food, energy and water	Resource efficiency > Food, energy and water	Climate issues > Climate mitigation	Resource efficiency > Food, energy and water	Water management and quality > Flood management	Climate issues > Climate mitigation	Climate issues > Climate adaptation	Biodiversity and urban space	Air quality **!USC not studied in WP2 matrix!**
1 - Parks and gardens **Urban gardens** **Woody species** **Herbaceous vegetation**			Via C seq.		Absorbed water associated with surfaces	Intermediate calculation	Requires simulation	Biotope coef.	No model / CF
2 - Structures associated to urban networks **Woody species** **Herbaceous vegetation**			Via C seq. (only street trees)		Absorbed water associated with surfaces (only trees & green parking surf.)	Intermediate calculation	Requires simulation	Biotope coef.	No model / CF
3 - Structures characterized by food and resources production								Biotope coef.	No model / CF
4 - Natural and semi-natural water bodies and hydrographic networks					No water model			Biotope coef.	
5 - Constructed wetlands and built					Absorbed water associated with			Biotope coef.	

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structures for water management **Permeable pavements**					surfaces (only permeable pavement)				
6 - Green roofs	Reduction of average cooling/heating energy demands		Change in building compositi on	Change in building composition	Absorbed water associated with surfaces	Missing impact of GR on C seq.		Biotope coef.	No model / CF
7 - Urban planning strategies					Not the scale of assessment in NEST			Not the scale of assessmen t in NEST	No model / CF
8 – Works on soil					Absorbed water associated with surfaces				
9 – Vertical structures (Green walls and facades)	Reduction of average cooling/heating energy demands*		Change in building compositi on	Change in building composition*		Missing impact of GW on C seq.	Requires simulation*		No model / CF
10 – Direct human interventions								Too specific	No model / CF

** No significant impact according to WP2 matrix, but NBK disagrees.*

Legend:

Not relevant according to WP2 matrix
No evidence of **significant link** between NBS type and indicator according to WP2 matrix *Complex analysis because WP2 matrix results (1) differ depending on the NBS type within the same "NBS family", and (2) are provided by urban challenge (not by indicator).*

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When the link to UC / USC is established (at least some NBS in the NBS family have a significant effect on the given challenge), the feasibility to assess these effects with NEST tool is evaluated according to the following colour code:

Already included in NEST tool
Not included in NEST tool, but could be easily incorporated without IT developments
Not included in NEST tool, and its incorporation would ask huge IT developments
Not included in NEST tool, and cannot be incorporated (not compatible with the functional structure of the tool)

In purple, specific NBS types related to Txomin Enea case study (Note: "**Fountain**" isn't listed in WP1 NBS list).

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The four investigated NBS types for the Txomin Enea case study are permeable pavement, green roof, vegetation, and fountain. The conclusions of the previous analysis are that NEST, in its current version, can assess the impacts of:

(1) Vegetation on GWP and runoff reduction

(2) Permeable pavements and green roofs on runoff reduction

Regarding the Txomin Enea case study, NEST is used to provide a quantitative assessment of the environmental impacts of an urban project including NBS with varying degrees of implementation (i.e. from a feasible scenario to an ideal scenario).

Figure 15 includes screenshots of the NBS modelled by NEST.

Feasible scenario	Ideal scenario
	

Figure 15: NBS feasible and ideal scenarios modelled with NEST

The results of NEST are expressed in terms of kg CO_2 eq. for Global Warming Potential (GWP) and m^3/year for runoff reduction (Table 16).

Table 16: Results provided by NEST

NEST indicators (with Nest16_10)	**Units**	***NBS feasible scenario***	***NBS ideal scenario***
GWP			
Infrastructures	kg CO_2 eq.	108 815	95 306
Runoff reduction			
Absorbed water (green spaces)	m^3/year	69 416	76 119
Absorbed water (mineralised areas with low permeability)	m^3/year	3772	11015
Unabsorbed water	m^3/year	130 992	117 046

As expected, NEST results show that the implementation of permeable pavement, green roof and vegetation reduces the GWP of the infrastructures and the water runoff. The improved

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performance of the ideal scenario is captured by the NEST results: GWP is reduced by 12% between the ideal and feasible scenario, and runoff is reduced by 11% between the ideal and feasible scenario thanks to green spaces and mineralised areas with low permeability which absorb the water.

As a conclusion, NEST is a method easy to apply when the required data (location, buildings, public spaces, green spaces, infrastructures, etc.) is well provided. However, the scale of the assessment (neighbourhood) can make the modelling time-consuming.
Regarding the potential of the tool for NBS assessment, NEST not only assesses NBS implemented in buildings (green roofs) but also NBS implemented in the neighbourhood infrastructure (vegetation, permeable pavements). In its current version NEST can assess the impacts of vegetation on GWP, and the impacts of vegetation, permeable pavements and green roofs on runoff reduction. Other indicators (e.g. building energy demand reduction, or biodiversity) and other NBS (e.g. green wall) could be assessed with NEST in the future providing IT developments on the tool.
Lastly, regarding the results, they are easy to interpret and non-experts can easily understand them.

6.2 Alcalá de Henares (centre of Spain)

The selection of the applicable methods for the Municipality of Alcalá de Henares was based on the questionnaire provided to the representatives of the pilot site and their feedback to the questionnaire revealed the following interests in the following fields:

- climate trends:
- air temperature,
- rainfall;
- air quality;
- threats/impacts:
- flooding/runoff;
- air pollution;
- water quality;
- strategy:
- adaptation,
- mitigation;
- output:
- quantitative assessment;
- qualitative assessment;
- decision support;
- indicators:
- GWP reduction;
- primary energy demand reduction;

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- carbon sequestration;
- scale:
- district or neighborhood;
- city;
- specific NBS:
- parks and gardens;
- structures associated to urban networks;
- structures characterized by food and resources;
- natural and semi-natural water bodies and hydrographic networks;
- urban planning.

On the basis of the needs expressed by Alcalá de Henares, the following methods and tools have been identified: GreenPass, EPESUS, Enviro-HIRLAM, Scalable Integrated Risk and Vulnerability Assessment tool for climate change adaptation (SIRVA) and Simile. The details of such tools will be analysed in the following sections.

6.2.1 GreenPass

GreenPass is a software that helps to measure multiple effects of green infrastructure and nature-based solutions at different urban planning phases. It makes performance assessments on climate resilience, rain water management, CO_2 sequestration, wind field and resource and cost efficiency. This tool can be used by municipalities for choosing the proper building structures for their regions and for developing climate strategies, controlling micro-climate targets and reducing urban heat islands (UHIs).

GreenPass was selected because it allows developing mitigation and adaptation strategies by providing both qualitative and quantitative assessments and decision support for various climate impacts such as runoff, air pollution and wind field. The tool does not identify climate trends but generates optimized results based on a fixed set of climate-resilience KPIs potentially including building cooling/heating energy demand reduction, runoff reduction, carbon sequestration and external air temperature reduction. It is applicable at object, district/neighbourhood and city scales and for a variety of NBS classifications such as parks and gardens, structures associated to urban networks, structures characterized by food and resources production, natural and semi-natural water bodies and hydrographic networks or other urban planning strategies. The tool covers most of the selections made by Alcala de Henares municipality in the questionnaire.

Data from the municipality to be assessed needs to be collected individually. Therefore, the quality of this data is not dependent on the method. Once the data is collected, projects are imported in the Software, edited, adapted and prepared for evaluation. Projects star with preliminary design followed by concept and detailed design.

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GreenPass is an interesting tool for providing a comprehensive analysis from design to implementation stages of urban planning projects. Thus, it can be used for comparing selected indicators for intended NBS implementation by the municipalities. It seems promising for being developed to support decision making and to evaluate and control climate adaptation measures at all levels and stages of urban development.

Weakness of this tool can be that it needs support for application and municipalities depend on external services to make the necessary assessments. The tools needed are available at cost with different options such as assessment, pre-certification and complete certification services. Costs vary from 250€ to 30.000€.

In conclusion, GreenPass is suitable for assessing climate change impacts and developing mitigation and adaptation strategies with analyses of NBS effectiveness like green and blue infrastructures for the cities in this regard.

6.2.2 EPESUS

EPESUS is an IT Platform for big data management and decision support for districts or cities. This tool can be used to see and compare environmental impacts resulted from NBS implementation. It allows modelling and monitoring of material and energy flows occurring in built environment, districts and cities, industrial zones, waste and infrastructure facilities, with geographical information system (GIS) based analysis and visualization capabilities and it supports informed decision making at district or city level.

EPESUS is capable of

- Modelling of urban flows based on urban metabolism concept,
- Agent based modelling to assess social aspects of sustainability measures,
- Integrated assessment of all urban flows via multi-objective optimization,
- Life cycle cost analysis,
- Life cycle assessment,
- Dynamic assessment based on trend analysis,
- Integration with BIM tools to utilize hourly energy simulations,
- Analysis and visualization of complex urban data,
- Identification of representative buildings (residential, public, commercial etc.) in district,
- Up-scaling to city or municipality level with geo-referencing.

EPESUS is selected because it allows assessing both mitigation and adaptation strategies at different scales for the intended use (from building to up-to-the-city scale), with quantitative results and decision support mechanisms considering different NBS types like parks and gardens, structures associated to urban networks or green roofs and green walls. Climate trends related to air quality can be included in the analysis. EPESUS conducts LCA with an indicators based approach. Hence, it can generate results based on the indicators defined by

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the user to the inventory. Indicators such as building cooling/heating energy demand reduction, primary energy demand reduction, GWP reduction or carbon sequestration can be analysed once the flows linked with these indicators are identified. Users can perform analyses using different metrics and methods for scenario comparison with proper KPIs and sustainability metrics selections.

If pre-designed components do not fit with the needs, users can design components to model real life needs in platform data inventory. Moreover, users can design system models to model different scenarios and flows between processes of real life systems. These system models will help to store real life relations and to do before-after cases, trend analyses, material flow analyses, network analysis. This provides an important decision support for planning mitigation and adaptation actions for cities.

Depending on the specific use, different inputs are needed. EPESUS can use input gathered from other tasks such as Task 3.1 or Task 3.3 as well as its own LCA indicators as datasets. For example, if the aim is to calculate runoff reduction for a given region, users should define input/output flows such as rainfall volumes, dimensions of the target area etc. For city modelling, all building types needs to be pre-defined or modelled before selecting a specific area to make an analysis.

Its use within a municipality seems feasible, provided that users have some engineering or architectural background or some knowledge in environmental terms. Webinars and workshops can be given to explain the workflow and the idea behind modelling and analysis. A weak point for the application of this tool may be that it is not available for free, but service is available upon demand. Cost of services varies depending on the content of the demand.

Overall, this method can be applied to Alcalá de Henares case for comparative analysis of NBS effectiveness using LCA based and other defined indicators; for energy simulations in buildings/districts and energy demand optimizations with cost analyses. It can provide support in decision making as users can apply different scenarios for comparison. Especially environmental impact analyses and energy simulations can help municipalities with applicable NBS selection for increasing climate resilience in their cities.

6.2.3 Enviro-HIRLAM

The Enviro-HIRLAM (Environment – High Resolution Limited Area Model) is a fully online-coupled ACT-NWP (Atmospheric Chemistry Transport – Numerical Weather Prediction) modeling system. It is useful for predicting the atmospheric weather (meteorological weather, including the precipitation, thunderstorms, radiation budget, cloud processes, and boundary layer structure) taking into account the concentrations of chemical species (especially aerosols) in the atmosphere. Its application includes detection and forecasting of severe weather events and services related to public safety.

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The model is not directly linked with adaptation or mitigation strategies. Nevertheless, the model was selected because it allows to assess and predict climate trends like air quality by generating quantitative weather forecast outputs. Moreover, regarding the climate impacts, the tool takes into account chemical air emissions as input so it allows to calculate climate impacts such as air pollution (and the effect of the chemicals on the weather).

The model uses input data like from GIS, Corinne Land Cover, Global aerosol data, dataset of yearly accumulated fluxes and this guarantees a good level of traceability of information. So, the tool can be used for giving trends on effectivity of NBS solution but it does not allow to assess it directly as it takes into account real land information rather than scenarios, where a NBS could be introduced.

Possible weaknesses of the model can be;

- It has no direct link to NBS effectiveness to improve the resilience of the city and minimize the threats.
- Due to the availability of local information limited to some regions only, the inputs do not seem to be easy to collect.
- The tool is more scientists-oriented to be used for research purposes mostly, and not directly for municipalities. Thus, municipalities need external services to conduct the assessment.
- The tool is focused on real single cases and this makes it less useful for making comparisons.

To conclude, the HIRLAM modelling system can be used by Alcalá de Henares municipality for short-term predictions and assessments on climate trends like air temperature, air quality and rainfall. It can provide forecasts for a situation in the selected region (e.g., in a neighbourhood) and these results can set a before-scenario or baseline for an NBS implementation (e.g. public park implementation within a neighbourhood). These data can be used later for comparison.

6.2.4 SIRVA

Scalable Integrated Risk and Vulnerability Assessment (SIRVA) is an integrated risk and vulnerability assessment tool for climate change adaptation at different scales. It is developed to generate composite index for vulnerability and risk, using different methods for normalizing, weighting and aggregation indicators, included statistical ones.

This tool was selected for Alcalá de Henares because it has the potentiality of assessing different climate trends and climate impacts for implementiation of all types of NBS. It allows to make quantitative analysis on all of the climate trends Alcalá de Henares municipality takes into consideration i.e., runoff reduction, air quality and external air temperature using several methods which also support decision making processes for climate adaptation strategies.

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Linked with these climate trends, a risk and vulnerability assessment can be made for climate impacts such as runoff, air pollution and water quality. These analyses can be carried out for all types of NBS implementation.

Possible weaknesses of the tool can be summarized as:

- The tool is very useful for decision making but access for use is not freely available except the developer. This can make it difficult to apply in Alcalá de Henares.
- Data requirements for the assessments are not clearly identified.
- For application of the tool, deep knowledge is needed.

To conclude, SIRVA tool is suitable for risk and vulnerability assessment of climate trends and climate impacts relevant to runoff and air quality. Service is available at costs for municipalities.

6.2.5 Simile

Simile is a visual modelling environment, allowing to draw the elements of a model, and the relationships between them. It is a modelling and simulation software for complex dynamic systems in the earth, environmental and life science. It is comprised of two-step process. Firstly, the user describes the system using the graphical and mathematical tools provided and then, it simulates the system behavior over a period of time.

This tool was selected because it is found very relevant covering lots of the selections made by Alcalá de Henares regarding both climate mitigation and adaptation. It makes qualitative and quantitative assessment along with decision support mechanisms and it is applicable for differing scales, from object to up-to-the-city scales.

In theory, it can cover all strategy, climate trends, climate impacts and the indicators selected by Alcalá de Henares municipality, but all the modelling has to be done case by case and hence the modeling has to be aggregated through the software.

Main potentialities of the tool can be listed as follows.

- It can help NBS implementation scenarios. For example, the tool is used in T4.1 of N4C project for the socio-economic assessment of NBS related to ecosystem services.
- Simile has already been used for agriculture, ecosystem service, forestry and water management/hydrology and it is very useful for decision making.
- GWP reduction, carbon sequestration and primary energy reduction indicators can be assessed for potentially all of the applicable NBS implementations in Alcalá de Henares.

On the other hand, the following points may be the potential weaknesses of this tool:

- Since modelling has to be done case by case by the users, data requirements strongly depend on the generated models and data inputs should be determined for each

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modelling. Also, strong efforts are needed to collect good quality data. No database is linked with the tool because Simile is a method of visualization.

- It is a complex tool and for the results interpretation, additional explanations are needed for the analyses.
- Municipalities will need external services to make the assessments since expertise is needed for systems modelling.

Nevertheless, there is free download availability for limited services and detailed services are available at costs varying according to the content of the user requirements.

To conclude, although the model needs special expertise and case-by-case modelling, Simile has a strong potential for different scenario visualizations. For having a wide range of application areas, the tool can be applied in Alcalá de Henares municipality to make visualizations for water management and ecosystem services –or for other NBS implementations provided that necessary modelling can be done. Indicators such as GWP reduction, primary energy demand reduction and carbon sequestration and other indicators related with climate threats like flooding, water quality and air pollution can be assessed using Simile.

6.3 Szeged (Hungary)

The selection of the applicable methods for the Municipality of Szeged was based on the adopted methodology consisting in the submission of the questionnaire to the representatives of the pilot site and in the following transposition of feedback from Szeged in the yes/no matrix. The questionnaire revealed interest in the following fields:

- climate trends:
- air temperature,
- rainfall;
- threats/impacts:
- colder winters, warmer summers,
- urban heat island,
- flooding/runoff;
- strategy:
- adaptation,
- mitigation;
- output: decision support;
- indicators:
- building cooling energy demand reduction,
- runoff reduction,
- carbon sequestration,

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- external air temperature reduction;
- scale:
- district or neighbourhood,
- city;
- specific NBS:
- parks and gardens,
- structures associated to urban networks,
- natural and semi-natural water bodies and hydrographic networks,
- urban planning.

On the basis of the needs expressed by Szeged, the following methods and tools have been identified: DesignBuilder, Impact and Vulnerability Analysis of Vital Infrastructure and built-up areas (IVAVIA), Library of Adaptation options (LAO) and UrbClim. The details of such tools will be analysed in the following sections.
These methods can be considered complementary and they could be potentially being all applied without obtaining results with the same meaning.

6.3.1 DesignBuilder

DesignBuilder is an EnergyPlus based software tool used for energy, carbon, lighting and comfort measurement and control.
The tool aims at easing the building simulation process with the final goal of achieving high quality, comfortable buildings that also comply with building regulations, minimise upfront costs to the client, optimise on-going energy costs and reduce environmental impact.

It was selected because it allows assessing mitigation strategies at building scale, considering – among others – factors related to energy demand and consumption that guarantee adequate indoor comfort and the effects of NBSs such as green roofs and walls. Results can support with the optimization of building cooling energy demand or indoor confort. In addition, results are quantitative and can support the decision making process when comparing multiple design solutions. Climatic trends related to air temperature and precipitation may be included in the analysis.
The application of this method was considered proper also since most of this information is expected to be easily available to municipalities and, specifically, to building managers and designers.

DesignBuilder has a modular structure and, depending on the specific use, different inputs are needed. Most relevant inputs to perform energetic analyses include:

- environmental performance requirements (e.g.: energy consumption, carbon emissions, room comfort temperature);
- local climate conditions;
- building properties (e.g.: glazed areas, type of walls, etc.);

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- layout of the building, HVAC systems, natural ventilation systems.

As mentioned, DesignBuilder is composed by various packages and modules. Starting from a 3D model, it allows performing analyses and simulations related to the performance of the building in terms of energy consumptions, thermal, lighting and ventilation comfort, emissions, costs, LEED certification scheme.

Its use within a municipality seems feasible, providing that users are provided with some engineering or architectural background. In addition, climate input data may also be used for the implementation of other models, such as UrbClim. A weak point for the application of this tool in Szeged is that it depends on the activation of specific licensed packages.

By the way, as for the accessibility of the tool, it shall be specified that DesignBuilder is not available for free (except for a 30-day trial version), whereas a number of licensing options are foreseen: the user may decide to purchase one or more of the several packages, each with a license fee varying from 250 to 5.000 €.

Overall, the main potentialities of applying this method in Szeged are:

- identifying mitigation strategies for urban resilience;
- including explicitly air temperature and precipitation trends in building design strategies;
- facing threats related to colder winters and warmer summers, assuring climate comfort in building;
- analyzing heating and cooling energy demand in buildings.

Nevertheless, the following weaknesses for the application of this method in Szeged are identified:

- the model operates at building scale and, thus, multiple analyses, possibly covering all the building types encountered, should be performed to understand the effects of NBSs at larger scale (i.e. a district or the entire city);
- only effects of building-related NBS, such as green roofs and walls, can be assessed.

To conclude, the application of this method can provide interesting results for Szeged municipality. An effective application of the method in the view of increasing urban climate resiliency through measures including NBSs is particularly foreseen when new urban areas for residential or commercial use are being designed, as, in such case, the replication of buildings would assure to gain benefits also at urban scale. In addition, the use of this model could support in identifying building types particularly performing in the specific local climate conditions that, in turn, can be promoted as models for new buildings design or for refurbishment within the city.

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6.3.2 Library of Adaptation Options (LAO)

The Library of Adaptation Options (LAO) is a database of scientific literature related to the performance of adaptation measures to climate related issues.

This tool was selected because it allows assessing adaptation strategies in general, potentially at all scales and including the possibility to take into account most of climate-related hazards. In addition, the LAO is able to filters those literature works dealing with adaptation measures related to ecosystem-based adaptation and, when a work is selected, multiple indicators can be extrapolated, including flood effectiveness and heat effectiveness when they are relevant for the source considered.
The application of this method was considered proper especially as a starting point to improve research and knowledge about existing adaptation strategies and the other themes of interest for the municipality. In addition, the LAO can be useful to gather information about real case studies where these options have been implemented. In addition, no specific knowledge is necessary and its use is free.

The options in the LAO can be filtered according to a number of criteria, including the type of hazard, the scale of application and the type of adaptation option. In this last category, ecosystem based adaptation options are explicitly mentioned.
For each option, according to the results available from the sources that the library collects, general features, cost-efficiency, effectiveness against climate hazards, vulnerability and details about implementation are extrapolated from the pertinent scientific literature.

Overall, the main potentialities of applying this method in Szeged are:

- identifying adaptation strategies for urban resilience;
- identifying reference case studies where adaptation strategies including NBSs have been implemented;
- including a wide number of hazards and trend scenarios;
- neither specific needs in terms of personnel skills or costs existing.

Nevertheless, the following weaknesses for the application of this method in Szeged are identified:

- this tool is a database, and not properly a model. In this sense, its uses are strongly correlated to its contents and to the sources it includes;
- the NBSs explicitly considered (green roofs, green facades, trees, vegetation and green urban areas) match only partially with those of interest for the municipality with

To conclude, the application of this method can be seen as an interesting starting point for building knowledge with respect to NBS aimed at adaptation at various scales and with respect to various hazards. In addition, if the LAO will be constantly updated, its use may acquire a great value added with respect to other models.

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6.3.3 Impact and Vulnerability Analysis of Vital Infrastructure and built-up Areas (IVAVIA)

IVAVIA is a risk analysis methodology that helps cities in understanding cause-effect relationships of climate change, identifying geographical risk and vulnerability hotspots, assessing the demographic, economic and local impact of climate change now and for the future.

This methodology was selected because it allows assessing adaptation strategies in general, at all scales and including the possibility to take into account all climate-related hazards. The theme of NBSs is included in the methodology as a contribution to coping capacity (i.e. ability of systems, using available skills, values, resources, and opportunities, to address, manage, and overcome adverse conditions in the short to medium term) and, in this sense, NBSs such as those selected by Szeged are particularly suitable to be assessed by the methodology.
Results can be either qualitative or quantitative, they are provided in terms of potential climate change risk and can be used for decision making, for example, by introducing a threshold of acceptable risk.
The application of this method was considered suitable also because, being very general, the municipality has the possibility to tailor the level of application according to data availability and personnel background and knowledge, which could turn crucial aspects when trying to perform analyses at urban scale. Nevertheless, due to the fact that this tool is a general methodology, the quality of the results of the assessment is strongly influenced by data availability and by users expertise and ability to catch the most important factors for vulnerability assessments in the local area where it is applied. The methodology is developed within the H2020 Resin project and – according to the latest knowledge – it is private..

The main steps for the application of the methodology are:

- prepare for the vulnerability assessment and gather the necessary information;
- structure the information;
- quantify and combine the vulnerability indicators;
- assess risk;
- present outcomes.

Each step is organized in modules, and for each module precise instructions are given in the methodology guidelines.

Overall, the main potentialities of applying this method in Szeged are:

- identifying adaptation strategies for urban resilience;
- assessing the impacts various climate-related hazards, including air temperature and rainfall trends in a climate change perspective;

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- providing and comprehensive assessment of the vulnerability at various scales in a synthetic result, allowing to plan strategies to reduce risk that can be seen as strategies towards resilience;
- measuring how NBSs such as parks and gardens, structures associated to urban networks, natural and semi-natural water bodies and hydrographic networks are effective in reducing risks by increasing the coping capacity.

Nevertheless, the following weaknesses for the application of this method to any city (and to Szeged, too) are identified:

- being a general methodology, the tool provides results whose quality is strongly influenced by data availability and capabilities of the users; indeed, most of the data necessary for planning and strategy building are often inadequate in resolution and limited in access;
- the model is not supported by a software or kind of tools. The methodology is purely theoretical. Since a software and/or an Excel sheet to support the implementation of the methodology do not exist, the municipality adopting the method will have to customize its own methodology, for example, by creating an editable spreadsheet or questionnaires, in order to facilitate the use and the collection of results.

To conclude, the application of this method, if properly customized and fed with precise and reliable information, can support Szeged in the assessment of the effectiveness of NBSs in increasing urban resilience. The use of such wide methodology may also enable the city to integrate the evaluation of other aspects affecting urban resilience in general. However, it is pointed out once more that the Municipality shall duly select the input information and the assumptions at the basis of the customization so that the result of the method can be useful to the planning of adaptation strategies.

6.3.4 UrbClim

UrbClim is a model for performing detailed urban climate analyses, providing results in terms of temperature, wind speed and humidity. The main parameters of the model are aimed to characterize both surface and atmospheric features.

It was selected because it allows assessing adaptation and mitigation strategies at both district and city scale considering aspects related specifically to air temperature, which can be interpreted also in terms of external air temperature reduction. The results of the model are quantitative and can be used to objectively compare different strategies of land use and to guide the decision making process according to the output obtained. Climatic trends related to air temperature may be also included in the analysis.
The application of this model was considered proper also since most of this information is expected to be easily available to municipalities from local meteorological data.

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As mentioned, UrbClim is a software that performs meteorological simulations aimed at performing urban climate analyses. Before launching the simulation, the user has to go through the surface module, where land use features (vegetation, urbanization) are set for each cell of the grid that will be analysed and then through the atmospheric module, in order to represent the atmospheric boundary layer.
Its use within a municipality seems feasible, especially in Szeged where a urban climate measurement network with 24 stations is in operation and could provide high-resolution basic meteorological data, but users shall be provided with proper background in order to set the simulation correctly and to analyse the results to provide synthetic outputs for decision makes or stakeholders. In addition, the results of this analysis can be used an input information for the IVAVIA methodology, when defining the hazard for the risk assessment. A weak point for the application of this tool in Szeged is that it seems that the tool cannot be purchased, as it is private, but there are services provided by the owner company that includes the use of the tool.

Overall, the main potentialities of applying this method in Szeged are:

- identifying mitigation and adaptation strategies for urban resilience at both district and city scale;
- including explicitly air temperature trends in planning strategies in order to face threats related to colder winters, warmer summers and urban heat island effects;
- relying on quantitative results for the decision making process.

Nevertheless, the following weaknesses for the application of this method in Szeged are identified:

- the model requires expert users and its accessibility is limited;
- NBSs are not considered specifically, but their effect is taken into account when characterizing land surface feature.

To conclude, the application of this method in Szeged may be effective in addressing some specific issue of interest of the municipality using a scientific-based approach. Nevertheless, the scale of the analyses and the options of the model may not able to capture the specific nature of the NBS selected.

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7 Conclusions

Nature Based Solutions contribute both to mitigate and to adapt the cities to the impacts caused by climate change at urban level. Several methods and tools exist for assessing each strategy. However, none of them allow to cover the whole steps included from analyzing climate trends that could affect the cities, to NBS effectiveness. This fact highlights the need of the work done in task 3.4, that aimed to organize the huge amount of information existing in the field of climate resilience, to understand to which extend the NBS are considered in this area and to bring all this information closer to the municipalities.

As the main result of the task a decision support guideline has been created with the aim of helping the municipalities in the selection of the methods and tools that can answer to their specific interests in the field of climate resilience and NBS. A detailed process has been followed to create the guidelines and several results have been obtained in the meanwhile:

- A collection of all the issues that a deep climate resilience and NBS assessment must cover.
- A detailed analysis of the methods for understanding which parts of the climate resilience they allow to consider.
- A ranking of methods according to which extend they answer to climate resilience needs.
- Real case studies of the most promising methods.
- Theoretical case studies for other promising methods.

Thanks to developed guidelines, municipalities will have at their disposal a tool that:

- Allows them to understand which kind of tools provide information in the fields of their interest.
- Provides completed information about selected tools: climate trends, strategies, hazards, indicators and NBS considered, at which scale they work and the availability of them.
- Allows understanding the possibility to the municipality of making the assessment without the help of external support services.
- It also allows to estimate the potential cost of a study related to climate resilience assessment and NBS implementation.
- Moreover, it provides links where the municipalities can find more information about selected methods and tools.

The guidelines are going to be implemented in Nature4Cities platform and municipalities will be able to make the assessment for free. With all, the aim of bringing closer urban climate resilience assessment and NBS to the municipalities is fulfilled.

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On the other hand, several lacks from existing methodologies have been identified too. The main challenge in the methodology development has been the lack of connections between the different parts that the methodology must cover. This is because strategies and climate hazards has been worked in a split way. Therefore, the need of connecting better mitigation and adaptation information to facilitate the municipalities taking robust decisions regarding the NBS implementation has been identified as one area to be further investigated.

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9 References

Chapter 2.2 T.3.1 Urban metabolism

[N4C D.3.1] Nature4Cities Project deliverable 3.1 – Inventory and report on N4C urban flows, components and system boundaries.

Chapter 3.2 RACER assessment

[EU, 2005 and 2009] European Commission, 2005. Impact Assessment Guidelines.

[EU, 2005 and 2009] European Commission, 2009. Impact Assessment Guidelines. Online available: http://ec.europa.eu/smart-regulation/impact/commission_guidelines/docs/iag_2009_en.pdf

[EU, 2005 and 2009] European Commission, 2009. Part III: Annexes to Impact Assessment Guidelines.

Chapter 4.2.1 Climate trend analysis

[IPCC, 2014] Revi, A., D.E. Satterthwaite, F. Aragón-Durand, J. Corfee-Morlot, R.B.R. Kiunsi, M. Pelling, D.C. Roberts, and W. Solecki, 2014: Urban areas. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 535-612.

[IPCC annex II 2014] IPCC, 2014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130.

[Adaptecca] http://escenarios.adaptecca.es/#model

[Copernicus] https://cds.climate.copernicus.eu/#!/home

[EuroCordex] https://www.euro-cordex.net/

Chapter 4.2 Methodology: From climate trends to NBS effectiveness

[CoM, 2018] Bertoldi P. (editor), Guidebook 'How to develop a Sustainable Energy and Climate Action Plan (SECAP) – Part 1 - The SECAP process, step-by-step towards low carbon and climate resilient cities by 2030, EUR 29412 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96847-1, doi:10.2760/223399, JRC112986

Chapter 4.3 Results from the RACER assessment: methods and tools classification

[N4C, D2.2] Nature4Cities project deliverable 2.2 - Expert modelling toolbox report and build models.

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10 Annexes

10.1 Annex I: References studied in the state of the art

10.1.1 List of scientific articles reviewed

1) A conceptual framework for an urban areas typology to integrate climate change mitigation and adaptation (William Solecki et al., 2015)
2) A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas (Christopher M. Raymond et al., 2017)
3) A Study of Climate-Smart Farming Practices and Climate-resiliency Field Schools in Mindanao, the Philippines (Alvin Chandra et al., 2017)
4) Adapting or maladapting: Building resilience to climate-related disasters in coastal cities (Elnaz Torabi et al., 2018)
5) Analyses of extreme precipitation and runoff events including uncertainties and reliability in design and management of urban water infrastructure (Teklu T. Hailegeorgis et al., 2017)
6) Applicability of open rainfall data to event-scale urban rainfall-runoff modelling (Tero J. Niemi et al., 2017)
7) Assessing climate change-induced flooding mitigation for adaptation in Boston's Charles River watershed, USA (Chingwen Cheng et al., 2017)
8) Building Resilient Cities: A Simulation-Based Scenario Assessment Methodology for the Integration of DRR and CCA in a Multi-Scale Design Perspective (Giulio Zuccaro et al., 2018)
9) Building up resilience in cities worldwide – Rotterdam as participant in the 100 Resilient Cities Programme (Marjolein Spaans et al., 2016)
10) Building up resilience in cities worldwide – Rotterdam as participant in the 100 Resilient Cities Programme (Marjolein Spaans et al., 2016)
11) City membership in climate change adaptation networks (Sierra C. Woodruff, 2018)
12) CityFeel - micro climate monitoring for climate mitigation and urban design (Peter Gallinelli et al., 2017)
13) Climate change and the city: Building capacity for urban adaptation (Jeremy G. Carter et al., 2015)
14) Climate change in the urban environment: Advancing, measuring and achieving resiliency (Meghan Doherty et al., 2016)
15) Climate resilient urban development: Why responsible land governance is important (David Mitchell et al., 2015)
16) Designing backcasting scenarios for resilient energy futures (Yusuke Kishita et al., 2017)
17) Designing, planning, and managing resilient cities: A conceptual framework (Kevin C. Desouza et al., 2013)

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18) Ecosystem-based adaptation in cities: An analysis of European urbanclimate adaptation plans (Davide Geneletti et al., 2016)
19) Ecosystem-based solutions for disaster risk reduction: Lessons from European applications of ecosystem-based adaptation measures (Alistair McVittie et al., 2017)
20) Edible green infrastructure: An approach and review of provisioning ecosystem services and disservices in urban environments. (Alessio Russo et all, 2017)
21) Empowering local governments in making cities resilient to disasters: research methodological perspectives (Chamindi Malalgoda et. al; 2018)
22) From urban meteorology, climate and environment research to integrated city services. (A.Baklanov, 2018)
23) Green strategies for flood resilient cities: the Benevento case study (Adriana Galderisi et al., 2017)
24) How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28 (Diana Reckien et al., 2018)
25) How can urban green spaces be planned for climate adaptation in subtropical cities? (Zhaowu Yu et al., 2017)
26) How do urban characteristics affect climate change mitigation policies? (Hidemichi Fujii et al., 2017)
27) In search of the principles of resilient urban design: Implementabilityof the principles in the case of the cities in Serbia (Eva Vaniˇsta Lazarevi´c et al., 2018)
28) Indicators of urban climate resilience: A contextual approach. (Stephen Tyler et al., 2016)
29) Innovative urban forestry governance in Melbourne?: Investigating "green placemaking" as a nature-based solution (Natalie Marie Gulsrud et al., 2018)
30) Monetary value of urban green space as an ecosystem service provider: A case study of urban runoff management in Finland (Sveta Silvennoinen et al., 2017)
31) Nature based solutions to mitigate soil sealing in urban areas: Results from a 4-year study comparing permeable, porous, and impermeable pavements (A. Fini et al., 2017)
32) Nature-based solutions for resilient landscapes and cities Raffaele Lafortezza (Raffaele Lafortezza et al., 2017)
33) Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges (Nicolas Faivre et al., 2017)
34) Nature-based solutions to promote human resilience and wellbeing in cities during increasingly hot summers (Angelo Panno et al., 2017)
35) New Strategies for Resilient Planning in response to Climate Change for Urban Development. (Kumjin Lee et all, 2018)
36) Opportunities for mutual implementation of nature conservation and climate change policies: A multilevel case study based on local stakeholder perceptions (I. Essl et al., 2018)
37) Outdoor comfort conditions in urban areas: On citizens' perspective about microclimate mitigation of urban transit areas (C. Piselli et al., 2018)
38) Overview of challenges and achievements in the climate adaptation of cities and in the

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Climate Proof Cities program (2015)
39) Participatory land-use approach for integrating climate change adaptation and mitigation into basin-scale local planning (Isao Endo et al., 2017)
40) Place Based Approach to plan for Resilient Cities: a local government perspective (Anumitra V. Mirti Chand, 2018)
41) Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk. (Yosef Jabareen, 2013)
42) Prevention, mitigation and adaptation to climate change from perspectives of urban population in an emerging economy (Clara Ines Pardo Martínez et al., 2018)
43) Projecting future climate change impacts on heat-related mortality in large urban areas in China (Ying Li et al., 2018)
44) Regulating urban surface runoff through nature-based solutions – An assessment at the micro-scale (Teresa Zölch et al., 2017)
45) Review of urban surface parameterizations for numerical climate models (Gemechu Fanta Garuma, 2017)
46) Scenarios for adaptation and mitigation in urban Africa under 1.5 C global warming (Shuaib Lwasa, 2018)
47) Sustainable smart resilient low carbon eco knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization (Martin de Jong et al., 2015)
48) The health benefits of nature-based solutions to urbanization challenges for children and the elderly – A systematic review (Nadja Kabisch et al., 2017)
49) The role of cities in multi-level climate governance: local climate policies and the 1.5 C target (Harald Fuhr, 2018)
50) The role of ecohydrology in creating more resilient cities (Iwona Wagner et al., 2013)
51) The superior effect of nature based solutions in land management for enhancing ecosystem services (Saskia Keesstra et al., 2018)
52) Towards resilient flood risk management for Asian coastal cities: Lessons learned from Hong Kong and Singapore (F.K.S. Chan et al., 2018)
53) Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors? (Francisco J. Escobedo et al., 2018)
54) Urban Green Infrastructure as a tool for urban heat mitigation: Survey of research methodologies and findings across different climatic regions (H. Saaroni et al., 2018)
55) Urban green space as a countermeasure to increasing urban risk and the UGS-3CC resilience framework (Mahua Mukherjee et al., 2018)
56) Urban natural environments as nature-based solutions for improved public health – A systematic review of reviews (M. van den Bosch et al., 2017)
57) Urban Sustainability Transformations in lights of resource efficiency and resilient city concepts (Kerstin Krellenberg et al., 2016)
58) Utilising green and bluespace to mitigate urban heat island intensity. (K.R. Gunawardena et all, 2017)
59) What might 'just green enough' urban development mean in the context of climate change adaptation? The case of urban greenspace planning in Taipei Metropolis,

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Taiwan (Leslie Mabon et al., 2018)
60) Why climate change adaptation in cities needs customised and flexible climate services (Jörg Cortekar et al., 2016)

10.1.2 List of related projects reviewed

1) BIOTOPE CITY - Not a project- A foundation set up in Amsterdam (Founded in 2004)
2) CITYFIED - Replicable and innovative future efficient districts and cities (2014-2019)
3) CLARITY - Integrated Climate Adaptation Service Tools for Improving Resilience Measure Efficiency (http://clarity-h2020.eu/)
4) CLEVER CITIES - Co-designing Locally tailored Ecological solutions for Value added, socially inclusivE Regeneration in Cities (2018-2023)
5) CLIMA.C.3/SER/2015/0007 - EU strategy on adaptation to climate change: knowledge assessments
6) ESPREssO - Enhancing Synergies for disaster PRevention in the EurOpean Union (2016-2018)
7) ESSAI URBAN (2013-2015)
8) EUROGATE – Masterplan for a microclimatic aligned district in Vienna (2015-2020)
9) GO GREEN (2010-2012)
10) GREEN 4 CITIES (2012-2015)
11) GREEN SURGE - Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy (2014-2016)
12) GREEN.RESILIENT.CITY - Management and planning tools for a climate-sensitive urban development
13) GRETA - GReen infrastructure: Enhancing biodiversity and ecosysTem services for territoriAl development (2017-2019)
14) GROW GREEN - Green Cities for Climate and Water Resilience, Sustainable Economic Growth, Healthy Citizens and Environments (2017-2022)
15) I-REACT - Improving Resilience to Emergencies through Advanced Cyber Technologies (2016-2019)
16) LUCID - Development of a Local Urban Climate Model and its Application to the Intelligent Design of Cities (2007-2010)
17) METAVERDE - Metodologie produttive e gestionali per migliorare la qualità del verde ornamentale (2010)
18) MySmartLife - Smart Transition of EU cities towards a new concept of smart Life and Economy (2016-2021)
19) OPENESS - Operationalisation of natural capital and ecosystem services (2012-2017)
20) OPERAs - Ecosystem Science for Policy and Practice (2012-2017)
21) OPPLA - online platform with the aim of to simplify how we share, obtain and create knowledge related to ecosystem services, natural capital and nature based solutions. (created in 2016)
22) OPTEEMAL - Optimised Energy Efficient design platform for refurbishent at district

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scale (2015-2019)

23) PLANHEAT - Integrated tool for empowering public authorities in he development of sustainable plans for low carbon heating and cooling (2016-2019)
24) RAMSES - Reconciling Adaptation, Mitigation and Sustainable Development for citiES (2012-2017)
25) RESIN - Climate Resilient Cities and Infrastructures (2015-2018)
26) URCA - The Quality and Quantity of Runoff Water in Relation to Land Use in Urbanised Catchments (2012-2016)
27) Water JPI MUFFIN – Multi-scale urban flood forecasting: from local tailored system to a Pan-European service (2016-?)

10.1.3 List of models and tools identified in the context of the task

1) ANOVA - Analysis of variance applied to the evaluation of nature based therapy on mental health and well-being
2) CityCAT – Runoff
3) CityCanopy
4) Climate-ADAPT web platform
5) Design Builder - Energy demand and consumption
6) Ecosystem-based adaptation in cities (EbA) - Developing a classification of EbA and a scoring system to analyze the treatment of EbA in urban climate adaptation planning, and apply it to a sample of plans in Europe. CoM (Covenant of Mayors)
7) E-guide - decision support for climate change adaptation planning by city administrators
8) EnerKad - Energy diagnosis and definition of mitigation scenarios
9) EnviMET - model for the simulation of surface-plant-air interactions
10) Enviro-HIRLAM - online coupled (integrated) NWP and ACT modelling system for research and forecasting of meteorological, chemical and biological weather
11) EPESUS - LCA, indicator based analysis, ABM simulation results, dynamic assessment result
12) FTA - fault tree analysis - Used to support the generation of various risk factors and countermeasures to improve resilience
13) FRM - Flood Risk Management practices with model-based assessments
14) GREENPASS - visualize and explain the deficiencies and potentials of urban areas and give suggestions how to integrate GI
15) HAVURI - Scenario-based vulnerability and risk assessment of climate change
16) IPCC projections of Future Changes in Climate
17) IVAVIA - Impact and Vulnerability Analysis of Vital Infrastructure and built-up Areas
18) Library of Adaptation Option
19) Myclimateservice.eu
20) NEST - Neighborhood Evaluation for Sustainable Territories

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21) PDE Toolbook for Matlab (v.2015, Mathworks, Natick, MA, USA) - Modeling of soil respiration and soil CO2 concentration
22) PLINIVS models - allows to determine realistic impacts on selected elements at risk
23) Rayman - Is developed to calculate short wave and long wave radiation fluxes affecting the human body
24) Simile - visual modelling environment, allowing you to draw the elements of your model, and the relationships between them.
25) SIRVA - Scalable Integrated Risk and Vulnerability Assessment tool for climate change adaptation.
26) SWAT - Soil and Water Assessment Tool.
27) SUA - tool will enhance efficiency and effectiveness in dissemination and communication of climate information and knowledge to all actors who need it.
28) Transition handbook - step-by-step guide containing resources that cities can use in climate adaptation planning.
29) UrbCLEAN - Urban climate modelling
30) SWMM - US EPA Storm Water Management Model
31) WRF - Weather Research and Forecasting Model

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10.2 Annex II: Forms of the methods

To be included in the platform.

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