WEGENERATE IMPACT MODEL

D7.1 - WeGenerate Impact Model for Sustainable Inclusive Neighbourhood (Initial)

PEOPLE-CENTRIC SUSTAINABLE NEIGHBOURHOODS

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Document Information

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List of Abbreviations

Abbreviation	Description
BAPV	Building Applied Photovoltaics
BEMS	Building Energy Monitoring System
BIPV	Building-Integrated Photovoltaics
CEC	Citizen Energy Community
CO2	Carbon Dioxide
DHW	Domestic Hot Water
DQI	Design Quality Indicator
DSO	Distribution System Operators
DUT	Driving Urban Transition
EIC	Expected Impact from the Call
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
EPOV	European Energy Poverty Observatory
EV	Electric Vehicle
FI	Flexibility Index
FTE	Full Time Equivalent
GHG	Greenhouse Gas
H2020	Horizon 2020
HVAC	Heating, Ventilation, and Air Conditioning

IAQ	Indoor Air Quality
ICT	Information and Communication Technologies
IEQ	Indoor Environmental Quality
IM	Impact Model
KPIs	Key Performance Indicators
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCE	Life Cycle Energy
LED	Light-Emitting Diode
LowEx	Low Exergy
NPV	Net Present Value
NZC	Net Zero Cities
NZEB	Nearly Zero-Energy Building
PED	Positive Energy District
PMV	Predicted Mean Vote
POE	Post Occupancy Evaluation
PPD	Predicted Percentage Dissatisfied
PV	Photovoltaic
PV-T	Photovoltaic-Thermal
RER	Renewable Energy Ratio
RES	Renewable Energy Sources

RH	Relative Humidity
SDGs	Sustainable Development Goals
SPEN	Sustainable Plus Energy Neighbourhood
TSP	Total Suspended Particles
V2G	Vehicle-to-Grid
V2H	Vehicle-to-Home
WP	Work Package
ZEN	Zero Emission Neighbourhood

About the WeGenerate project

The Project 'WeGenerate' as signified by its name, seeks to infuse the elements of people and co-creation in the urban regeneration processes. It fully embraces the paradigm shift from building for the people to building with the people. We – cities, citizens, communities, businesses, researchers, and practitioners – take ownership of the urban regeneration processes and co-create together sustainable, people-centric, accessible, and beautiful neighbourhoods. This project is based on the stories of four neighbourhoods and their communities located in different parts of Europe. Although they are at different stages of development and are facing different urban challenges, they share the same vision of positive change. WeGenerate will help them to reinvent themselves and in the process find new values and opportunities. WeGenerate sets out a journey to find the right ingredients and recipes for sustainable and inclusive urban regeneration that can create long-lasting positive impacts within the neighbourhoods and beyond. The process will be highly participatory with close collaboration with the city administrations as well as the citizens, local communities, and businesses. Advanced digital applications (such as Digital Twins, Metaverse and extended reality) will be implemented and experimented with to support decision-making and stimulate citizen engagement. Expertise in Social Science and Humanities is called upon to foster social innovation and participatory actions across the project. In addition to technological and social interventions, the art and cultural dimensions will be drawn on in the co-creation processes. Four sustainable and people-centric neighbourhoods will be realised by the end of the project, the legacy will be upheld through replication by five Fellow Cities and others, who are inspired by the WeGeneration stories.

Executive Summary

The main objective of this report is to provide an Impact Model for the effective design and assessment of successful urban regeneration processes in People-Centric Sustainable Neighbourhoods (PCSN). In the WeGenerate project, a People-Centric Sustainable Neighbourhood is defined as an urban area that take action to empower the community and to upgrade the reduction of greenhouse gas emissions throughout sustainable and inclusive urban interventions that can create long-lasting positive impacts within the neighbourhoods and beyond. The PCSN concept focuses strongly on the **interaction** and **integration between the built environment and open spaces, urban services, users and communities, energy, and mobility systems/facilities, facilitated by Digital tools and platforms to provide attractive, resilient, and affordable solutions** for citizens**.** Acting at community level would enhance the transformation of the built environment towards carbon-neutral societies.

The proposed Impact Model goes beyond standardised sustainability assessments accounting for stand-alone urban sectors, to highlight the importance of a neighbourhood-based integrated approach in long-term perspective taking into account social inclusiveness and low carbon lifestyles.

Several on-going initiatives at both European and international level are focusing on the neighbourhood and district levels, such as concept of Zero Emissions Neighbourhoods and Climate Neutral Cities, Positive Energy Districts, New European Bauhaus, and other EU projects/initiatives. The WeGenerate impact assessment framework includes indicators from established and emerging EU methodologies that aim to assess the performance of People-Centric Sustainable Neighbourhoods (PCSN), and cities, by adapting a number of carefully selected KPIs to characterize the multidimensional perspectives of PCSN.

The WeGenerate Impact Model focuses on the environmental, social, well-being, and economic impacts of PCSN, emphasising integrated urban regeneration approaches, such as circularity, resilience, and digitalisation aspects. Hence, the main categories of Key Performance Indicators (KPIs) selected for the WeGenerate Impact Model are Energy, Environment, Social Inclusion & Citizens Participation, Socio-Economics, Sustainable Mobility, and Integrated Urban Regeneration.

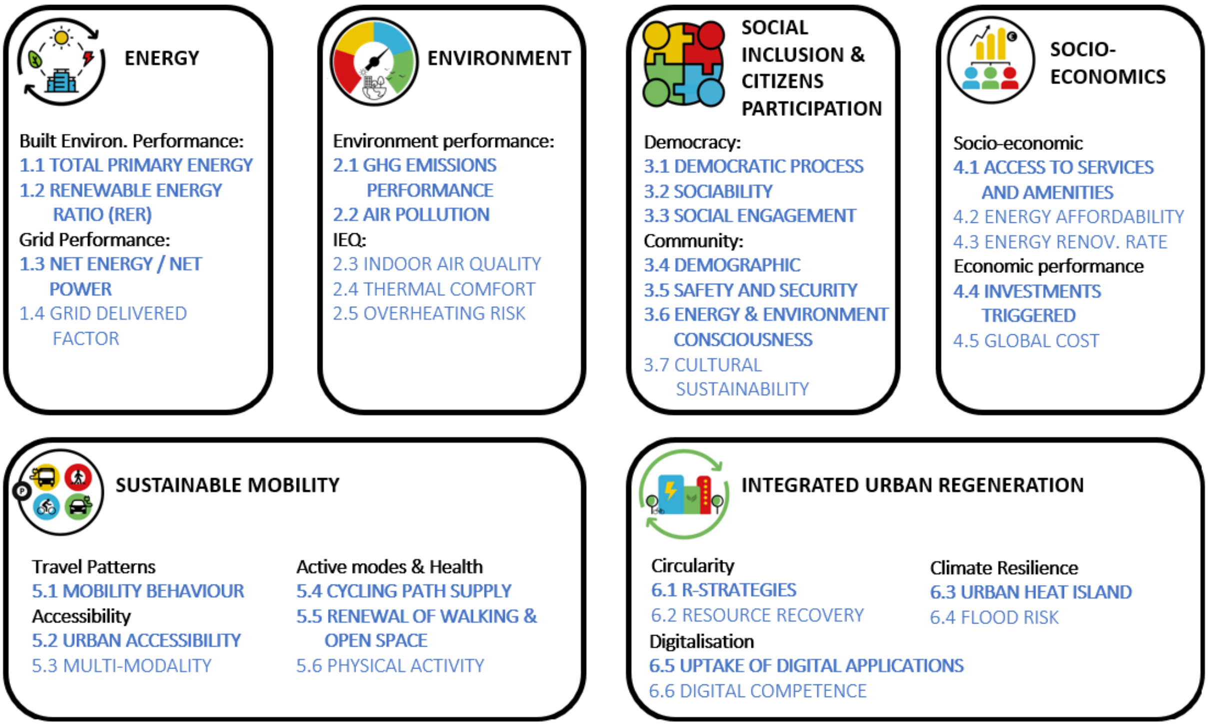


Figure 1. WeGenerate Impact Model overview – Categories and KPIs sets.

The WeGenerate Impact Model is designed as an integrated indicators system composed by:

- **6 KPI Categories** are proposed to group the various KPI sets according to sustainable urban domains for impact evaluation.
- **14 macro-objectives** are addressed as part of the Impact Model.
- **20 KPIs are defined as Core Indicators** to measure sustainability and inclusiveness within the neighbourhoods under analysis.
- **13 KPIs defined as Optional Indicators** to complement the impact assessment process.

The proposed KPIs are presented by explaining the motivation for the selection, the definition, and the unit, as well as the calculation method used for each KPI and considering aspects mainly at community level.

The assessment of some indicators is sometimes difficult to calculate due to their quantitative and data-based nature. Therefore, some supporting indicators have been selected to provide a qualitative assessment of the urban regeneration progress in neighbourhoods. For instance, the people-centred approach for social indicators applied by the WeGenerate storytelling actions have a multiple-method approach where both quantitative and qualitative procedures can be applied to evaluate social sustainability and the interactions between urban communities, built environment, and environmental qualities.

The Impact Model provides a common starting point for the WeGenerate project, which brings together key stakeholders from the demo sites and the consortium's expert partners to jointly develop, define and apply a comprehensive impact assessment framework. A continuous testing process during the implementation of actions in the different communities across Europe (Italy, Portugal, Romania, and Finland) will result in a proven, validated, and consistent Impact Model at the end of the project in alignment with the harmonization and standardisation strategies at EU level.

Finally, this Impact Model aims to provide a coherent guideline for the evaluation of urban regeneration projects targeting sustainable communities in order to assess the multidimensional impacts of a neighbourhood-based approach at a long-term perspective.

This document is structured mainly in 2 main parts as follows:

Firstly, it provides the general information on the scope of the present deliverable at the introduction and objectives sections. Consecutively, the background section provides an overview of considered existing assessment frameworks used to assess sustainable neighbourhoods, and cities, along with the Expected Impacts of the Call (EICs). The following section includes an explanation of the methodological approach used to develop the WeGenerate Impact Model.

Secondly, the KPIs categories sections introduce the proposed indicators (see **Figure 1**) by explaining the motivation for selection, the definition and unit, and the calculation method used for each KPI.

The report concludes with an application of the Impact Model to WeGenerate demo projects and an explanation of future updates.

1. Introduction

This task will form a common starting point for the WeGenerate, bringing main stakeholders from Demos and expert partners in the consortium together to jointly prepare and define a clear framework with the specification that addressed Sustainable Development Goals SDGs, ambition levels, boundary conditions, and KPIs for Sustainable Inclusive Neighbourhoods. Specific quantitative KPIs (and associate definition) covering the entire sustainability range including energy, mobility, environment, social (e.g., quality of life, citizen engagement), health, accessibility, economic circularity, digital aspects, etc. at neighbourhood level will be considered in the framework to ensure a robust and all-rounded assessment. This task will have its most intensive development during the first year of the project; thereafter, WP7 will follow and monitor the implementation of the impact model across the Demos.

The WeGenerate Impact Model (IM) provides an overview of the defined Key Performance Indicators (KPIs), taking into account a multidimensional perspective, to characterise the urban regeneration impacts in People-Centric Sustainable Neighbourhoods accounting for long-term strategies for sustainable transitions. The proposed assessment framework aims to go beyond the traditional sustainability development assessment of buildings based mainly on environmental, economic, and social impacts and highlights the importance of the community-based approach.

In the WeGenerate project, a People-Centric Sustainable Neighbourhood is defined as an urban area that take action to empower the community to upgrade the reduction of greenhouse gas emissions throughout sustainable and inclusive urban regeneration that can create long-lasting positive impacts within the neighbourhoods and beyond. The WeGenerate process is highly participatory with close collaboration with the city administrations as well as the citizens, local communities, and businesses. In addition, advanced digital applications are designed and demonstrated to support decision-making and to stimulate citizen engagement through attractive, resilient, and affordable solutions for low carbon footprint lifestyles and businesses.

The main KPIs categories selected for the WeGenerate Impact Model are energy, environment, social inclusion & citizens participation, socio-economics, sustainable mobility, and integrated urban regeneration, taking into account aspects mainly at neighbourhood level.

The WeGenerate Impact Model for People-Centric Sustainable Neighbourhoods will be regularly updated through a structured monitoring process based on regular follow-up questionnaires and workshops in cooperation with the Demos and Innovation Clusters, as well as it will be presented in periodic project meetings. A number of KPIs will be assessed in all the Demo, while an additional set will be Demo-specific. Based on monitoring and experience gained, the model will be reviewed and updated throughout the project and the Final WeGenerate Impact Model for Sustainable Inclusive Neighbourhood will be delivered at the end of the project.

2. Objectives

The main objective of this report is to provide an assessment framework for efficient design and successful implementation of People-Centric Sustainable Neighbourhoods (PCSN). It defines a set of Key Performance Indicators (KPIs) which aims to support the promotion, implementation, and replicability of PCSNs.

The Impact Model assesses the multidimensional aspects of PCSN such as energy, environmental, economic, and social impacts while emphasizing specific aspects of the concept such as citizens participation and inclusion, mobility, and integrated urban regeneration qualities.

The task of the Impact Model does not finish with this document but will accompany the development of the demo projects to monitor how the Impact Model is implemented and used in the demos. This will be done in periodical sessions involving the Innovation Hub and through follow-up questionnaires in cooperation with the demo's implementers and the responsible partners (WP7) for providing monitoring guidelines and the evaluation of impact assessment. A continuous process will result in a proven, validated, and consistent Impact Model at the end of the project.

The proposed model aims to provide background and scientific knowledge to the on-going international activities that pursue the harmonization of characterizing climate neutral neighbourhood initiatives, which are named differently depending on the analysis perspective: Zero Emission Neighbourhoods, Positive Energy Districts, Smart Cities, NetZeroCities, etc. Particular attention was paid to the integration of social inclusion quality aspects, as it was assumed that citizens should be at the centre of any urban intervention, in line with the New European Bauhaus Initiative.

Concerning the scale of study for WeGenerate KPIs, most of the indicators proposed are planned to be calculated at neighbourhood scale by integrating data within its boundaries. In addition, a group of proposed KPIs address the building and/or household levels to assess specific conditions that cannot be measured at different scale; in those cases, statistical approaches or representative typologies will be consolidated to illustrate the impact of WeGenerate intervention in the Demo Neighbourhoods.

2.1. WeGenerate IM at a glance

***Figure 2.** Impact Model Categories.*

The WeGenerate Impact Model is designed as an integrated indicators systems composed by:

- **6 KPI Categories** are proposed to group the various KPI sets according to sustainable urban domains for impact evaluation
- **14 macro-objectives** are addressed as part of the Impact Model
- **20 KPIs are defined as Core Indicators** to measure sustainability and inclusiveness within the neighbourhoods under analysis
- **13 KPIs defined as Optional Indicators** to complement the impact assessment process

***Table 1.** Summary of KPI used in the WeGenerate IM sorted by categories.*

Number	*Name*	*Units*	*Core*	*Optional*
1 – Energy				
Built Environment Performance				
1.1	Total Primary Energy Balance	kWh/(m^2·y)	•	
1.2	Renewable Energy Ratio	%	•	
Renewable Energy Ratio (RER)				
1.3	Net Energy/Net Power	kWh or kW	•	
1.4	Grid Delivered Factor	Dimensionless		•
2 – Environment				

Number	*Name*	*Units*	*Core*	*Optional*
Environmental Performance				
2.1	GHG Emissions Performance	kg CO2eq/y	•	
2.2	Air Pollution from the Energy Consumption	kg/m^2 y	•	
IEQ				
2.3	Indoor Air Quality	ppm, % of time		•
2.4	Thermal Comfort	˚C, PMV or PPD%, of time		•
2.5	Overheating risk – Heat Index	%		•
3 – Social Inclusion and Citizen Participation				
Democracy				
3.1	Democratic process	%, Likert scale	•	
3.2	Sociability	#, Likert scale	•	
3.3	Social engagement	%, Likert scale	•	
Community				
3.4	Demographic Composition	%	•	
3.5	Safety and Security	% per thousand population, Likert scale	•	
3.6	Energy and Environmental Consciousness	%, Likert scale, kWh/year/person, L/year/person, Sales share	•	
3.7	Cultural Sustainability	#, %		•
4 – Socio-Economics				
Socio-economic				
4.1	Access to services and Amenities	%	•	
4.2	Affordability of Energy	%		•
4.3	Energy Renovation Rate	%		•
Economic performance				
4.4	Investments Triggered	€/m2, € (total)	•	
4.5	Global Cost	Ç/m^2		•
5 – Sustainable Mobility				
Traver patterns				
5.1	Transport Behaviour	%, #	•	
Accessibility				
5.2	Urban Accessibility	Likert scale, %	•	
5.3	Multi-modality	Likert scale		•
Active modes & health				

Number	*Name*	*Units*	*Core*	*Optional*
5.4	Cycling path supply	km^2	•	
5.5	Renewal of Walking and Open Spaces	#, km^2	•	
5.6	Physical activity	minutes		•
6 – Integrated Urban Regeneration				
Circularity				
6.1	Recycling and circular economy initiatives	-	•	
6.2	Resource Recovery	#, kg		•
Digitalisation				
6.3	Urban Heat Island	%	•	
6.4	Flood Risk	%		•
Climate resilience				
6.5	Uptake of Digital Applications in Urban Regeneration Processes	#	•	
6.6	Digital Competence	#		•

3. Background

Today, urban areas worldwide are on a path of radical transformation, driven by the need to meet the ambitious climate goals of the Paris Agreement [1]. The European Green Deal [2]and the Mission on Climate-neutral and Smart Cities [3]have set ambitious energy and climate targets in Europe to reduce greenhouse gas (GHG) emissions, energy vulnerability, and increasing the reuse and recycling of materials. The EU initiative NetZeroCities (NZC) [4] has been designed to help cities overcome the obstacles they face in achieving climate neutrality by 2030 by developing and promoting a methodology for planning and implementing net zero cities. The European Commission has also launched the New European Bauhaus initiative, which provides a forum where Europeans can come together to exchange ideas on climate-friendly architecture [5].

In this context, the built environment could make a major contribution to the transformation of the EU energy sector towards carbon-neutrality, as the building stock and mobility is responsible for over 60% of total EU energy consumption and over 50% of GHG emissions [6]. By incorporating renewable energy systems (RES), energy storage and heat recovery systems, buildings can become net zero-energy or even energy positive, while reducing energy consumption and associated emissions.

It is essential to go beyond the concept of individual buildings and adopt a neighbourhood and community approach, which enables multiple synergies that can contribute to enhance urban sustainability in a profitable way, while also incorporating the collective social potential of sustainable solutions [7]. In the Renovation Wave strategy [8], the European Commission has highlighted the importance of neighbourhoods' spatial dimension by "placing an integrated, participatory and neighbourhood-based approach at the heart of the Renovation Wave".

In this context, the People-Centric Sustainable Neighbourhoods (PCSN) requires integration of different systems, interaction between buildings and users, and other mobility, Information and Communication Technologies (ICT) and energy systems. In parallel, several ongoing concepts are closely related to the concept of PCSN, such as Zero Emission Neighbourhood (ZEN) [9]and Sustainable Plus Energy Neighbourhood (SPEN) [10].

3.1. Reference Assessment Frameworks for Urban Regeneration

The WeGenerate Impact Model is consistent with a number of EU and international directives and policies that call for decarbonisation, sustainability, affordability, resource efficiency, and resilience in the built environment and beyond. In particular, the assessment framework considers the revised the Renovation Wave [8], the New European Bauhaus [5], Clean Energy for all Europeans [11], the Paris Agreement [1], and the Energy Performance of Buildings Directive (EPBD) [12]. In addition, it considers the new framework that is being developed in relation to the Sustainable Development Goals (SDGs) [13], with a specific focus on:

- SDG 7 (Affordable and Clean Energy)
- SDG 8 (Decent Work and Economic Growth)
- SDG 9 (Industry, Innovation, and Infrastructure)
- SDG 11 (Sustainable Cities and Communities)
- SDG 12 (Responsible Consumption and Production)
- SDG 13 (Climate Action)

Table 2 summarises the main methodologies used as key reference to develop WeGenerate Impact Model. In particular, it explains when the methodology was developed and describes which objective and which KPIs categories it covers, the total number of indicators applied, and whether the methodology is applicable at the building, district, or city levels.

Table 2. *Summary of main Reference Assessment Framework consulted for the WeGenerate IM design.*

Methodology	*Objective*	*Categories*	*Level*
ARV – Assessment Framework for CPCC [14] 	The framework assesses the multidimensional aspects of Climate Positive Circular Communities (CPCC) such as energy, environmental, economic and social impacts while emphasizing specific aspects of the concept such as circularity and architectural quality.	Energy and Environmental (9); Social (11); Architectural Quality (10); Circularity (2); Economic (4); ***In total: 36 indicators***	Building and District levels
CrAFT - NEB Impact Model [15] 	To develop an assessment and guidance tool geared at a whole systems approach for use in complex urban interventions.	Governance (4); Economic (9); Social-cultural (12); Healthy living (7); Environmental (14) ***In total: 46 indicators***	City level

Syn.Ikia [16] syn.ikia Methodology Framework for Plus Energy Buildings and Neighbourhoods	To provide a joint framework for the evaluation of the performance of positive energy buildings and neighbourhoods	Energy and Environmental (9); Economic (11); Indoor Environmental Quality (IEQ) (8); Social (14); Smartness and Flexibility (2). ***In total: 44 indicators.***	Building and District levels
Thriving places Index [17] THRIVING PLACES INDEX	The Thriving Places Index (TPI) is a new compass for the 21st century. It supports decision makers across sectors to assess and prioritise policy, based on the impact it has on the wellbeing and sustainability of people and communities.	Equality (5); Place and environment (4); Mental and Physical health(4); Education and learning (2); Work and local economy (4); People and community (3); Sustainability (3) ***In total: 25 indicators***.	Town, city or region
Urban Mobility Indicators [18] A COMFORT AND SAFETY B SERVICE DEMAND C CONNECTING DESTINATIONS D SUPPORT AND ENCOURAGEMENT	Urban agenda indicators relating to Sustainable Development Goal 11.2 to invest in more accessible, safe, efficient, affordable and sustainable infrastructure for walking and public transport.	Comfort and Safety (7); Service and Demand (1); Connecting destinations (2); Support and encouragement (4) ***In total: 14 principal indicators***.	Town, City, District levels.
EU Smart Cities Information System (SCIS) [19] EU Smart Cities Information System	To develop indicators to measure technical and economic aspects of energy, mobility, and ICT related measures in European funded demonstration projects.	Energy Peformance (3); Environmental (3); Economic (5); ICT related technologies (7); Mobility related technologies (9). ***In total: 27 indicators***	Building, Set of Buildings, District, City levels.

As part of T7.1 workflow, the WeGenerate Impact Model (IM) accounts for the abovementioned established methodologies at the European level that aim to assess the performance and inclusiveness of sustainable neighbourhoods and cities, in view to extract valuable approaches and lessons learnt which could inspire and strengthen the WeGenerate Impact Model design and KPIs selection process. Simultaneously, the WeGenerate IM covers all the Expected Impacts of the Call (EOCs) resulting from the implementation of urban regeneration processes of People-Centric Sustainable Neighbourhood.

From the Impact Models described below, the ARV [14] project in particular has been used as reference. The energy, environment, social engagement, and other punctual KPIs were extracted from that Framework, with punctual adaptations to the WeGenerate Framework needs, E.G., using Total Primary Energy instead of Non-Renewable.

Figure 3 illustrates how the WeGenerate Impact Model combines categories from established methodologies, core dimensions of sustainable development goals and additional categories to meet the EOCs of the call and successful urban regenerations in project Demos.

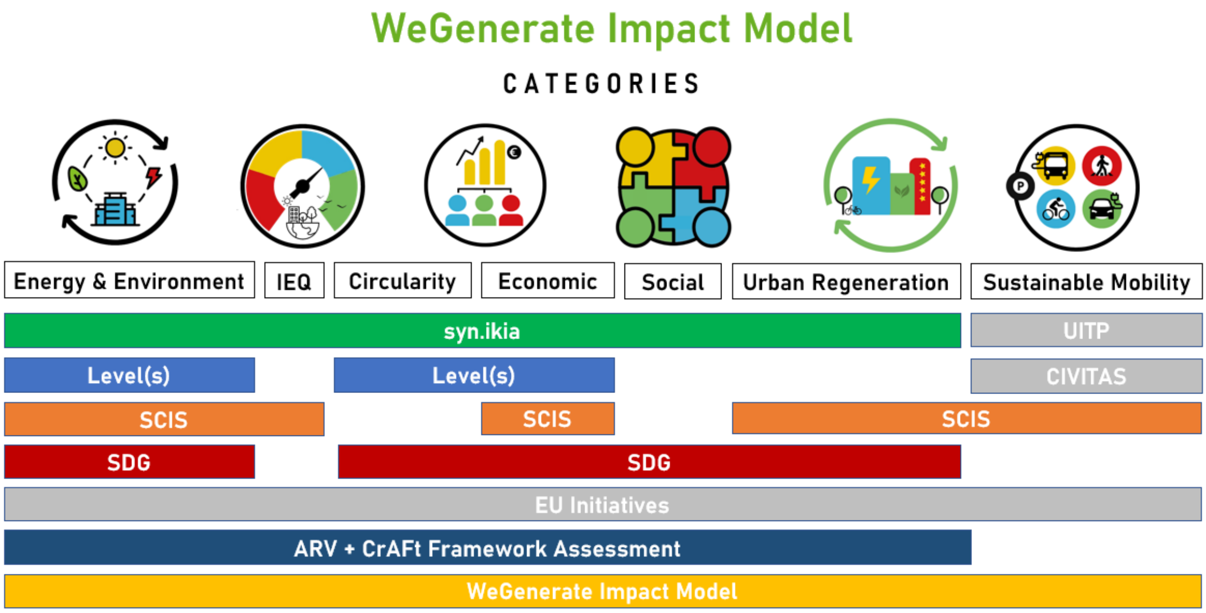


Figure 3. *Reference Assessment Frameworks and Initiatives reviewed as part of WeGenerate Impact Model.*

3.2. Impact Model for People-Centric Sustainable Neighbourhoods

This section addresses how the WeGenerate Impact Model supports the Action Plans design and the Implementation Roadmaps planning towards People-Centric Sustainable Neighbourhoods based on the Expect Outcomes of the call (EOC).

Table 3 provides an overview of WeGenerate´s EOCs, Highlights under scope and Wider Long-Term Expected Impacts as required by the EU as a funding institution. The proposed Impact

Model directly addresses and goes beyond all the core EOCs. The complete list is included and categorised here below:

***Table 3**. Overview of WeGenerate's Expected Outcomes & Highlights under Scope of the Call*

Expected Outcomes & Highlights under Scope of the Call
1 /2 – Energy / Environment
EOC #3: More sustainable, low emission, inclusive and affordable neighbourhoods and built environment.
EOC #7: Increased well-being and economic prosperity of citizens in a low carbon, sustainable built environment by ensuring high **indoor and outdoor quality**, and affordability of renovation solutions.
S02: Ensure the proposed solutions allow to identify and integrate local sources of raw materials
S06: Ensure the proposed solutions contribute to **optimising energy balancing** at local level…
S09 Where relevant, include **concepts for energy circularity**…
3 – Social Inclusion and Citizen Participation
EOC #1: Lasting behavioural change of people and economic actors to lower carbon footprint lifestyles and businesses.
EOC #2: Mainstreamed participatory planning processes & interaction with relevant stakeholder groups **in city planning.**
EOC #6: Raised awareness and increased capacity of citizens on participatory processes for enhanced sustainability and environmental performance.
S01: Deliver innovative methods and solutions for the regeneration of neighbourhoods… **based on participatory planning processes and innovative decision-making procedures and digital applications.**
S12 Consider social innovation where relevant…
5 – Sustainable Mobility
EOC #4: Improved accessibility of neighbourhoods through building-integrated**, sustainable mobility solutions.**
S05 Ensure the proposed solutions include concepts for local renewable energy integrated at building and district level **in combination with multi-modal mobility** concepts targeted to both urban and rural neighbourhoods
4 – Socio-Economics
EOC #7: Increased well-being and economic prosperity of citizens in a low carbon, sustainable built environment by ensuring high indoor and outdoor quality, and **affordability of renovation solutions**.
S04 Ensure the proposed solutions allow for involving all stakeholder groups… also seeking to address gentrification issues in neighbourhoods affected by energy poverty.
6 – Integrated Urban Regeneration
EOC #5: Extended application of digital apps. & tools to ease decision-making processes in complex stakeholder structures.
EOC #8: Increased attractiveness of deep renovation, new regeneration & smart growth models for sustainable living.
S03 Ensure the proposed solutions include new evidence-based approaches (e.g., strategies and digital tools) to help quantify the benefits of integrated built environment transformation aimed at climate neutrality
S07: Ensure the proposed solutions comply with the **principles of circular economy**, favouring urban mining, efficient use of resources, durability, reuse, and recyclability.
Transversal aspects
S08 Ensure the proposed solutions are developed taking into account **local environmental, social, and economic conditions and** are relevant for the **different geographical locations** targeted.
S11 Lead at least 3 **large-scale demonstrations of the solutions in diverse geographical areas**, with various local environmental, social, and economic conditions.
S10 Where relevant, investigate whether and how the proposed approaches could apply to **cultural heritage buildings.**
S13 Facilitate awareness raising and capacity building of citizens and relevant stakeholders…
Wider Long-Term Expected Impacts
#1 Efficient and sustainable use of energy, accessible for all is ensured by a **clean energy system and a just transition** **#2 Higher buildings' performance** with **lower environmental impact**s through increased rates of **holistic renovations**. **#3 Higher quality, more affordable built environment** preserving **climate and environment**, and safeguarding **cultural heritage** and ensuring better **living conditions**. **#4 More energy efficient building stock**s supported by an accurate **understanding of buildings performance** in Europe and of related evolutions. **#5 Building stocks that effectively combine energy efficiency, renewable energy sources and digital and smart technologies** to support the transformation of the **energy system towards climate neutrality**.

In addition, transversal EOCs and Highlight under scope addressed by various KPIs are included in the dedicated category sections. Furthermore, the Impact Model covers common aspects of planned Demos interventions through the proposed 6 categories and sets of Core KPIs, as well as it allows to deepen the assessment based on the optional indicators, which complement the analysis across the various categories, in accordance with demos specific actions. For further information, preliminary Demos' action plans can be consulted in **Appendix A – Preliminary Plans for the Application of the IM in the Demo-sites**.

4. Methodology

Evaluating People-centric Sustainability in urban regenerated areas is not a straightforward task since district and neighbourhood scale for GHG emission sectors are both complex just as sustainability itself [20], [21], [21]. Therefore, most existing sustainability evaluation frameworks at neighbourhood scale share this principle, which could only be properly assessed by taking into account the interconnected effects of multiple criteria. From another perspective, it is important for policies and interventions to react to standardised practices which accounts for stand-alone urban sectors, otherwise there is a chance, that they will have limited effectiveness. Therefore, to adopt proper measures and attenuate the existing challenges and barriers, a holistic perspective should be used for People-Centric Sustainable Neighbourhoods, as well [22] as decision making processes usually involve multiple and often different criteria, that differ by stakeholders. Despite the differences in opinions when making decision, it is key to take all drivers into consideration.

Thus, there lies a need for a holistic, multidimensional assessment framework within the wider people-centric sustainable urban regeneration process that is able to recognize the technical capabilities of various district resources, accommodate various markets and enable the effect of stakeholders and businesses arrangements.

In accordance with the abovementioned need for multidimensional assessment, the Impact model design followed the procedure described below, in view to overcome the multi criteria-driven challenges derived the different nature of Demos interventions:

1. **Identification of categories** to align the WeGenerate Impact Model with Demos' planned interventions and expected outcomes of the call, which already were stated at WeGenerate project level.
2. **Selection of a Core Group of experts' partners** involved in the WP7, which focuses on designing the framework for impact assessment and the performance monitoring protocol, aimed to address the various KPIs categories according to expert partners' knowledge domains. A meetings series was coordinated from early task developments to define a join approach for the Impact Model design process.

3. **Initial distribution of KPIs categories** is done among core partners to allow a robust initial KPIs-set proposal, which integrates key sustainability domains as part of the urban regeneration process to a People-Centric Sustainable Neighbourhood model.
4. Inspired by the **established assessment frameworks identified** (see Section 3.1), core partners delivered their insights to define an initial KPIs selection, in view to share it with Demos and Innovation Cluster to feedback collection.
5. A series of **City Dialogues on Impact Model design** were developed to introduce a first draft of KPI sets proposed and collect initial feedback from Demos, as well as to present a tentative workflow and planning schedule up to D7.1 submission date.
6. Once first consultations were conducted, core partners initiated **drafting KPIs descriptions and calculation methods** accounting for required amendments in alignment with the collected insights.
7. A **1st Impact Model draft** was shared with Demos & Innovation Clusters.
8. After a review period, the **Impact Model was enhanced based on Demos and Clusters' analysis** through a structured feedback collection questionnaire.
9. **A dedicated workshop on Impact Model definition** involving Local Circles, Innovation Clusters and WP7 Core Group was developed with the aim to consolidate the proposed categories and KPI sets.
10. **A revised 2nd version of the Impact Model** is drafted by the task leader, which also included further contributions from core partners.
11. **The Impact Model (Initial version) is sent to Quality Review**, which led integrating received comments and completing required modifications in accordance with QAP.
12. **Deliverable D7.1 submission (Initial version)** is completed at the due date (M9).

Future steps:

- Integrating Lessons Learnt (Final version)
- Impact Model submission (Final version)

4.1. Impact Model design

The first phase of the Impact Model design for People-Centric Sustainable Neighbourhoods (PCSN) was based on desktop research and analysis of reference models, which are described in the background section. From the analysis of existing assessment systems, it can be concluded that the most widely used approach for assessing the sustainability of urban regenerations is a multi-criteria approach taking into account the three dimensions of urban sustainability: environmental aspects (mostly represented by indicators such as GHG emissions and primary energy), economic aspects (e.g., investments triggered or global cost) and social requirements (e.g., social engagement), in line with the triple bottom line sustainability framework.

However, achieving all ambitions of the WeGenerate project requires a multidisciplinary focus that includes a number of additional features. As previously highlighted, successful innovations of People-Centric Sustainable Neighbourhoods (PCSN) are based on the application of the following two conceptual pillars: integration and simplicity. Specifically, the successful innovations and solutions in a PCSN should be based on the application of those concepts:

- Integration means dealing with several aspects in combination. For example, it is not sufficient to build a highly energy-efficient building if it is not affordable due to high costs, or if a good indoor climate is not guaranteed. Environmental quality, affordability, and people's well-being are therefore important indicators that need to be taken into account.
- Simplicity means to make solutions that are easy to understand and use for all stakeholders. In particular, WeGenerate focuses on resource-efficient, integrated regeneration processes through inclusive and participatory approaches.

4.2.Analysis of KPIs for Urban regeneration

This section focuses on the analysis and definition of Impact Model (IM) categories and KPIs accounting for project expected outcomes and Demos action plans. Also, it describes how the consolidated Impact Model (initial version) is defined based on a preliminary set of KPIs proposed by core expert partners, which are, lately, adapted and validated according to the series of consultations and a dedicated workshop with Demos and Innovation Cluster (next section 4.3).

Firstly, the IM design exercise was based on the analysis of integrated reference frameworks, and, secondly, complemented by a comprehensive set of Impact Models reviewed (see section 3.1). The structure evaluation was developed using a series of dedicated Excel spreadsheets including sustainable and inclusiveness criteria analysis, such as: (i) Expected Outcomes of the Call (EOC #1-8) and Highlights under scope (S #1-13), (ii) Related indicators from established assessment frameworks; (iii) Motivation and alignment with Demo Actions.

In a first instance, a dedicated Excel spreadsheet was elaborated with the aim to provide an overview of potential KPIs which allowed running the selection process to define the WeGenerate Impact Model, with the final goal to assess the success of the regeneration models implemented towards Sustainable Inclusive Demo Neighbourhoods. Established frameworks and methodologies were reviewed to determine whether the indicators to be proposed were in line with the existing EU frameworks. In addition, other relevant KPIs were identified and revised to articulate an integrated approach for evaluating sustainable urban interventions.

As second step, based on the preliminary analysis, a tentative selection of categories, macro-objectives and KPIs was proposed (core indicator, sub-indicator, and discarded indicator). This was a tentative selection based on internal discussions and cooperation with WP2 and Demo sites, as well as inspired by the ARV Project, Craft Project, Thriving places, UITP, SCIS, Scientific publications, and other relevant sources, as well as accounting for the Expected Outcomes of the Call (EOCs).

Thirdly, a structured feedback collection was developed through a dedicated questionnaire template, which supported Demos deepening in the KPIs description and calculation approaches proposed. This structured process provided insightful analysis on how Demo actions are aligned/not-related, as well as to assess motivations and data requirements to proposed Indicators.

Finally, the KPIs selection was further revised based on the collected insights from Demos and subsequent expert discussions. A revised set of KPIs was consolidated at a dedicated workshop, as part of the Project General Assembly, in cooperation with involved partners from WP7, WP2 and Demos.

4.3. Demos and Innovation Clusters Dialogues

As part of the Impact Model design process, a series of consultations to Demos and Innovation Clusters were conducted to integrate their perspective within the project assessment framework definition, as well as to align the selection of KPIs with Demos planned actions and implementation roadmaps under definition. In addition, a dedicated workshop with Demos and Innovation Clusters was developed as part of a Project General Assembly to consolidate the Impact Model structure and selected KPI sets, initially elaborated by WP7 core partners.

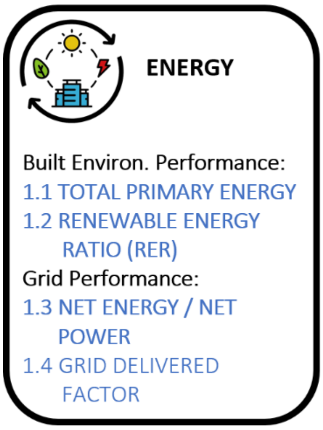
1. The **series of Demos' consultations** were held as part of the WeGenerate City Dialogues and dedicated bilateral meetings organised by WP2, in which Innovation Clusters and WP7 coordinated the revision of planned interventions and related impact categories to drive the design of Demos' Action Plans and Implementation Roadmaps from an integrated urban regeneration approach.

   The Dialogues on the Impact Model design allowed collecting first Demos' feedback focused on their priority intervention areas according to proposed impact categories, in view to define a set of KPIs that will effectively illustrates how the expected outcomes of Demo actions aim at achieving People-Centric Sustainable Neighbourhoods. In addition, complementary criteria were applied to: (i) identify a common approach to cover the full umbrella of intervention domains, and (ii) to define standardised set of urban indicators to allow further comparison across established EU frameworks and beyond.
2. The **Workshop on Impact Model** aimed to consolidate a robust KPIs selection accounting for Demos' structured feedback on the first Impact Model version, which supported an exhaustive alignment and fine-tuning of KPIs set to meet both demos' priorities and project expected outcomes. The resulting analysis ended up defining a concise and comprehensive Impact Model, composed by 20 Core and 13 Optional Indicators distributed in 6 Main categories which covered a range of 14 macro-objectives, which are driven by project ambitions to enhance sustainability and social inclusiveness in WeGenerate Demo sites.

5. WeGenerate Impact Model

5.1. Energy

This category addresses the following macro-objectives with 3 core KPI and 1 optional.



- Building Performance
  - 1.1 Total Primary Energy
  - 1.2 Renewable energy ratio (RER)
- Grid Performance
  - 1.3 Net Energy / Net power
  - 1.4 Grid Delivered Factor (Optional KPI)

The Expected Outcomes (EOC) and Highlight Under Scope (S) of the call addressed by the category are:

- EOC #3: More sustainable, low emission, inclusive and affordable neighbourhoods and built environment.
- EO #7: Increased well-being and economic prosperity of citizens in a low carbon, sustainable built environment by ensuring high indoor and outdoor quality, and affordability of renovation solutions.
- EO #8: Increased attractiveness of deep renovation through new regeneration and smart growth models for sustainable living.
- EO #5 Extended application of digital applications and tools to ease decision-making processes in complex stakeholder structures.
- S05 Ensure the proposed solutions include concepts for local renewable energy integrated at building and district level in combination with multi-modal mobility concepts targeted to both urban and rural neighbourhoods
- S06 Ensure the proposed solutions contribute to optimising energy balancing at local level.

- S08 Ensure the proposed solutions are developed taking into account local environmental, social, and economic conditions and are relevant for the different geographical locations targeted.
- S09 Where relevant, include concepts for energy circularity.
- S10 Where relevant, investigate whether and how the proposed approaches could apply to cultural heritage buildings.

5.1.1. Total primary energy balance – KPI 1.1

Motivation:

Primary Energy consumption is used as one of the main indicators for the assessment of the annual energy use in the EPBD directives and adopted in most of the countries in Europe. It measures the energy performance of the building, reflecting the energy mix of the grid of the site of the building.

Description:

This indicator takes into consideration all types of energy consumed and produced by the system, and the exchange with the energy networks. It is calculated using the following equation which sums up all delivered and exported energy for all energy carries into a single indicator with the corresponding total primary energy weighting factors. Therefore, this indicator considers differences as well in the energetic effort within the supply chain of different energy carriers, e.g. domestic gas versus electricity [23].

Unit:

- Building: kWh/(m² y)
- Neighbourhood: kWh/(m² y)

Calculation:

Primary energy calculation is not explicitly defined in the EPBD, leaving many options and room for interpretation at national implementation. In this document it is proposed to calculate EP-value based on the total primary energy as building site boundary as proposed in JRC (2023) [24] and depicted in **Figure 4** that accounts delivered and exported energy through the boundary. On-site solar and ambient energy is not considered in the total primary energy indicator calculation, as the aim is, to calculate both total and non-renewable primary energy from delivered energy products to the site.

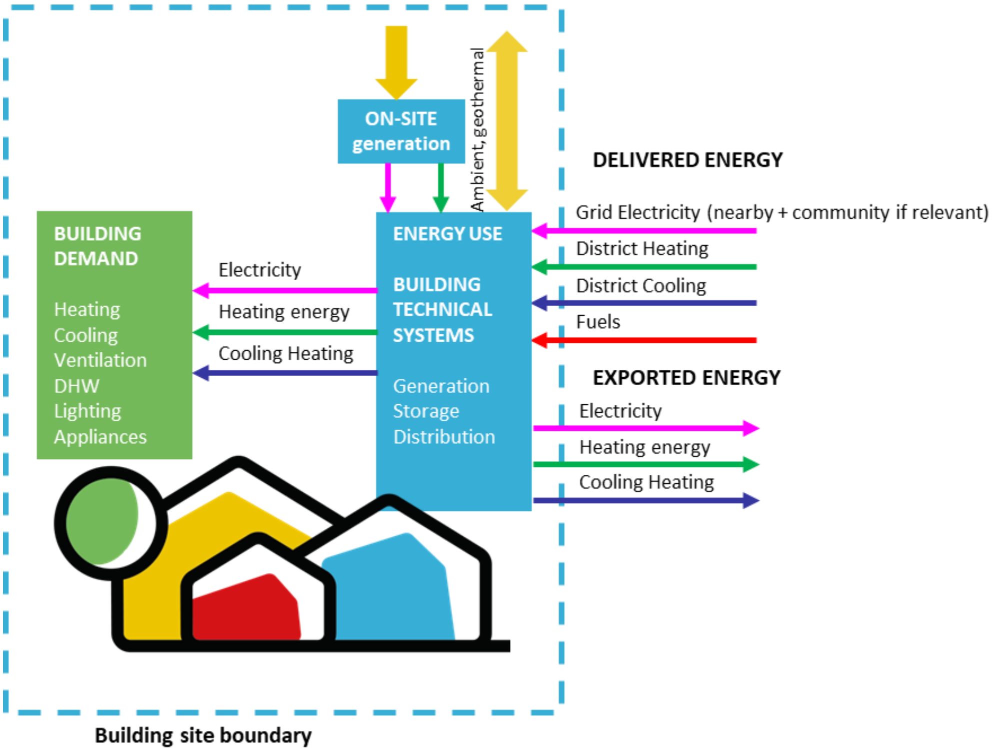


Figure 4. *Building site boundary for primary energy calculation that complements building assessment boundary of EN ISO 52000-1 [5].*

$$E_{P,tot} = \sum_i E_{p,tot,del,i} - \sum_i E_{p,tot,exp,i}$$

$$= \sum_i \int P_{del,i}(t) \cdot w_{del,tot,i}(t) \cdot dt - \sum_i \int P_{exp,i}(t) \cdot w_{exp,tot,i}(t) \cdot dt$$

Where:

$E_{P,tot}$ – the total primary energy, [kWh/ m² y];

$E_{p,tot,del,i}$ – delivered total primary energy per energy carrier i, [kWh/ m² y];

$E_{p,tot,exp,i}$ – exported total primary energy per energy carrier i, [kWh/ m² y];

$P_{del,i}$ – the delivered power on site or nearby for energy carrier i, [kW/ m²];

$w_{del,tot,i}$ – the total primary energy factor (-) for the delivered energy carrier i;

$P_{exp,i}$ – the exported power on site or nearby for energy carrier i, [kW/m²];

$\boldsymbol{w_{exp,tot,i}}$ – the total primary energy factor (-) of the exported energy for energy carrier i;

$\boldsymbol{dt}$ – time-step [h];

ISO 52000-1 [25] defines the different forms in the consideration of the resources avoided by the external grid due to the export of the energy carrier, and each EU country can choose what considerations to apply in the energy balance. In the framework of WeGenerate, weighting factors for exported energy are recommended to be selected based on the resources avoided from the external grid, which is equivalent to "Step B" stated in ISO-52000. This means that for example the values of the delivered and exported weighting factors for electricity are considered to be equal ($\kappa_{exp} = 1$). Finally, energy calculation should be conducted on an hourly basis, but monthly calculation is also accepted, as mentioned in EPBD ANNEX I [26].

5.1.2. Renewable Energy Ratio (RER) – KPI 1.2

Motivation:

A People-Centric Sustainable Neighbourhood aims improving baseline conditions to support long-term planning to an annual net zero energy and GHG emissions balance. This can be achieved by working towards an annual local surplus of renewable energy production by using local renewable energy generation, e.g. building integrated photovoltaics (BIPV) and building applied photovoltaics (BAPV). Therefore, it is important to monitor the share of renewable energy in the total energy consumption.

Description:

Renewable Energy Ratio (RER) is the percentage of energy from renewable sources in the total primary energy consumption.

Unit: Dimensionless.

Calculation:

$$\boldsymbol{RER = \frac{E_{p,ren}}{E_{p,tot}}}$$

Where:

$\boldsymbol{RER}$ – Renewable Energy Ratio [-];

$\boldsymbol{E_{p,ren}}$ – renewable primary energy consumption [kWh/m² y];

$\boldsymbol{E_{p,tot}}$ – total primary energy consumption [kWh/m² y].

5.1.3. Net Energy/Net Power – KPI 1.3

KPI 1.3 - Motivation:

The visual representation of net energy/power can be a useful tool in the decision-making process, as it helps to visualise the interaction between the people-centric sustainable neighbourhood and the grid as well as the differences between alternative solutions for energy carriers or system solutions for a neighbourhood.

Description:

Net energy or net power is the sum of delivered and exported energy per energy carrier in each of the calculation time steps, where negative values represent energy/power exported to the grid, whereas positive values demonstrate energy/power delivered from the grid.

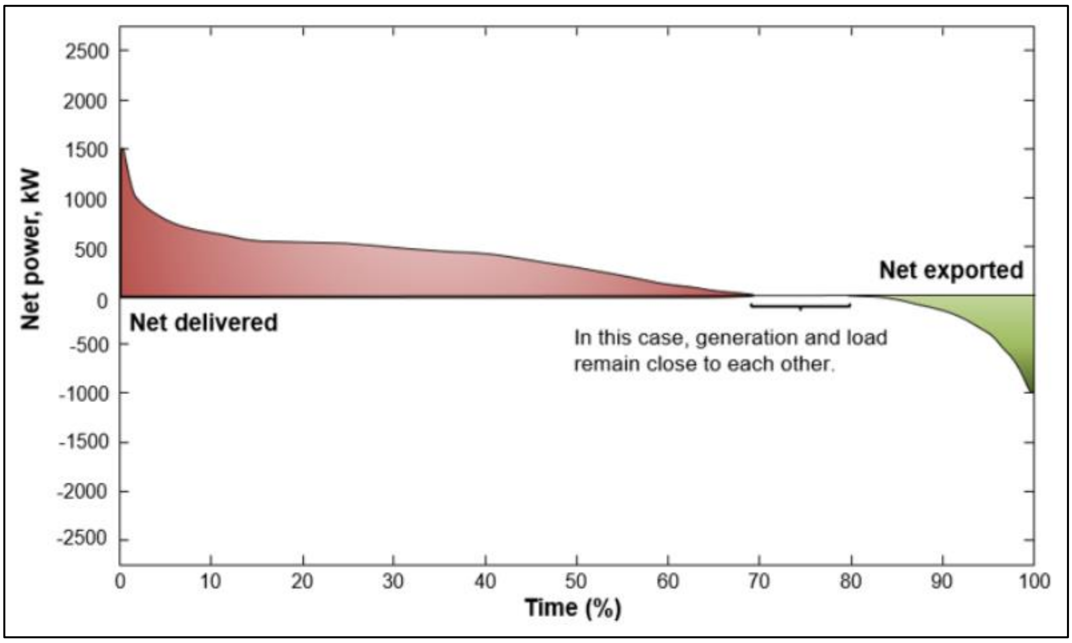


Figure 5. *Net energy duration curve: conceptual scheme. Source* [16].

Unit: kWh (energy) or kW (power).

Calculation:

$$\boldsymbol{E_{net,i} = \int P_{net,i}(t) \cdot dt = \int \left[P_{del,i}(t) - P_{exp,i}(t)\right] \cdot dt}$$

Where:

$\boldsymbol{E_{net,i}}$ – net energy per energy carrier *i* [kWh];

$\boldsymbol{P_{net,i}}$ – net power per energy carrier *i* [kW];

$\boldsymbol{P_{del,i}}$ – the delivered power on site or nearby for energy carrier *i* [kW];

$\boldsymbol{P_{exp,i}}$ – the exported power on site or nearby for energy carrier *i* [kW].

5.1.4. Grid Delivered Factor (Optional) – KPI 1.4

Motivation:

The grid delivered factor is intended to evaluate the proportion of energy delivered from the grid in the total energy used by the system. This indicator is used to assess the quality of the energy system and its control and allows a fairer comparison of the different systems compared to the load cover factor and supply cover factor [27].

The load cover factor (use matching fraction) and supply cover factor (production matching fraction) are the matching factors presented in ISO 52000-1 [28]. These factors are mainly used to analyse mismatch between renewable electricity produced on-site and electricity load in the buildings and are proposed in this framework as complementary indicators.

Description:

Grid delivered factor or grid purchase ratio [27] is the ratio between the energy delivered from the grid and the total energy used by the system. Grid delivered factor should be computed in terms of final energy and is commonly used for electricity as energy carrier but can be extended to other energy carriers as for example thermal energy from a district heating and cooling system.

Unit: Dimensionless.

Calculation:

$$\gamma_{grid} = \frac{E_{del,grid}}{E_{used,tot}} = \frac{\int max\left[P_{used}(t) - P_{prod}(t), 0\right] \cdot dt}{\int P_{used}(t) \cdot dt}$$

Where:

γ_{grid} – grid delivered factor [-];

$E_{del,grid}$ – delivered energy form the grid [kWh];

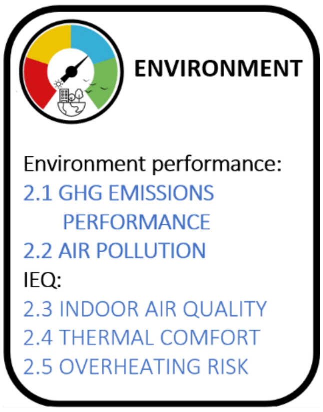
$E_{used,tot}$ – total energy used by the system [kWh];

P_{prod} – on-site produced power [kW];

P_{used} – on-site used power [kW].

5.2. Environment

This category addresses the following macro-objectives with 2 core KPI and 3 optional.



- Environmental Performance
  - 2.1 GHG emissions performance in People-Centric Sustainable Neighbourhoods
  - 2.2 Indoor Air Quality
- Indoor Environmental Quality
  - 2.3 Air Pollution from the Energy Consumption (Optional KPI)
  - 2.4 Thermal Comfort (Optional KPI)
  - 2.5 Overheating Risk (Optional KPI)

The Expected Outcomes (EOC) and Highlight Under Scope (S) of the call addressed by the category are:

- EOC #3: More sustainable, low emission, inclusive and affordable neighbourhoods and built environment.
- EO #7: Increased well-being and economic prosperity of citizens in a low carbon, sustainable built environment by ensuring high indoor and outdoor quality, and affordability of renovation solutions.
- EO #8: Increased attractiveness of deep renovation through new regeneration and smart growth models for sustainable living.
- S02: Ensure the proposed solutions allow to identify and integrate local sources of raw materials
- S05 Ensure the proposed solutions include concepts for local renewable energy integrated at building and district level in combination with multi-modal mobility concepts targeted to both urban and rural neighbourhoods
- S07 Ensure the proposed solutions comply with the principles of circular economy, favouring urban mining, efficient use of resources, durability, reuse and recyclability.

- S08 Ensure the proposed solutions are developed taking into account local environmental, social, and economic conditions and are relevant for the different geographical locations targeted.
- S09 Where relevant, include concepts for energy circularity...
- S10 Where relevant, investigate whether and how the proposed approaches could apply to cultural heritage buildings.

5.2.1. GHG Emissions Performance – KPI 2.1

Motivation:

To evaluate the impact of GHG emissions from the built environment, LCA studies have traditionally been used to assess the impacts of buildings, mobility, and energy systems separately. Recently, however, several studies have been published that conduct integrated analyses at the neighbourhood, district, and city levels [29]. Linking buildings, mobility, and energy systems in the context of communities through the goal of creating people-centric sustainable neighbourhoods, provides a unique opportunity to contribute to climate change mitigation. At the same time, other potential sources of GHG emissions such as water consumption and waste generation should not be neglected in GHG analysis at the People-Centric Sustainable Neighbourhoods level [25] [30]. A full analysis can help in the assessment of which variables have the greatest impact on the carbon footprint in order to minimise emissions by applying carbon sequestration/saving measures (water conservation, green areas and roofs, deployment of RES, and other) and setting climate change policies (or mitigation interventions).

The emissions and mitigation measures that should be taken into account for the assessment framework are the ones that can be allocated to the interventions that are the object of the People-Centric Sustainable Neighbourhoods. GHG emissions sources that are considered in the framework are:

- Emissions in the use stage (buildings, mobility).
- Emissions from water consumption.
- Emissions from waste management.

Emission offset measures that are considered in the framework:

- Emissions offsets by on-site generation of surplus renewable energy in community infrastructures.
- Biological carbon sequestration in green areas such as trees and green roofs.

Description:

The total GHG emissions of the People-Centric Sustainable Neighbourhoods are the balance between the total GHG generated emissions and the total GHG offsets in the use-stage of an urban area.

Unit: kg CO2eq/y.

Calculation:

$$GHG_{PCSN} = B_U + M_U + W_C + WS - RES_U - U_G - U_T$$

Where:

GHG_{PCSN} – total GHG emissions in People-Centric Sustainable Neighbourhoods [kg CO_2eq/y];

B_U - emissions in the use stage (buildings) [kg CO_2eq/y];

M_U – emissions in the use stage (mobility) [kg CO_2eq/y];

W_C – emissions from water consumption, deducting the avoided emissions from rainwater collection and grey water reuse [kg CO_2eq/y]; *(optional)*

WS – emissions from waste management [kg CO_2eq/y]; *(optional)*

RES_U – emissions offsets in the use stage (on-site RES) [kg CO_2eq/y];

U_G – emissions offsets from green areas and green roofs [kg CO_2eq/y];

U_T – emissions offsets from trees in the street [kg CO_2eq/y].

The total GHG emissions and offsets included in the formula are intended to demonstrate the overall GHG footprint of People-Centric Sustainable Neighbourhoods. However, the core components should be determined by each project based on its objectives. Some of them are marked as optional.

The GHG emissions from buildings in the use stage can be calculated as follows:

$$B_U = \sum_i B_{E_{p,nren,del,i}} - \sum_i B_{E_{p,nren,exp,i}}$$
$$= \sum_i \int P_{del,i}(t) \cdot w_{CO_2,del,i}(t) \cdot dt - \sum_i \int P_{exp,i}(t) \cdot w_{CO_2,exp,i}(t) \cdot dt$$

Where:

$\boldsymbol{B_U}$ – emissions in the use stage [kg CO_2eq/y];

$\boldsymbol{B_{E_{p,nren,del,i}}}$ – emissions from delivered non-renewable primary energy per energy carrier *i* [kg CO_2eq/y];

$\boldsymbol{B_{E_{p,nren,exp,i}}}$ – emissions from exported non-renewable primary energy per energy carrier *i* [kg CO_2eq/y];

$\boldsymbol{P_{del,i}}$ – delivered power for energy carrier *i* into object of assessment [kW];

$\boldsymbol{w_{CO_2,del,i}}$ – emission coefficient for delivered energy carrier *i* [kg CO_2eq/kWh];

$\boldsymbol{P_{exp,i}}$ – exported power for energy carrier *i* out of object of assessment [kW];

$\boldsymbol{w_{CO_2,exp,i}}$- emission coefficient for exported energy carrier *i* [kg CO_2eq/kWh].

The total GHG emissions from mobility operation in the use stage can be computed by:

$$\boldsymbol{M_U = \sum_i w_{vehicle_i} \cdot L_{tot_i}}$$

Where:

$\boldsymbol{M_U}$ – emissions in use stage (mobility) [kg CO_2eq/y];

$\boldsymbol{w_{vehicle_i}}$ - emissions per km driven by vehicle type *i* [kg CO_2eq/km];

$\boldsymbol{L_{tot_i}}$ – average annual mileage run by vehicle type *i* [km/y].

$$\boldsymbol{L_{tot_i} = \alpha_i \cdot L_{daily} \cdot p_i \cdot d}$$

$\boldsymbol{L_{tot_i}}$- average annual mileage run by vehicle type *i* [km/y];

$\boldsymbol{\alpha_i}$ – share of the different vehicle type *i* [%];

$\boldsymbol{L_{daily}}$ – total daily travel length for commuting [km/person/day];

$\boldsymbol{p_i}$ – total number of people travelling by vehicle type *i* in People-Centric Sustainable Neighbourhoods [person];

$\boldsymbol{d}$ – total travelling days in a year [day/y].

Reference data for the determination of the GHG emissions from mobility operation in the use stage can be found in Table__ and Table __ (Annex B – Link in the document).

The total GHG emissions from water consumption is computed based on the amount of water consumption. It can be determined from utility bills, however, if this information is not available, this indicator can be computed considering total number of inhabitants and estimated amount of water per person:

$$\boldsymbol{W_C = V_C \cdot w_{water} = l \cdot p \cdot w_{water}}$$

Where:

$\boldsymbol{W_C}$ – emissions from water consumption [kg CO_2eq/y];

$\boldsymbol{V_C}$ – amount of water consumption [l/y];

$\boldsymbol{l}$ – amount of water consumption per person [l/person·y];

$\boldsymbol{p}$ – total number of inhabitants [person];

$\boldsymbol{w_{water}}$ – emission coefficient for water consumption [kg CO_2eq/l].

The total GHG emissions from waste management:

$$\boldsymbol{WS = y \cdot p \cdot w_{waste}}$$

Where:

WS – emissions from waste management [kg CO_2eq/y];

$\boldsymbol{y}$ – amount of waste generated per inhabitant [kg/person·y];

$\boldsymbol{p}$ – total number of inhabitants [person];

$\boldsymbol{w_{waste}}$ – emission coefficient for waste management [kg CO_2eq/kg].

If GHG emissions offsets measures are adopted, their positive impacts on the reduction of total GHG emissions can also be considered.

The total GHG emissions offsets from on-site RES, e.g. a PV system, in the use stage:

$$\boldsymbol{RES_U = E_{prod,PV} \cdot w_{CO_2,elect}}$$

Where:

$\boldsymbol{RES_U}$ – emissions offsets from on-site RES, e.g. a PV system, in the use stage [kg CO_2eq/y];

$\boldsymbol{E_{prod,PV}}$ – electricity production from PV system [kWh/y]

$\boldsymbol{w_{CO_2,elect}}$ – emission coefficient for electricity [kg CO_2eq/kWh].

To assess the GHG emissions offsets from carbon sinks (green areas and roofs) the surfaces of green areas and roofs should be multiplied by a corresponding GHG emission absorption factors:

$$\boldsymbol{U_G = \sum_i S_{G_i} \cdot w_{G_i}}$$

Where:

$\boldsymbol{U_G}$ – emissions offsets by green surface area [kg CO_2eq/y];

$\boldsymbol{S_{G_i}}$ – total green surface area *i* [m^2];

$\boldsymbol{w_{G_i}}$ – emission absorption factor for green surface area *i* [kg CO_2eq/ m^2 y].

The total GHG emissions offsets from trees in the street:

$$\boldsymbol{U_T = \sum_i N_{tree_i} \cdot w_{tree_i}}$$

Where:

$\boldsymbol{U_T}$ – emissions offsets by trees in the street [kg CO_2eq/y];

$\boldsymbol{N_{tree_i}}$ – number of trees of type *i* [unit];

$\boldsymbol{w_{tree_i}}$ – emission absorption factor for type of tree *i* [kg CO_2eq/unit·y].

There are other GHG emissions offsets measures, e.g. development of sustainable mobility (establishment of bicycle lanes, creation of traffic-free zones in pedestrian-only areas, improvement of public transport). Calculation methods for such emissions offset's measures should be developed on a case-by-case basis.

5.2.2. Air Pollution – KPI 2.4

Motivation:

Air pollutants have a significant impact on human health and the environment. Therefore, reducing air pollution is an important step towards vibrant, people-centric, and sustainable neighbourhoods.

Air pollution can be assessed at different stages, e.g., energy production, transport, processing, and operation. However, only air pollutants generated in the building stock operation phase and road transport within the Neighbourhood boundaries will be calculated as they directly affect human health and the environment in the neighbourhood due to combustion of fossil fuels.

Main proposed air pollutants relevant to the combustion process that affect human health are small particles (namely, PM2.5), nitrogen oxides (NOx) and sulphur dioxide (SO2):

- PM2.5 is closely associated with heart and lung diseases. In addition, PM2.5 is the main component of smog, which affects crop cultivation.
- NOx is associated with the formation of smog and thus with respiratory problems and other human diseases. It also has a negative impact on agriculture, as smog reduces sunlight.
- SO2 has local and regional impacts: it is linked to heart and lung diseases and causes acidification that affects forests, lakes, and buildings.

Description:

Air pollution from energy consumption (Built Environment and Transport sectors) is an indicator that measures the total annual amount of air pollution produced by combustion processes.

Unit: kg/y.

Calculation:

The approach proposes to calculate separately Air Pollution from energy consumption in both sectors under analysis: (i) Built environment and (ii) Road transport at Neighbourhood level; both are lately combined in a single KPI as the sum of both sector's annual air pollution of pollutants (PM2.5, NOx and SO2) expressed in kg/y.

(i) Annual air pollution of each pollutant in the Built Environment can be calculated using the following equation (adopted from [31]):

$$\boldsymbol{AP_i = \sum_{j,k} EF_{i,j,k} \cdot E_{P,nren,j,k}}$$

Where:

$\boldsymbol{AP_i}$ – annual air pollution of pollutant *i* [g/m^2 y];

$\boldsymbol{EF_{i,j,k}}$ – default emission factor of pollutant *i* for source type *j* and fuel *k* [g/kWh];

$\boldsymbol{E_{P,nren,j,k}}$ - annual consumption of fuel *k* in source type *j* [kWh/m^{2}y].

The emission factor of a pollutant represents the mass of a particular pollutant that is emitted per unit of energy delivered (or of heat produced) by a given source type (e.g., conventional boiler) and fuel (e.g., natural gas). **Appendix C – Emission Factors for Air Pollutants per Energy Carrier** reports the emission factors for different energy carriers. Given factors correspond to conventional boilers below 50 kW, emission factors related to other technologies will be evaluated case by case.

Air pollution from electricity consumption is not considered by this indicator, as electricity is not generated on site and therefore air pollution from electricity generation is not directly related to the neighbourhood. However, in case electricity needs to be considered in the calculation, emission factors for low-voltage electricity generation could be found in **Table 30** and **Table 31** (**Appendix C – Emission Factors for Air Pollutants per Energy Carrier**).

(ii) Annual air pollution of each pollutant from the road transport can be calculated using the following equation (adopted from [32]):

The methodology approach for exhaust emissions from the road transport uses the following general equation:

$$E_i = \sum_j (\sum_m (\mathrm{FC}_{j,m} \text{ x } EF_{i,j,m}))$$

Where:

$\boldsymbol{E_i}$ – annual emission of pollutant i [g/y],

$\boldsymbol{FC_{j,m}}$ – fuel consumption of vehicle category j using fuel m [kg],

$\boldsymbol{EF_{i,j,m}}$ – annual fuel consumption-specific emission factor of pollutant i for vehicle category j and fuel m [g/kg y].

The vehicle categories to be considered are passenger cars, light commercial vehicles, heavy-duty vehicles, and L-category vehicles. The fuels to be considered include petrol, diesel, LPG and natural gas.

This equation requires the fuel consumption/sales statistics to be split by vehicle category, as national statistics do not provide vehicle category details. Guidance on splitting fuel consumption/sales is provided in **Table 32** and **Table 33** (**Appendix C – Emission Factors for Air Pollutants per Energy Carrier**).

5.2.3. Indoor Air Quality (Optional) – KPI 2.3

Motivation:

People-Centric Sustainable Neighbourhood focus on people, i.e. their specific needs and well-being, and therefore aim for excellent IEQ. In this context, it is crucial to address the CO_2 level, which is a recognised indicator of poor indoor ventilation. Lack of ventilation significantly affects people's health by causing various building-related health symptoms such as respiratory diseases, allergies, headaches, and others [33].

The European Standard EN16798-1-2019 [34] defines four categories of IEQ, related to the level of expectations of the building occupants (Table 4). Pre-and post-occupancy evaluations will be carried out in all demos regeneration to ensure the improvement in IEQ.

Table 4. *Categories of IEQ* [34].

Category	Level of expectations
IEQ_{I}	High
IEQ_{II}	Medium
IEQ_{III}	Moderate
IEQ_{IV}	Low

Description:

Indoor Air Quality (IAQ) KPI indicates the percentage of time that air quality is in each category during occupied hours. The Carbon Dioxide (CO_2) concentration range is used to assess IAQ according to the four quality categories listed in **Table 5**. In addition, IAQ assessment can be complemented with surveys.

Table 5. CO2 concentrations per category based on a standard CO2 emission of 20 l/h per person[34].

Category	Level of expectations
IEQ_{I}	≤ 550 ppm
IEQ_{II}	>550 and ≤ 800 ppm
IEQ_{III}	>800 ppm and ≤1350 ppm
IEQ_{IV}	>1350 ppm

Units: %, based on time in each category (ppm).

Calculation:

The calculation method refers to the percentage of time that the indicator for CO_2 concentration is in each category during the occupied hours. It can be visualized in the form similar to **Table 6**.

Table 6. Visualization of the evaluation of the air quality in the four categories.

Percentage of time (%)	5	15	60	20
Air quality IEQ	IV	III	II	I

In a further step, the time outside the comfort range should be calculated as the percentage of time the CO_2 concentrations are out of the established comfort ranges.

5.2.4. Thermal Comfort (Optional) – KPI 2.4

Motivation:

The temperature range of the air is a recognised indicator of thermal comfort. Extreme temperature fluctuations can lead to reduced air quality for the building's occupants and significantly affect their productivity and sleep quality, reducing overall well-being.

Description:

Thermal comfort KPI indicates the percentage of time that air temperature is within certain categories during occupied hours. Operative temperature ranges are used to assess thermal comfort for buildings according to the four quality categories listed in **Table 7**. Alternatively, thermal comfort can be assessed using the predicted mean vote (PMV) and the predicted percentage dissatisfied (PPD) indexes. Recommended PMV and PPD ranges are defined in EN16798-1-2019 [35].

Units: %, based on time in each category (˚C, PMV or PPD).

Calculation:

The calculation method refers to the percentage of time that the indicator for air temperature is in each category during the occupied hours. It can be visualized in a form similar to **Table 7**.

Table 7. *Visualisation of the evaluation of the thermal comfort in the four categories.*

Percentage of time (%)	***5***	***15***	***60***	***20***
Thermal Comfort IEQ	**IV**	**III**	**II**	**I**

In a further step, the time outside the comfort range should be calculated as the percentage of time the temperatures are out of the established comfort ranges.

To calculate in which Thermal Comfort category is each moment, it is described in **Table 8**.

Table 8. *Operative temperature ranges for summer and winter in buildings with and without mechanical cooling systems classified in the 4 categories* [36].

Category	**Operative temperature (˚C)**			
	Buildings with mechanical cooling systems		Buildings without mechanical cooling systems	
	Minimum for heating season (Winter) ~ 1,0 clo	Maximum for cooling season (Summer) ~ 0.5 clo	Minimum for heating season (Winter) ~ 1,0 clo	Maximum for cooling season (Summer) ~ 0.5 clo
IEQ_{I}	21	25.5	21	upper limit: $\Theta_o = 0{,}33\ \Theta_{rm} + 18{,}8 + 2$ lower limit: $\Theta_o = 0{,}33\ \Theta_{rm} + 18{,}8 - 3$
IEQ_{II}	20	26	20	upper limit: $\Theta_o = 0{,}33\ \Theta_{rm} + 18{,}8 + 3$ lower limit: $\Theta_o = 0{,}33\ \Theta_{rm} + 18{,}8 - 4$
IEQ_{III}	18	27	18	upper limit: $\Theta_o = 0{,}33\ \Theta_{rm} + 18{,}8 + 4$ lower limit: $\Theta_o = 0{,}33\ \Theta_{rm} + 18{,}8 - 5$
IEQ_{IV}	16	28	16	

Where:

$\boldsymbol{\Theta_{rm}}$ – Outdoor Running mean temperature for the considered day (°C) which can be calculated by:

$\boldsymbol{\Theta_{rm}}$ = (1-α) { $\boldsymbol{\Theta_{ed}}$ -1 + α $\boldsymbol{\Theta_{ed}}$ -2 + α2 $\boldsymbol{\Theta_{ed}}$ -3 }

$\boldsymbol{\Theta_{ed}}$ -1 – daily mean outdoor air temperature for previous day

α – constant between 0 and 1 (recommended value is 0,8)

$\boldsymbol{\Theta_{ed}}$ -i – daily mean outdoor air temperature for the i th previous day

In case that daily running mean outdoor temperatures are not available, the following formula can be used:

$\boldsymbol{\Theta_{m}}$ = ($\boldsymbol{\Theta_{ed}}$-1 + 0.8 $\boldsymbol{\Theta_{ed}}$-2 + 0.6 $\boldsymbol{\Theta_{ed}}$-3 + 0.5 $\boldsymbol{\Theta_{ed}}$-4 + 0.4 $\boldsymbol{\Theta_{ed}}$-5 + 0.3 $\boldsymbol{\Theta_{ed}}$-6 + 0.2 $\boldsymbol{\Theta_{ed}}$-7)/3.8

The optimal operative temperature represented by:

$$\boldsymbol{\Theta_c = 0.33 \cdot \Theta_{rm} + 18.8}$$

Where:

$\boldsymbol{\Theta_o}$ – indoor operative temperature, °C 61

$\boldsymbol{\Theta_{rm}}$ – running mean outdoor temperature, °C

$\boldsymbol{\Theta_c}$ – Optimal operative temperature, °C

Where the limits apply when 10 < $\boldsymbol{\Theta_{rm}}$ < 30°C

5.2.5. Overheating Risk (Optional) – KPI 2.5

Motivation:

There is growing evidence that overheating occurs in warm weather in buildings without air conditioning [37]. Overheating affects the health and well-being of occupants, especially when sleep is compromised. In extreme cases, heat stress can lead to premature mortality, especially among the more vulnerable members of society. For the assessment framework, the Heat index is proposed as a risk parameter for assessing overheating risk in the building.

Description:

The Heat Index describes how hot the weather feels to the average person, by combining the effect of temperature and humidity, derived from the dew point. The Heat Index, also known as apparent temperature, represents the human-perceived equivalent temperature in shaded areas when relative humidity (RH) is combined with the air temperature. This KPI indicates the percentage of time that Heat Index is in each discomfort band or Heat Index is in each category during occupied hours.

Units: Heat Index (HI): % of time in each category, based on ˚C.

Calculation:

The equation for obtaining the Heat Index is described in [38] as follows:

$$\boldsymbol{HI = 0.5 \cdot [T_a + 61 + 1.2 \cdot (T_a - 68) + 0.094 \cdot RH] HI = 0.5 \cdot [T_a + 61 + 1.2 \cdot (T_a - 68) + 0.094 \cdot RH]}$$

Where:

$\boldsymbol{T_a}$ – dry-bulb air temperature (in F);

$\boldsymbol{RH}$ – the relative humidity (in %).;

If HI is higher than 26.7 °C (80F), it is necessary to use the regression equation proposed by Rothfusz [39]:

$$\boldsymbol{HI = -42.379 + 2.04901523 * T + 10.14333127 * RH - .22475541 * T * RH - .00683783 * T^2 - .05481717 * RH^2 + .00122874 * T^2 * RH + .00085282 * T * RH^2 - .00000199 * T^2 * RH^2}$$

The United States National Weather Service [38] divides the HI as follows in **Table 9*Table 9***.

Table 9. *Correlation between Heat Index category and possible health effects* [40].

Heat Index Category	Effects description	Heat Index [°C]
Caution	Fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramps.	26-32
Extreme	Heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.	32-41
Danger	Heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.	41-54
Extreme danger	Heat stroke is imminent.	>54

The share of time spent in each Heat Index category can be visualized in the form similar to **Table 7** (categories in Thermal Comfort).

5.3. Social Inclusion and Citizen Participation

This category addresses the following macro-objectives with 6 core KPI and 1 optional.

SOCIAL INCLUSION & CITIZENS PARTICIPATION

Democracy:
3.1 DEMOCRATIC PROCESS
3.2 SOCIABILITY
3.3 SOCIAL ENGAGEMENT
Community:
3.4 DEMOGRAPHIC
3.5 SAFETY AND SECURITY
3.6 ENERGY & ENVIRONMENT CONSCIOUSNESS
3.7 CULTURAL SUSTAINABILITY

- Democracy
    - 3.1 Democratic Process
    - 3.2 Social Inclusion and Cohesion
    - 3.3 Social Engagement
- Community
    - 3.4 Demographic composition
    - 3.5 Safety and Security
    - 3.6 Energy and Environmental Consciousness
    - 3.7 Cultural Sustainability (Optional KPI)

The Expected Outcomes (EOC) and Highlight Under Scope (S) of the call addressed by the category are:

- EO #1: Lasting behavioural change of people and economic actors towards lower carbon footprint lifestyles and businesses.
- EO #8: Increased attractiveness of deep renovation through new regeneration and smart growth models for sustainable living.
- EO #2: Mainstreamed participatory planning processes and interaction with all relevant stakeholder groups in city planning.
- EO #6: Raised awareness and increased capacity of citizens on participatory processes for enhanced sustainability and environmental performance.
- S01 Deliver innovative methods and solutions for the regeneration of neighbourhoods... based on participatory planning processes and innovative decision-making procedures and digital applications.
- S04 Ensure the proposed solutions allow for involving all stakeholder groups... also seeking to address gentrification issues in neighbourhoods affected by energy poverty.

- S08 Ensure the proposed solutions are developed taking into account local environmental, social, and economic conditions and are relevant for the different geographical locations targeted.
- S12 Consider social innovation where relevant.
- S13 Facilitate awareness raising and capacity building of citizens and relevant stakeholders.

5.3.1. Democratic Process – KPI 3.1

Motivation:

A democratic process should aim to fostering citizen engagement, redistributing power and benefits via inclusive decision-making, and empowering citizens. This encompasses promoting interactive communication, allowing citizens to be informed, participate in decision-making, and see tangible outcomes from their input. Beyond conventional methods like public consultations, it demands diverse and meaningful activities for genuine participation. Besides community engagement, the creation of a sense of trust that authorities will hear the population and undertake actions to promote real change based on the community's voice is essential.

Description:

This indicator evaluates community engagement and trust in local governance. By assessing the consultation elements of Demo implementation, measuring trust levels through survey responses, and quantifying democratic participation via election rates, the goal is to provide a comprehensive view of civic involvement. This approach highlights the community's confidence in its leaders and also reflects active participation in democratic processes, which essential for fostering a responsive and inclusive governance model.

The set of Specific Indicators described in **Table 10** can support an assessment of the Demo's effects on democratic process through: (i) providing an assessment on whether citizens' voices were heard for the implementation of the Demo; and (ii) indicating whether the democratic process been strengthened locally.

***Table 10**. Specific Indicators for Democratic Process.*

Specific Indicator	Description	Unit	Calculation
(i) Share of the affected population consulted (SPC)	Quantification of the number of people that were consulted about the Demo's implementation as a percentage of the total population that is estimated to be affected by the implementation (e.g., local residents).	% of the affected population that was consulted	SPC = absolute number of people consulted / total neighbourhood population
(ii) People's perception that their voices were heard *	Responses to be collected via interview/surveys to questions such as: 'How you feel that your/the community's voice was heard in the context of the implementation of	Likert scale	Mean score = ∑ individual scores attributed / number of responses

	the Demo?'. Responses should be based on a Likert-type-scale of 1-5.		
(iii) Election participation rate (EPR)	Quantification of the share of the local population that participated in elections before and after the implementation of the Demo.	%	EPR = absolute number of voters / total neighbourhood eligible voters

* KPIs that need to be assessed via interviews/surveys.

(i) Share of the affected population consulted (SPC)

First, calculate the mean score of trust from community survey responses.

$$\textbf{Mean Trust Score} = \frac{\sum \textbf{(Trust Scores (1-5) from Surveys)}}{\textbf{Number of Survey Responses}}$$

Second, we propose to add an indicator on local election participation rate, whenever this is available:

$$\textbf{Election Participation Rate (\%)} = \left(\frac{\textbf{Number of Voters}}{\textbf{Total Number of Eligible Voters}}\right) \times \mathbf{100}$$

Combine these measures into a composite score or index to reflect overall community involvement with local leadership.

5.3.2. Sociability – KPI 3.2

Motivation:

This indicator is driven by the aim to enhance community bonds and social well-being through increased interactions and cohesive relationships among community members. It recognizes that a socially cohesive community is more resilient, supportive, and capable of collective action towards common goals.

Description:

This indicator measures the frequency, quality, and diversity of interactions within the community, assessing how these interactions contribute to a sense of belonging, mutual support, and community identity. It reflects the community's strength in fostering an inclusive environment where all members feel valued and connected.

The set of Specific Indicators described in **Table 11** can support an assessment of the Demo's effects on sociability through: (i) indicating what actions have been taken to increase local participation and to make the community more inclusive; and (ii) providing an assessment on whether the region has become a more inclusive and interactive place.

Table 11*.Specific indicators for Sociability.*

Specific Indicator	Description	Unit	Calculation
(i) Actions taken to increase local participation accounting for vulnerable groups (AP)	Actions taken throughout the Demo implementation process to increase local participation and make the community more inclusive for vulnerable groups (e.g., events, community spaces, forums, etc.) should as a minimum be described. Potentially, quantitative information can also be included (e.g., number of participants to events, number of events, square meters of community spaces created, etc.) as well as information on the success of these actions (e.g., participation statistics, etc.).	# of actions	AP = absolute number of actions taken to increase local participation Description of the actions and further detail on the actions can be included qualitatively.
(ii) People's perception of the inclusiveness of the community *	Responses to be collected via interview/surveys to questions such as: 'Do you feel that this is an inclusive community that promotes interactions between individuals and groups?'. Responses should be based on a Likert-type-scale of 1-5.	Likert scale	Mean score = ∑ individual scores attributed / number of responses

(iii) People's participation in local groups/networks (PPGN)	Responses to be collected via interview/surveys to questions such as: 'How familiar are you with local groups/networks?', 'How motivated are you to participate in local groups/networks?', and 'I am an active participant of local groups and communities'. Responses should be based on a Likert-type-scale of 1-5.	Likert scale	Mean score = ∑ individual scores attributed / number of responses

***** KPIs that need to be assessed via interviews/surveys.

Combine these measures into a composite score or index to reflect overall community involvement with local leadership.

$$\text{Sociability Index} = \frac{\sum \text{Average Scores of All Questions}}{\text{Number of Questions}}$$

5.3.3. Social Engagement – KPI 3.3

Motivation:

This indicator evaluates if citizens endorse and engage in relevant activities and feel that social engagement is accomplished.

As digitalization is becoming ever more important, accessibility and quality of digital services needs to be guaranteed, specifically taking into account the accessibility for social groups that have a reduced capacity for using digital information channels and tools. The range of digital services to consider may be extensive, starting from specific communication strategies towards different target groups up to the use of digital twins for the management of entire cities.

Description:

It quantifies community engagement by tracking participation in workshops, forums, social media interactions, use of digital tools, and feedback mechanisms, emphasizing both the breadth (how many participate) and depth (how meaningful the participation is) of engagement. The level of successful inclusive digitalisation in neighbourhood transformation processes can be measured through the evaluation of citizens' engagement in digital tools for urban regeneration.

The set of Specific Indicators described in **Table 12** can support an assessment of the Demo's effects on social engagement through providing an assessment on the level of engagement and participation of the community.

***Table 12**. Specific Indicators for Social Engagement.*

Specific Indicator	Description	Unit	Calculation
(i) Relative participation rates (RPR)	Number of people that participated in Demo activities (e.g., workshops, forums, events, digital tools) as a proportion of the number of people that were invited to participate. In some cases, the number of people invited might need to be estimated.	% of invitees that participated in a given activity	RPR = absolute number of participants / total number of invitees
(ii) Relative response rates (RRR)	Number of people that responded to Demo surveys, interviews, and consultation instruments as a proportion of the number of people that were invited to respond. In some	% of invitees that responded to surveys	RRR = absolute number of respondents / total number of invitees

	cases, the number of people invited might need to be estimated.		
(iii) People's perception of the Demo's activities *	Responses to be collected via interview/surveys to questions such as: 'Have you participated in the activities (e.g., events, workshops) promoted in the context of the implementation of the Demo?', 'How satisfied were you with the activities promoted in the context of the implementation of the Demo?'. Responses should be based on a Likert-type-scale of 1-5.	Likert scale	Mean score = ∑ individual scores attributed / number of responses

* KPIs that need to be assessed via interviews/surveys.

(i) Relative participation rates (RPR)

$$\text{RPR} = \left(\frac{\text{Number of Community Members Participating}}{\text{Total Community Members Invited}}\right) \times \mathbf{100}$$

(iii) People's perception of the Demo's activities

$$\text{Satisfaction Rate} = \left(\frac{\sum(\text{Individual Satisfaction Scores})}{(\text{Number of Respondents}) \times (\text{Maximum Score})}\right) \times \mathbf{100}$$

5.3.4. Demographic Composition – KPI 3.4

Motivation:

Assessing the diversity and demographic changes within the community throughout the project, by comparing data over time on aspects such as gender, age, economic level and place of origin.

Description:

The demographic composition of a neighbourhood is the proportion or number of people in the area who can be identified according to a certain characteristic such as gender, age, social mix, etc., and relates to their needs, as well as the potential for increases in social capital.

The set of Specific Indicators described in **Table 13** can support an assessment of the Demo's effects on demographic composition. The ranges and categories for each variable will depend on the data sources to be used and how the information is available to support calculations.

Table 13. *Specific Indicators for Demographic Composition.*

Specific Indicator	Description	Unit	Calculation
(i) Age group	This Indicators set should be calculated using statistical data available for example through Eurostat or local registries to provide information on the local demographic composition.	% of the neighbourhood population in each category	% = ∑ population in a specific category / total neighbourhood population
(ii) Gender			
(iii) Income category			
(iv) (iv) Education level			
(v) Nationality			
(vi) Employment status			
(vii) State benefit status			

5.3.5. Safety and Security – KPI 3.5

Motivation:

Ensuring that community members feel secure in their living environment promotes a foundation of trust and mutual support. Recognizing that perceptions of safety contribute significantly to the quality of community life, it is important to measure and improve the tangible and intangible aspects of safety through both statistical data on crime rates and traffic incidents, and through qualitative assessments of residents' feelings of security. This comprehensive approach facilitates targeted interventions to enhance overall community well-being.

Description:

The set of Specific Indicators described in **Table 14** can support an assessment of the Demo's effects on safety and security through combining crime and traffic incident data with community perceptions of safety and security. The units for each variable might change depending on the data sources to be used and how the information is available.

***Table 14**. Specific Indicators for Safety and Security.*

Specific Indicator	Description	Unit	Calculation
(i) Traffic Incident Rate (TI)	Rate of traffic accidents in the demo to be calculated using statistical data available for example through Eurostat or local registries (e.g., police, fire brigade, ambulance services).	# of traffic incidents per thousand population	TI = number of traffic incidents / total neighbourhood population (thousand)
(ii) Number of fire-related incidents (FI)	Number of fire-related incidents in the region to be calculated using statistical data available for example through Eurostat or local registries (e.g., police, fire brigade, ambulance services).	# of fire-related incidents per thousand population	FI = number of fire-related incidents / total neighbourhood population (thousand)
(iii) Crime rates (CR)	Number of crimes in the region to be calculated using statistical data available for example through Eurostat or local registries (e.g., police, fire brigade, ambulance services).	# of crimes per thousand population	CR = number of crimes / total neighbourhood population (thousand)
(iv) People's perception of safety in the community *	Responses to be collected via interview/surveys to questions such as: 'Do you feel the traffic conditions are safe with respect to walking or using a bicycle in your neighbourhood?', 'Do you feel you are well informed on fire prevention measures?'. Responses should be based on a Likert-type-scale of 1-5.	Likert scale	Mean score = ∑ individual scores attributed / number of responses

(v) People's perception of security in the community *	Responses to be collected via interview/surveys to questions such as: 'Is your neighbourhood free of crime, violence, and vandalism?' and 'Do you feel safe walking alone at night in your neighbourhood?'. Responses should be based on a Likert-type-scale of 1-5.	Likert scale	Mean score = ∑ individual scores attributed / number of responses

* KPIs that need to be assessed via interviews/surveys.

(i) Traffic Incident Rate (TI)

$$\text{Incident Rate} = \left(\frac{\text{Total Reported Safety Incidents}}{\text{Community Size}}\right) \times \mathbf{1000}$$

(iv) People's perception of safety in the community

$$\text{Average Perceived Safety Score} = \frac{\sum(\text{Survey Scores on a 1-5 Scale})}{\text{Number of Survey Responses}}$$

5.3.6. Energy and Environmental Consciousness – KPI 3.6

Motivation:

To assess and enhance the community's commitment to sustainable practices and awareness of environmental impacts, aiming to promote a culture of energy efficiency and ecological responsibility.

Description:

Measures the overall engagement and awareness levels regarding energy and resource conservation, and participation in environmental sustainability efforts within the community.

The set of Specific Indicators described in **Table 15** can support an assessment of the Demo's effects on energy and environmental consciousness. The units for each variable might change depending on the data sources to be used and how the information is available.

Table 15. *Specific Indicators for Energy and Environmental Consciousness.*

Specific Variable	Description	Unit	Calculation
(i) People's energy and environmental consciousness *	Responses to be collected via interview/surveys to affirmations such as: 'Shared energy management improves energy efficiency.', 'I am aware of my own energy consumption pattern and composition.', 'I aim to live a more environmentally friendly lifestyle.', and 'I actively optimize my energy consumption and select appliances to reduce my carbon footprint.'. Responses should be based on a Likert-type-scale of 1-5.	Likert scale	Mean score = ∑ individual scores attributed / number of responses
(ii) Recycling rates	Statistics on local households' recycling rates to be calculated using statistical data available for example through Eurostat or local registries (e.g., local waste management company).	% of waste collected that is disposed as recyclable	WRR = weight of recycling waste (tons) / total weight of solid waste generated (tons)
(iii) Electricity consumption intensity (ECI)	Statistics on electricity consumption per household or per capita to be calculated using statistical data available for example through Eurostat or local registries (e.g., local electricity company).	kWh / year per person	ECI = ∑ kWh electricity consumption in the neighbourhood / total neighbourhood population
(iv) Gas consumption intensity (GCI)	Statistics on gas consumption per household or per capita to be calculated using statistical data available for example through Eurostat or local registries (e.g., local gas company).	kWh / year per person	GCI = ∑ kWh gas consumption in the neighbourhood / total neighbourhood population

(v) Water consumption intensity (WCI)	Statistics on water consumption per household or per capita to be calculated using statistical data available for example through Eurostat or local registries (e.g., local water company).	L / year per person	WCI = ∑ L water consumption in the neighbourhood / total neighbourhood population
(vi) Share of 'green' products sales (GPS)	A set of 'green' products offered in the region should be mapped (e.g., electric vehicles, lower GHG gasoline, green energy tariffs) and statistics on their sales should be used to calculate this KPI.	Share of green products sold	GPS = number of green products sold in the neighbourhood / number of total 'similar' products sold in the neighbourhood For each product to be considered in this KPI, a clear definition of the 'similar' products needs to be selected. For example: number of electric vehicles sold / total vehicles sold.

***** KPIs that need to be assessed via interviews/surveys.

5.3.7. Cultural Sustainability (Optional) – KPI 3.7

Motivation:

Cultural sustainability is related to nurturing a vibrant, culturally diverse community by actively involving various cultural groups in project activities, promoting inclusivity and cultural heritage.

Description:

Measures the number of cultural events and initiatives held in the community, and the engagement level of different cultural groups, reflecting the project's effectiveness in fostering cultural diversity and participation.

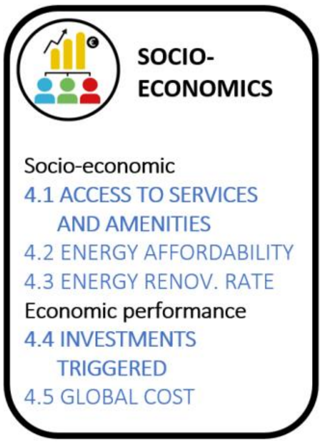
The following Specific Indicators described in **Table 16** can support an assessment of the Demo's effects on cultural sustainability.

Table 16. *Specific Indicators for Cultural Sustainability.*

Specific Indicator	Description	Unit	Calculation
(i) Cultural events (CE)	Number of cultural events held per year	# of events	CE = absolute number of events
(ii) Events participation (EV)	Average number of participants in cultural events	# of participants	CE = absolute number of event participants
(iii) Diversity and inclusion in events (DIE)	% of participants from different cultural groups and/or vulnerable/minorities	% of vulnerable / minorities participants	DIE = number of event participants from vulnerable or minority groups / absolute number of event participants

5.4. Socio-Economics

This category addresses the following macro-objectives with 2 core KPI and 2 optional.



- Socio-economic:
  - 4.1 Access to Services and Amenities
  - 4.2 Affordability of Energy (Optional KPI)
  - 4.3 Energy Renovation Rate (Optional KPI)
- Economic performance:
  - 4.4 Investments Triggered
  - 4.5 Global Cost (Optional KPI)

The Expected Outcomes (EOC) and Highlight Under Scope (S) of the call addressed by the category are:

- EO #1: Lasting behavioural change of people and economic actors towards lower carbon footprint lifestyles and businesses.
- EO #3: More sustainable, low emission, inclusive and affordable built environment.
- EO #7: Increased well-being and economic prosperity of citizens in a low carbon, sustainable built environment by ensuring high indoor and outdoor quality, and affordability of renovation solutions.
- EO #8: Increased attractiveness of deep renovation through new regeneration and smart growth models for sustainable living.
- S01 Deliver innovative methods and solutions for the regeneration of neighbourhoods... based on participatory planning processes and innovative decision-making procedures and digital applications.
- S04 Ensure the proposed solutions allow for involving all stakeholder groups… seeking to address gentrification issues in neighbourhoods affected by energy poverty.
- S08 Ensure the proposed solutions are developed taking into account local environmental, social, and economic conditions and are relevant for the different geographical locations targeted.
- S12 Consider social innovation where relevant…

5.4.1. Access to Services and Amenities – KPI 4.1

Motivation:

Services to which citizens should have equal access are social infrastructure: e.g. housing, local community centres, schools, kindergartens, and workplaces. There should also be grocery stores, pharmacies, and other shops, as well as healthcare facilities. Amenities that are necessary to provide social equity are different kinds of indoor and outdoor public spaces that enable recreational activities within sports and culture, i.e. parks and sports arenas, as well as places for people to meet and socialize, such as cafés and public benches with shade and protection from noise and transport. In this framework, this KPI can be evaluated by indication of the equitable access to services and amenities in the People-Centric Sustainable Neighbourhood under assessment.

Description:

The accessibility score for services and amenities indicates the equitable access to those in the People-Centric Sustainable Neighbourhood, where the normative target is 100%, and measures whether there is any service or amenity of the type within reach. Higher accessibility indicates that the population has more equitable access to valued amenities and services in People-Centric Sustainable Neighbourhood compared to others, while lower scores indicate that people would have to spend a disproportionate amount of time or a different mode of transport to reach certain amenities [16].

The accessibility score for services and amenities signals equitable access to all population segments, where the normative target is 100%. Lower values indicate that more people would have to spend a disproportionate amount of time, or a different mode of transport to access certain services.

Unit:

Accessibility score for services and amenities: % of population.

Calculation:

$$AM_A = \left(\frac{1}{N}\right) \cdot \sum_{Z=1}^{N} \frac{\sum_{i=1}^{n} P_{ser,i}}{P_{tot}}$$

Where:

AM_A - accessibility score for services and amenities [%];

N - number of service and amenity types [type];

n - number of services and amenities within type [amenity];

$P_{ser,i}$ - serviced population, the population in access far zones containing at least one instance of service and amenity in type [person];

P_{tot} - total People-Centric Sustainable Neighbourhood population [person].

5.4.2. Affordability of Energy (Optional) – KPI 4.2

Motivation:

The 7th UN Sustainable Development Goal (SDG), states that everyone should have access to "clean, sustainable, reliable, and affordable energy" [13]. In this framework, affordability of energy can be accessed with two European Energy Poverty Observatory (EPOV) metrics [41]: (i) assessment of energy costs in household expenditure versus income and (ii) assessment of people reporting arrears on utility bills.

Data is collected in annual household surveys of a statistically representative subset of households, comprising of two questions:

***Question 1** (related to affordability of energy as indicated by composition of household expenditure):*

- *Option 1:* Compared to your last residence: Have you spent more, less or the same on expenses connected to total annual energy consumption?
- *Option 2:* What is the "annual income of household" AND "number of people living in the household" AND "total annual energy spending"?

***Question 2** (related to affordability of energy as indicated by arrears in utility bills):*

- Has your household been at any time unable to pay utility bills on time due to financial difficulties for the last year?

Description:

Affordability of energy as indicated by composition of household expenditure could be assessed as the proportion of respondents with "True" answers in Question 1 to the total number of respondents. A "True" answer corresponds to higher energy costs in household expenditures compared to the previous residence. Similarly, affordability of energy as indicated by arrears in utility can be assessed as the proportion of residents with "True" answers to the total number of respondents from the surveys.

Unit: % of respondents.

Calculation:

$$AE_E = \frac{P_{True,E}}{P_{tot}} \cdot 100\%$$

Where:

AE_E - affordability of energy as indicated by composition of household expenditure [%];

$P_{True,E}$ - number of respondents responding with “True” for *Question 1* [respondent];

P_{tot} - total number of respondents [respondent].

$$AE_A = \frac{P_{True,E}}{P_{tot}} \cdot 100\%$$

Where:

AE_A - affordability of energy as indicated by arrears in utility bills [%];

$P_{True,E}$ - number of respondents responding with “True” for *Question 2* [respondent];

P_{tot} - total number of respondents [respondent].

5.4.3. Energy Renovation Rate (Optional) – KPI 4.3

Motivation:

Increasing the energy renovation rate of buildings has been highlighted as one of the most important measures to increase energy efficiency in the building sector [2]. A long-term target for energy renovation of buildings in EU is at least 3% of the total useful floor area, however, the current figures are far from the EU targets: the weighted annual energy renovation rate is around 1% [8]. Therefore, the assessment of the energy renovation rate is important to promote the energy renovation of the building stock.

Renovated buildings that achieved an energy renovation target are defined in terms of the improvement in delivered energy after renovation (post works) compared to the national Nearly Zero Energy Building (NZEB) renovation methodology or other national/local considerations (e.g. eligible for energy renovation grant). Some Member States [42] have chosen to link the NZEB level to one of the best energy performance classes (e.g. building class A++), as specified in an energy performance certificate (EPC).

Description:

The energy renovation rate is an indicator that shows the percentage of useful floor area of renovated buildings that achieved the NZEB or another national/local target.

Unit: %.

Calculation:

$$\boldsymbol{ERR = \frac{S_{ren}}{S_{total}} \cdot 100}$$

Where:

$\boldsymbol{ERR}$ – energy renovation rate [%];

$\boldsymbol{S_{ren}}$ – useful floor area of renovated buildings that achieved the NZEB or another national or local target [m^2].

$\boldsymbol{S_{total}}$ – total useful area of a Sustainable Inclusive Neighbourhoods [m^2].

5.4.4. Investments Triggered – KPI 4.4

Motivation:

This KPI support to measure the economic performance of WeGenerate Demo interventions.

Total investment [43] accounts for all the interventions (EC funding and mobilised investments) related to urban sustainability aspects in each Demo Neighbourhood per regenerated area [€/m2], and it corresponds to the sum of investments for all the interventions related to urban sustainability aspects in the People-Centric Sustainable Neighbourhoods (PCSN).

Total mobilised investment [44] generated in the PCSN is the sum of non-EC funding investments related to all sustainable aspects of project interventions at demo/neighbourhood level.

Description: An investment is defined as the action of capital outlay for an asset or item that is purchased or implemented, with the aim to generate revenues or savings/benefits over time. The investment in a newly constructed system is defined as cumulative payments until the initial operation of the system. The investment in the regeneration of an existing system is defined as cumulative payments until the initial operation of the system after the regeneration (grants are not subtracted). The indicator estimates all EU funding contributions to project interventions, including all aspects of project investments in terms of technology, i.e. energy, mobility, ICT. The indicator also reports the total amount of investments [€] required and mobilised by the project. Regarding the urban solutions, total investments apply to the sustainability aspects of the system (e.g., highly efficient envelope in a building) and exclude non-sustainable related investments (e.g., regeneration of non-sustainable road transports' infrastructures). It is recommended to also consider the share of investment for sustainable solutions to the total investment of urban regeneration.

Unit: €/m2 and € (total)

Calculation:

$$PI_{UR} = \frac{EPI_{UR}}{A_b}$$

Where:

$\boldsymbol{AP_i}$ – annual air pollution of pollutant *i* [g/m^2 y];

$\boldsymbol{EF_{i,j,k}}$ – default emission factor of pollutant *i* for source type *j* and fuel *k* [g/kWh];

$\boldsymbol{E_{P,nren,j,k}}$ – annual consumption of fuel *k* in source type *j* [kWh/m^{2}y].

$\boldsymbol{A_b}$ – Total floor area of the system regenerated [m^2]

5.4.5. Global Cost (Optional) – KPI 4.5

Motivation:

Global cost helps to select the most cost-effective design alternative in a life cycle perspective, taking into account intervention, operation, maintenance, replacement, and end-of-life value, and can be used in different stages:

- Design phase: rapid selection of alternatives with the lowest/optimal global costs.
- Detailed post-implementation assessment: review of the performance targets from the design phase and comparison with the baseline building/urban intervention defined by legal requirements.
- Evaluation of retrofit measures: comparison of global costs before and after the intervention.

The global cost methodology proposed in this indicator is based on a comparative methodology framework for calculating cost-optimal levels of minimum environmental performance requirements for buildings/civil works and construction/technology elements referred in the Commission Delegated Regulation (EU) No 244/2012 [45]. In addition, the proposed methodology allows accounting for relevant external costs linked to demo interventions as to calculate socio-economic monetary benefits of air pollutant and CO2 emission reductions, such as: (i) external costs of electricity production [46], (ii) external costs of transport [47], Social Cost of Carbon [48] and other sources on cost-optimality for energy refurbishment [49].

Description:

The global cost for urban interventions and construction/technology elements is a sum of the different types of costs and applying to these the discount rate by means of a discount factor so as to express them in terms of value in the starting year (Net Present Value (NPV)). When applied to the building/urban facilities' life cycle, global cost is associated with the building/urban facilities design and intervention costs (Stage A: product stage and intervention process stage), operation and maintenance of the building/urban facilities (Stage B: Use stage), and the cost of disposing of the building/urban facilities at the end of its life cycle (Stage C: End of life).

Initial investment costs are all costs incurred up to the point when the building/urban facility or the construction/technology element is delivered to the customer, ready to use. These costs include design, purchase of building/urban facility elements, connection to suppliers, installation, and commissioning processes.

Annual cost is the sum of running costs and periodic costs or replacement costs paid in a certain year. Running costs are the sum of annual maintenance costs, operational costs, and energy costs. Replacement cost is the substitute investment for a specific building/urban facility component, according to its estimated lifecycle during the calculation period.

Disposal costs are the costs for deconstruction at the end of-life of a building/urban facility or construction/technology element and include deconstruction and removal of building/urban facility component that have not yet come to the end of their lifetime, as well as related transport and recycling.

The structure of the global costs' calculation is presented in **Figure 6**.

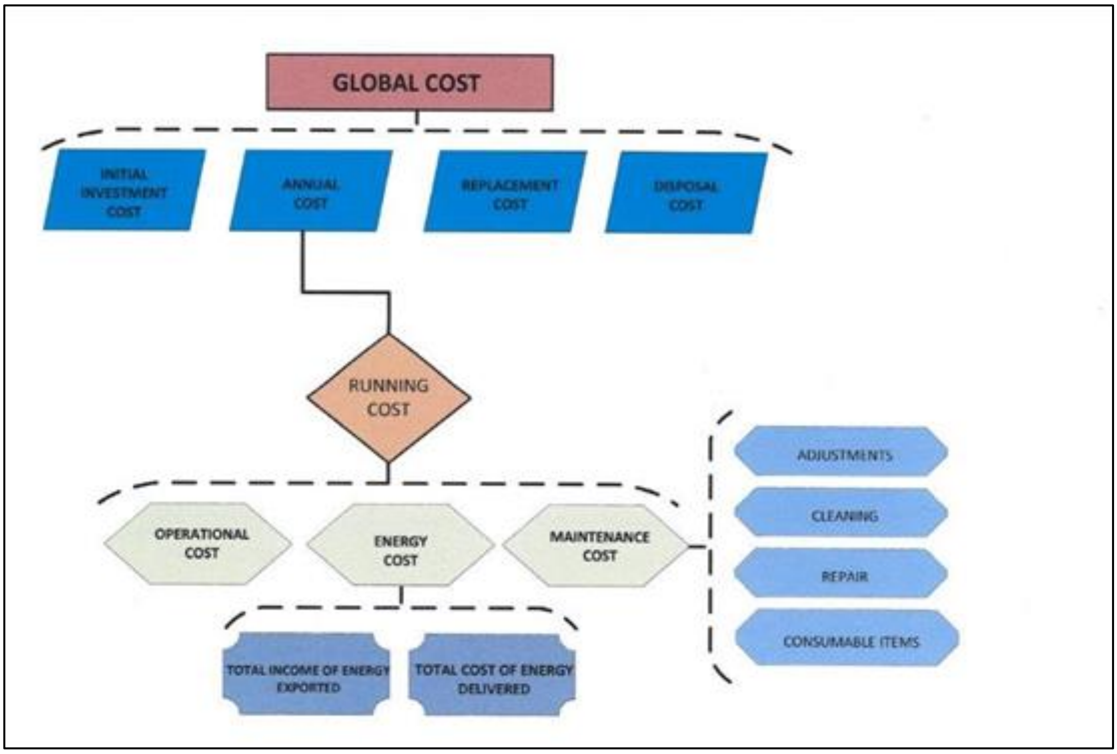


Figure 6. *Global cost calculation scheme. Adopted from [6].*

Unit: €/m^2

Calculation:

Global costs can be calculated as follows:

$$C_g = C_I + \sum_j \left[\sum_{i=1}^{t} \left(C_{a,i}(j) \cdot R_d(i) \right) + C_{repl}(j) - V_{f,t}(j) \right] + C_D$$

Where:

C_g – global cost (referred to starting year t_0) over the calculation period (t) [€/m²];

C_I – initial investment costs for measure or set of measures *j* [€/m²];

$C_{a,i}(j)$ – annual running cost during year *i* for measure or set of measures *j* [€/m² y];

$V_{f,t}(j)$ – residual value of measure or set of measures j at the end of the calculation period (discounted to the starting year t_0) [€/m²];

$C_{repl}(j)$ – replacement cost [€/m²];

$R_d(i)$ - discount factor for year *i* based on discount rate *r* to be calculated [-];

C_D – disposal cost [€/m²] (if applicable).

$$R_d(i) = \frac{1}{(1+r)^2}$$

Where:

$R_d(i)$ - discount factor for year i [-];

i – number of years from the starting period [y];

r – real discount rate [-].

$$C_a = C_e + C_{op} + C_m$$

Where:

$C_{a,i}$ – annual running cost [€/m² y];

$C_e(i)$ – energy cost [€/m² y];

$C_{op}(i)$ – operational cost [€/m² y];

$C(i)$ – maintenance cost [€/m² y].

5.5. Sustainable Mobility

This category addresses the following macro-objectives with 4 core KPI and 2 optional.

SUSTAINABLE MOBILITY

Travel Patterns
5.1 MOBILITY BEHAVIOUR
Accessibility
5.2 URBAN ACCESSIBILITY
5.3 MULTI-MODALITY
Active modes & Health
5.4 CYCLING PATH SUPPLY
5.5 RENEWAL OF WALKING & OPEN SPACE
5.6 PHYSICAL ACTIVITY

- Travel Patterns
  - 5.1 Mobility Behaviour
- Accessibility
  - 5.2 Urban Accessibility
  - 5.3 Multi-modality (Optional KPI)
- Active modes & Health
  - 5.4 Cycling path supply
  - 5.5 Renewal of Walking & Open space
  - 5.6 Physical activity (Optional KPI)

The Expected Outcomes (EOC) and Highlight Under Scope (S) of the call addressed by the category are:

EO #4: Improved accessibility of neighbourhoods through building-integrated, sustainable mobility solutions.

EO #3: More sustainable, low emission, inclusive and affordable neighbourhoods and built environment.

EO #2: Mainstreamed participatory planning processes and interaction with all relevant stakeholder groups in city planning.

EO #6: Raised awareness and increased capacity of citizens on participatory processes for enhanced sustainability and environmental performance.

S01 Deliver innovative methods and solutions for the regeneration of neighbourhoods... based on participatory planning processes and innovative decision-making procedures and digital applications.

S05 Ensure the proposed solutions include concepts for local renewable energy integrated at building and district level in combination with multi-modal mobility concepts targeted to both urban and rural neighbourhoods

S08 Ensure the proposed solutions are developed taking into account local environmental, social, and economic conditions and are relevant for the different geographical locations targeted.

5.5.1. Transport Behaviour – KPI 5.1

Motivation:

Choosing sustainable modes of transport is crucial in mitigating climate change, as the transportation sector is the second largest emitters of greenhouse gases [50]. The modal split (or mode share) is a core indicator for measuring mobility behaviour since it quantifies the users' active mode choices. Travellers choose their mode of transport mostly based on travel time, cost, or personal habits, and the modal split reflects this [51]. The modal split depends on the local circumstances and transport system offering, which also reflects the level of sustainability of the local mobility and transport system.

Mode shift from hight percentage share of cars to public transport and active modes contributes to the reduction of GHG emissions, improves the liveability of cities and provides health benefits to citizens due to more physical activity, reduced noise levels and PM emissions. In this framework, a main indicator is proposed, in addition a complementary criteria is suggested to allow a more comprehensive assessment of transport behaviour by also focusing on the uptake of sustainable modes of transport: 1) mode share (quantitative indicator) and 2) list of sustainable mobility enablers (descriptive indicator) as complementary one.

Description:

Passenger mobility behaviour is mainly assessed through the modal split, which is defined as the percentage share of each mode of transport (walking, cycling, public transport, car transport -driver or passenger- in total transport, expressed in number of trips), and, secondly, through an inventory of sustainable mobility enablers.

The modal split shows the percentage of trips made using a particular mode of transport compared to the ratio of all trips made in defined area during a certain period [52]. In case of multimodal journeys, the main mode of transport (i.e., most kilometres covered during the journey) is considered.

The descriptive variable of the indicator can be described as the list of sustainable mobility enablers present/absent from the evaluated neighbourhood [16].

Unit:

% share of each mode of the total number of trips starting or ending within the demonstration area (based in (i) number of trips).

In addition, a list of sustainable mobility enablers is suggested as complementary evaluation criteria: quantity of available enablers **Table 34** (**Appendix D – Sustainable Mobility Enablers**)

Calculation:

(i)

$$MS_x = \frac{N_{mx}}{N_{total}}$$

Where:

$\boldsymbol{MS_x}$ – mode share of mode X

$\boldsymbol{N_{mx}}$ – total number of trips starting or/and ending within the demonstration area using mode X in journey

$\boldsymbol{N_{total}}$ – total number of trips starting or/and ending within the demonstration area using all modes in journey

5.5.2. Urban Accessibility – KPI 5.2

Motivation:

To facilitate citizen needs, urban infrastructures and transport systems need–to provide sufficient and adequate access to different locations and urban services and have the capacity to accommodate the user demands in relation to levels of service (including impaired groups). Accessible and friendly sustainable modes and public facilities (walking, cycling, public transport, open spaces, public buildings, etc.) contributes to sustainable transport choices and promotes equality in serving the needs of diverse groups of users. It also implies that citizens can move freely and are not hindered or endangered by traffic or infrastructure such as junctions, major roads, or railway lines.

Description:

This indicator is quantitative, measuring how accessible urban facilities and transport services are within the demonstration area.

Alternatively, a simplified indicator alternative (adopted from ISO 21542:2011 [53]), gathering some of the more common, and urgent barriers for urban accessibility is proposed. This indicator is not comparable with a thorough universal design audit (which is not in the scope of WeGenerate).

The indicator is proposed at neighbourhood scale, with data being collected for four types of units: transport, public urban facilities, road segments, and junctions. Facilities refer to any public infrastructure/building, together with its site, and outdoor public destinations, such as parks and squares. Road segments refer to any pedestrian paths on streets, between two junctions. For each assessment, a checklist criterion must be defined (a checklist example is available at [16]). For a unit to pass the assessment, all criteria must be met. The assessment is concluded by plugging in the assessment results to equation corresponding to % of barrier-free units ($UDarea$).

Unit: Neighbourhood scale, % of barrier-free units ($UDarea$) is calculated [16].

Calculation:

$$UD_{area} = \frac{U_{pass}}{U_{tot}} \cdot 100$$

Where:

UD_{area} – barrier-free area score;

U_{pass} – number of barrier-free accessible units (max points on all relevant criteria) in area of investigation;

U_{tot} – total number of units within area of investigation.

5.5.3. Multi-modality (Optional) – KPI 5.3

Motivation:

Multimodal transport refers to using at least two different modes of transport in a journey to travel from one point to another. Multimodal transport includes public transport (bus and rail), cycling, walking and private car. Multimodality means more connections and more choices for the transport systems users. It can reduce the reliance on private cars, and the associated negative impacts, such as congestion, emissions, and accidents.

Description:

This indicator captures how the different mobility subsystems, i.e. different transport modes, function together, evaluating the quality of intermodal transfers within urban mobility [54]. This indicator is qualitative, measuring the perception of the quality of interchanges within the demonstration area.

Unit: Likert scale

Calculation:

Likert-scale (completely agree – completely disagree), example items:

- *Switching between modes is convenient in the area*
- *It is easy to plan and conduct journeys using multiple modes in the area*

5.5.4. Cycling path supply – KPI 5.4

Motivation:

Cycling infrastructure has proved to have a considerable impact on the cycling volumes in municipalities [50] [55]. Cycling infrastructure has proved to have a considerable impact on the cycling volumes in municipalities [56] [55]. High-quality main routes from residential areas to centres and workplace areas seem of special importance. The length of the public cycling infrastructure describes the amount (and quality) of infrastructure available for cyclists. Cycling infrastructure affects the safety, convenience, and attractiveness of cycling, encouraging people to shift from private cars to cycling.

Description:

The length of cycling infrastructure in the area.

Unit: Km

Calculation:

The length of cycling infrastructure collected from municipality databases or measured from map presentations (km) in the area.

5.5.5. Renewal of Walking and Open Spaces – KPI 5.5

Motivation:

Green areas and other open public urban space are a central part of the walkable urban structure [52] [57][58]. According to the UN's sustainable development goals, by 2030 there should be "equal access to safe, inclusive green and public spaces" for different population groups. Public open spaces are an important part of an urban space, offering opportunities for recreation, for relaxation and contact with [59], but they also encourage positive social interactions, which cultivate social cohesion in ways that enhance well-being as well as increased social engagement. Walking especially close to nature can also offer many benefits. In environmental terms, green spaces can moderate urban heat island effects and improve urban air quality. Green open spaces are considered as an integral part of a sustainable and inclusive neighbourhood.

Description:

This KPI determines the size and share of open and walkable spaces being renewed or improved as a result of the WeGenerate project. In addition, total urban open space for pedestrians is measured separately in demo areas (including sidewalks, squares, parks, recreational areas and other walkable public open spaces) [18].

In this assessment, walkable and open spaces include but are not limited to:

- Public parks, gardens, and green spaces
- Pedestrian zones, squares, promenades, street spaces
- Playgrounds
- Outdoor sport grounds
- Educational and health trails
- Rainwater management areas

Unit: Share of renewed open and walkable space areas (in %)

Calculation:

Mapping the available open spaces in the demo area (pre and post intervention), as well as specific data for public walking space collected from municipality databases or measured from map presentations (km^2) in the demo area, to allow evaluating the Demo progress regarding open spaces availability. Through this KPI calculation, it is expected to assess open and walkable spaces being renewed or improved (only post-intervention data), by calculating the share of these renewed surface areas (in km^2) in relation to total available open spaces (post intervention) in demo areas. Use the **Table 17** as template for reporting.

Table 17. *Renewal of Open Spaces –Reporting table.*

Renewal of Open Spaces Variables	
Total area of available open spaces (in km^2) (pre and post intervention)	
Total area of renewed open and walking space (in km2) (only post intervention)	
Share of open and walking spaces being renewed (in %) (only post intervention)	

5.5.6. Physical activity (Optional) – KPI 5.6

Motivation:

Active transport modes (walking and cycling) are important sources of regular physical activity supporting public health. Walking and cycling improve mental and physical health, and reduce the risk of chronic, e.g. cardiovascular diseases. Also, public transport trips may involve a substantial amount of walking to and from the stops. Switching from car travel to carless travel could thus yield substantial health benefits, in addition to making transport system more sustainable. WHO recommends at least 150 minutes of weekly physical activity, which could be gained rather easily by e.g. 22 minutes daily walk as a part of commuting/errand trip.

Description:

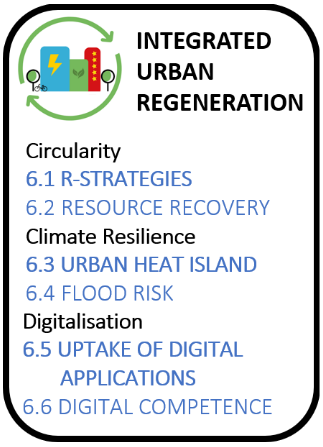
The average time spent walking/cycling per week for people working in the area, residents and other regular visitors of the demo area.

Unit: minutes (scale: <20, 20-60, 61-90, 91-120, >120)

Calculation:

Survey on average weekly time walking or cycling per person living or regularly visiting the demo area.

5.6. Integrated Urban Regeneration



This category addresses the following macro-objectives with 4 core KPI and 2 optional.

- Circularity
  - 6.1 R-Strategies
  - 6.2 Resource Recovery (Optional KPI)
- Climate Resilience
  - 6.3 Urban Heat Island
  - 6.4 Percentage change in Flood Risk Area (Optional KPI)
- Digitalisation
  - 6.5 Uptake of digital applications
  - 6.6 Digital Competence (Optional KPI)

The Expected Outcomes (EOC) and Highlight Under Scope (S) of the call addressed by the category are:

EO #1: Lasting behavioural change of people and economic actors towards lower carbon footprint lifestyles and businesses.

EO #2: Mainstreamed participatory planning processes and interaction with all relevant stakeholder groups in city planning.

EO #5: Extended application of digital applications and tools to ease decision-making processes in complex stakeholder structures.

EO #7: Increased well-being and economic prosperity of citizens in a low carbon, sustainable built environment by ensuring high indoor and outdoor quality, and affordability of renovation solutions.

EO #8: Increased attractiveness of deep renovation through new regeneration and smart growth models for sustainable living.

S01 Deliver innovative methods and solutions for the regeneration of neighbourhoods... based on participatory planning processes and innovative decision-making procedures and digital applications.

S02: Ensure the proposed solutions allow to identify and integrate local sources of raw materials

S03 Ensure the proposed solutions include new evidence-based approaches (e.g., strategies and digital tools) to help quantify the benefits of integrated built environment transformation aimed at climate neutrality.

S07 Ensure the proposed solutions comply with the principles of circular economy, favouring urban mining, efficient use of resources, durability, reuse, and recyclability.

S08 Ensure the proposed solutions are developed taking into account local environmental, social, and economic conditions and are relevant for the different geographical locations targeted.

S09 Where relevant, include concepts for energy circularity.

S10 Where relevant, investigate whether and how the proposed approaches could apply to cultural heritage buildings.

S11 Lead at least 3 large-scale demonstrations of the solutions in diverse geographical areas, with various local environmental, social, and economic conditions.

S13 Facilitate awareness raising and capacity building of citizens and relevant stakeholders.

5.6.1. Recycling and circular economy initiatives – KPI 6.1

Motivation:

The circular economy is a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products as long as possible. In this way, the life cycle of products is extended. This is a departure from the traditional, linear economic model, which is based on a take-make-consume-throw away [60]. The circular economy model for cities can decouple urban development from resource consumption, thereby integrating economic growth with social welfare and environmental sustainability. One of the scopes of WeGenerate is to ensure the proposed solutions comply with the principles of circular economy, favouring urban mining, efficient use of resources, durability, reuse, and recyclability.

Description:

The R-Strategies are often used as a framework for the circular economy, there are currently different R-Strategy frameworks and the one used in this KPI is adapted from the Circular City Actions Framework developed by the Circle Lab for Cities program [61]. The KPI aims to capture the number and level of R-strategies considered in the Demo's 'Action Plan and Implementation Roadmap'.

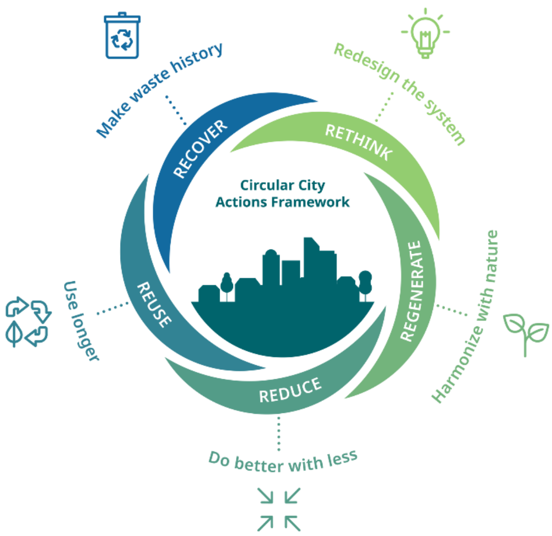


Figure 7. The Circular City Actions Framework with 5 Rs. Source **[61]**.

According to [61], the framework is structured into five complementary R strategies described in **Table 18**.

Table 18. *R strategies Framework.* Source [61].

Circular Economy	Level*	R-Strategy	Description	Actions
↑	***R1***	***Rethink***	Redesign systems to lay the foundation for circular activities and enable the transition to a circular economy.	• Eliminate linear incentives and set goals and incentives for circularity • Support closed-loop systems and cross-sectoral synergies • Enable sustainable lifestyles
	R2	***Regenerate***	Harmonize with nature by promoting infrastructure, production systems and sourcing that allows natural ecosystems to thrive.	• Protect and restore local ecosystems • Promote solutions inspired and supported by nature • Prioritize renewable resources
Increasing circularity	***R3***	***Reduce***	Do better with less by using and supporting infrastructure, processes and products that are designed to minimize material, water and energy use and waste generation from production to end of use.	• Design infrastructure and the built environment for resource efficiency • Support circular and resource-efficient business innovations • Support local, low-impact circular economies
	R4	***Reuse***	Use longer and more often by extending and intensifying use of existing resources, products, spaces and infrastructure.	• Design and regulate for extended use • Facilitate second-hand markets, sharing and exchange platforms • Support reuse, repair, remanufacturing and maintenance of existing resources, products, spaces, and infrastructure
Linear Economy	***R5***	***Recover***	Eliminate waste by maximizing the recovery of resources at the end of the use phase so that they can be reintroduced into production processes.	• Design and regulate for separation and recovery • Collect and sort waste to facilitate recovery • Process waste and ensure its re-entry into industry at its highest value

*The R level is not included in the original ‘Circular City Actions Framework’, it is added specifically for this KPI with reference to [62].

Unit: Number and level of R-Strategies deployment.

Calculation:

For each proposed action in the Demo, identify which R-strategies have been considered and describe briefly how. Overall, count the number of the R-strategies considered (0-5), list which Rs and level are included (R1-R5). Use the **Table 19** for reporting.

Table 19. *R-strategies – Data collection reporting table.*

R1	R2	R3	R4	R5	Total number of Rs
Rethink	**Regenerate**	**Reduce**	**Reuse**	**Recover**	
Y/N	Y/N	Y/N	Y/N	Y/N	0-5

5.6.2. Resource Recovery (Optional) – KPI 6.2

Motivation:

As one of the R-Strategies within the Circular City Actions Framework [61], 'Recover' asks cities to consider how to maximize the recovery of resources from residual streams during infrastructure planning and design phases. A key goal of the circular economy approach is to eliminate waste and pollution. Circular interventions should begin with R-Strategies that lie in the upstream of the circularity spectrum (i.e., Rethink, Regenerate, Reduce and Reuse). Recover, which pertains to residual material streams, enters the picture once all other R-Strategies have been pursued to the fullest extent possible.

Description:

This KPI determines the share (%) and amount (in kg) of materials recovered through reuse and recycling during the implementation of actions within the WeGenerate project.

Unit: Share of recovered materials % (from WeGenerate urban interventions)

Calculation:

Measure the weight (in kg) of waste materials and calculate the share of materials recovered through reuse and recycling during the implementation of actions within the WeGenerate project. Use **Table 20** for reporting.

Table 20. *Resource Recovery – Data collection reporting table.*

Resource Recovery KPI	
Total waste materials generated during the implementation process (kg)	
Total amount of materials recovered during the implementation process (kg)	
Share of materials recovered during the implementation process (%)	

5.6.3. Urban Heat Island – KPI 6.3

Motivation:

Global warming compounded with the expansion of the built environment is expected to intensify the urban heat island (UHI) effect in cities. UHI leads to a general shift in the temperature distribution to warmer conditions in urban environments. This results in greater mortality risk associated with heat and lower risk associated with cold compared to rural surroundings. However, for most European cities, the adverse effects of UHI on health during heat extremes significantly outweigh the protective effects it offers during cold extremes. Mortality risk generally increases towards the extreme ends of each city's typical temperature range, with greater risks to the vulnerable populations (including elderly, young children, and people with pre-existing conditions) [63]. The heat stress caused by UHI can be mitigated through measures such as increasing green and blue urban spaces (e.g., parks, gardens, rivers, lakes, and other bodies of water), increasing shading, installing green or cool roofs, and using cool pavements (either reflective or permeable). This KPI aims to evaluate the effect of actions implemented in the Demos on UHI mitigation.

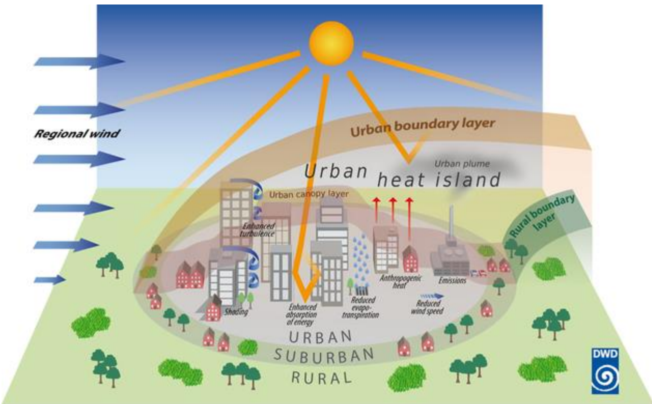


Figure 8. *Illustration of the urban heat island effect and its influencing factors (Source: Deutscher Wetterdienst DWD - German National Meteorological Service).*

Description:

Urban heat island (UHI) is classified in four main types based on different underlying atmospheric processes [64] and for the purpose of urban design and planning, the canopy layer urban heat island is the most relevant. The UHI intensity (UHII) is defined as a synchronous air temperature difference between one or more urban and rural measurement sites. The air temperature difference can be expressed in different metrics but for the purpose of evaluating the impacts of urban design interventions, measurement of the maximum UHII at night (with low wind speed and low cloud cover [65]) and the daily mean UHII over designated periods are deemed appropriate [66]. This KPI measures the change in the maximum UHII and daily mean UHII by comparing the measurements before and after the inventions introduced by the Demos.

Unit: % change

Calculation:

UHII can be estimated from synchronous differences in near-surface air temperatures between urban and rural areas as shown in the following equation [64]:

$$\boldsymbol{UHII = T_{urban} - T_{rural}}$$

where

$\boldsymbol{T_{urban}}$ – average temperature for all urban stations (in °C):

$$\boldsymbol{T_{urban} = \frac{1}{n}\sum_{i=1}^{n} T_i}$$

$\boldsymbol{T_i}$ – near surface air temperature measured at urban station i and n is the number of urban stations;

$\boldsymbol{T_{rural}}$ – average temperature of all reference rural stations (in °C):

$$\boldsymbol{T_{rural} = \frac{1}{m}\sum_{j=1}^{m} T_j}$$

$\boldsymbol{T_j}$ – near surface air temperature measured at rural station j and m is the number of rural stations;

$\boldsymbol{UHII_{max}}$– maximum UHII measured during the study period (in °C);

$\boldsymbol{UHII_{daily\,mean}} = \frac{\mathbf{1}}{\boldsymbol{N_d}}\sum_{\boldsymbol{k=1}}^{\boldsymbol{N_d}} \boldsymbol{UHII_k}$, (in °C);

$\boldsymbol{UHII_k}$ (in °C) is the daily average UHII of day k and N_d is the total number of days during the study period.

According to the WMO guidance, the term “urban” refers to areas that are built-up with increased density of structures such as houses, commercial buildings, roads, industrial facilities and city parks. Towns, cities and suburbs are all referred to as urban areas. Areas surrounding urban environments are called “rural”.

The typical measurement height for both urban and rural stations is about 1.5 m above ground level. However, considering that it might be more difficult to achieve the standard screen-level height in urban areas, measurement at 3-5 m is allowed (the air temperature gradients are generally small through most of the urban canopy layer). Installing sensors on street light poles can be an option if permissions can be obtained from the authority. Roofs should be avoided as the sensors installed there do not provide canopy layer temperatures. It is recommended to use the same height for both urban and rural stations. WMO guideline [65] details advice on the positioning of sensors for representative measurements of neighbourhoods and selection of rural reference sites.

The percentage change in UHII before and after the interventions can be calculated as follows. A negative value denotes a reduction in urban heat island intensity meaning an alleviation of heat stress in hot conditions.

$$\Delta\, \boldsymbol{UHII_{max}} = \frac{\boldsymbol{UHII_{max\_after}} - \boldsymbol{UHII_{max\_before}}}{\boldsymbol{UHII_{max\_before}}} \times \mathbf{100}\%$$

$$\Delta\, \boldsymbol{UHII_{daily\,mean}} = \frac{\boldsymbol{UHII_{daily\,mean\_after}} - \boldsymbol{UHII_{daily\,mean\_before}}}{\boldsymbol{UHII_{daily\,mean\_before}}} \times \mathbf{100}\%$$

5.6.4. Flood Risk (Optional) – KPI 6.4

Motivation:

Floods are the most common and most costly natural disasters in Europe that have devastating effects, endangering lives, and leading to heavy economic losses. Due to climate change, it is expected that the coming decades are likely to see a higher flood risk in Europe and greater economic damage [67]. Cities can make use of the opportunities offered by urban regeneration to introduce measures for reducing the likelihood and limiting the impact of floods. The C40 Cities Climate Leadership Group provides a list of main measures that cities can implement to reduce flood risk [68].

Description:

The Flood Risk KPI measures the percentage change in flood risk areas within the Demo neighbourhood. The estimation of flood risk areas is based on a flood risk assessment. There are different approaches that cities can take to assess flood risk, from lesser to great value and complexity. The C40 Cities Climate Leadership Group summarises the main approaches commonly used [68]. The selection of an appropriate approach can be influenced by factors such as relevant national/regional standards or guidance, availability of local data and the capacity and skill level of the municipality staff. The Demo allows the freedom to use an approach that is most suitable for them.

Unit: % change

Calculation:

The percentage change in flood risk area before and after the interventions ($\Delta\, \boldsymbol{Area}_{\,\boldsymbol{flood\ risk}}$) can be calculated as follows. A negative value denotes a reduction in flood risk.

$$\Delta\, \boldsymbol{Area}_{\,\boldsymbol{flood\ risk}} = \frac{\boldsymbol{Area}_{\boldsymbol{flood\ risk\_after}} - \boldsymbol{Area}_{\boldsymbol{flood\ risk\_before}}}{\boldsymbol{Area}_{\boldsymbol{flood\ risk\_before}}} \times \mathbf{100}\%$$

5.6.5. Uptake of Digital Applications in Urban Regeneration Processes – KPI 6.5

Motivation:

Digitalisation processes play a key role in supporting decision making processes at urban level. The creation/upgrade of digital applications are core developments embedded as part of WeGenerate Demo actions plans and implementation roadmaps. This indicator is designed to allow measuring and assessing the level of uptake of digital applications in urban planning processes.

Description:

This indicator measures the number of digital applications developed to support the urban regeneration planning and the quality of their integration as part of the design and management phases, i.e. the effectiveness with which the digital tools facilitate the decision-making processes. Because the process quality in the development phase has a permanent effect derived from the digital application design phase, it requires defining a well-thought-out operation from an early conceptualisation stage. Suitable communication structures between stakeholders and related agreements are the basic components for successful exploitation of digital applications in decision making processes.

Unit: Users' satisfaction rate accounting for the digital applications developed to support the urban regeneration processes.

Calculation:

Average satisfaction rate score accounting for the total number of digital applications developed to support the urban regeneration.

Target groups' satisfaction survey campaign (questionnaire to be defined as part of the Monitoring and data collection protocol D7.2).

$$\text{Satisfaction Rate} = \left(\frac{\sum(\text{Individual Satisfaction Scores})}{(\text{Number of Respondents}) \times (\text{Maximum Score})}\right) \times \mathbf{100}$$

5.6.6. Digital Competence (Optional) – KPI 6.6

Motivation:

Digital skills are becoming increasingly essential in today's knowledge-based society. In WeGenerate, digital technologies will be used not only to inform decision making at the city level, but also to stimulate social innovations and engage communities in the Demos. In this regard, digital competence of individuals in the local communities is identified as a factor to be considered during the process.

Description:

According to the European Council, digital competence involves the "confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It is defined as a combination of knowledge, skills and attitudes". In order to improve citizens' digital competence and help policymakers formulate policies that support digital competence building, an EU-wide Digital Competence Framework for Citizens (also known as DigComp) was developed to provide a common language to identify and describe the key areas of digital competence [69]. Based on DigComp, the Joint Research Council of the European Commission developed the Digital Skills Indicator (DSI) to monitor the progress of digital skills of the EU population [70]. The DSI defines a selection of activities that can be measured as proxies for digital skills. They are activities that individuals carry out using digital technologies, particularly on the internet. The DSI collects data through the EU Survey on the use of ICT in Households and by Individuals [71], which is targeted to the EU population between the ages of 16 and 74.

Unit: Dimensionless

Calculation:

The DigComp Framework (version 2.2) defines digital competence as a combination of 21 competences grouped in five main areas: (1) Information and data, (2) Communication and collaboration, (3) Digital content creation, (4) Safety and (5) Problem solving. For a detailed description of the 21 competences, please refer to [70], Section 2.1.

Assessment of the general digital competence of citizens can be done through a survey including all five main competence areas defined in the DigComp Framework (version 2.2) using the method set out in the Digital Skill Indicator 2.0 (see [70], Section 3.1). More information on the survey questions can be found in [71] and [72]. However, considering that the digital applications, which will be developed in WeGenerate intend to serve specific purposes, a general assessment of digital competence might not be sensible for all Demos under this context. Assessment of selected competences that are relevant to the specific digital applications could be an alternative approach. In this regard, tailor-made survey on digital competence fitting to the specific objectives of each Demo is recommended.

6. Conclusions and Future Updates

This document is the first version of the Impact Model for the WeGenerate project, which will be complemented by the Standardised Data Measurement and Processing Protocol (D7.2). This innovative framework has been developed with the aim to be applied to assess how community and urban interventions leading to climate neutral societies enable to uptake sustainable citizens' lifestyle and everyday practices. In addition, the WeGenerate Impact Model intends at providing a concise but comprehensive assessment framework as to support the design of Urban regeneration initiatives and strategies towards People-Centric Sustainable Neighbourhoods.

Therefore, it will be further reviewed by observing how effectively the proposed categories and KPIs cover the full range of urban interventions at neighbourhood level, as well as the suggested calculation methodologies are implemented and used by the Demo projects. Based on the WeGenerate Demo sites, it will be possible to analyse the energy, mobility and environmental patterns as well as to deepen the understanding of social aspects and citizens behaviour as core drivers to enhance neighbourhood sustainability. This will allow integrating the local culture, climate and markets and lead to practical recommendations for the refinement of the Impact Model to meet demo-based requirements. At the same time, it will help identify potential barriers and propose solutions for the effective implementation of this model during the project period and beyond. It will ensure that all measures are well embedded in the spatial, economic, technical, regulatory, environmental, and social context of the project.

Dissemination of the proposed framework will be done in interaction with on-going international activities around the concept of Zero Emissions Neighbourhoods and Climate Neutral Cities, Positive Energy Districts, New European Bauhaus, and other EU projects/initiative. Close and mutual interaction will be positive to increase the impact and the harmonization of the assessment methods.

Based on feedback received in the first year of the project, this model will be assessed periodically and adjusted, as necessary. This process will mainly take place in two steps. Firstly, the evaluation of the framework will be done in periodical workshops and through follow-up questionnaires or interviews in cooperation with monitoring (T7.2) and demo local circles, who are developing guidelines for monitoring and evaluation and performing the impact assessment in their sites, respectively. Feedback from monitoring and evaluation will help to provide a comprehensive picture of the complexity of the proposed framework. For the social KPIs, further developments and feedback are expected from Social Innovation Cluster (WP2), E.g., approaching aspects such as Community Engagement, Environment, and Well-Being. The KPIs related to Energy, Mobility and Urban Regeneration will be tested as part of the work of Sustainable Mobility and Energy in Built Environment Innovation Clusters (WP2). Additional feedback can be expected from other WPs working on the proposed KPI categories. The framework will be revised based on the feedback given and lessons learned. This continuous process will lead to a proven, validated, and consistent framework at the end of the project which will be reported in an updated version of the current document.

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Appendix A – Preliminary Plans for the Application of the IM in the Demo-sites

1. Cesena Demo

The Italian Demo site is called *Vigne-Railway Station* Neighbourhood and is located in the north-eastern Italian city of Cesena. The site area has an extension of 65 ha (0.65 km^2), and it is situated in the north of Cesena city centre, the built environment form is mainly composed by medium-high density building fabric with a prevalence of post-war buildings.

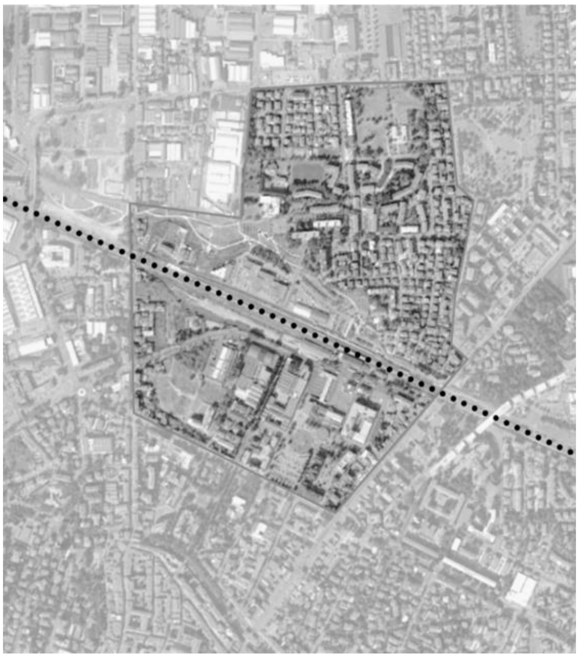

Figure 9. *Cesena Demo – map of the Vigne-Railway Station Neighbourhood*

The Cesena Demo case mainly consists of 2 distinctive areas:

- **Area 1 – Mixed-use Area.** Below the railway track (Railway Station area): mainly public spaces and public buildings (e.g., city railway station, bus station, high schools, etc.).
- **Area 2 – Multifamily Housing Neighbourhood.** Above the railway track (Vigne neighbourhood): mainly residential use, with some neighbourhood services (e.g., primary schools, small shops, church, etc.).

As part of the City Dialogues in coordination with the Innovation Hub, Demo planned actions were revised during the first 9 month of project implementation as indicted in **Table 21**.

Table 21. Cesena Demo – Revised Action for Urban Regeneration of Vigne Neighbourhood.

Cesena Demo Revised Actions
A1. Integrated and systemic approach A1.1 Develop a regeneration methodology based on the 'Active City' concept, involving key local actors in a participative perspective - e.g., Community Transition Pathway and Roadmaps (TRL3 to 7 and SRL 2 to 6)
A2. Multi-modal mobility system A2.1 Raise awareness on the active mobility concept - e.g., organisation of workshops/roundtables to favour a mindset change in transport habits (SRL2 to 9), contest format involving young local creatives to prototype an app for outdoor sports and recreational activities (TRL 2 to 5) A2.2 Implement a parking solution for Park & Ride facilities customised for the Cesena Demo (TRL 5 to 9).
A3. Climate-adaptive open spaces A3.1 Experiment small-scale (also temporary) greening intervention through the use of low-impact materials, co-developed with the local community - e.g., co-design workshops with experts (SRL 2 to 6). A3.2 Use of microclimatic simulation to evaluate greening intervention and installation of environmental sensors to monitor outdoor conditions. The ENVI-met (or equivalent) simulations will be carried out in the OFFLINE Laboratory of UNIBO with an advanced workstation composed of different components (i.e. thermal sensors, high-performance computer, etc.) for running the simulation (TRL 5 to 8). A3.3 Develop an urban digital platform (Digital Coffee Room) where all the relevant news, insights, and data on environmental, energy and ecological themes are communicated to citizens. Vigne-Railway station Demo will act as an experimental district where a participatory transition process is taking off. (TRL 2 to 6).
A4. Renovated built environment A4.1 Test the use of the Digital Twin to support decision-making process and users' engagement in the potential building renovation of Vigne Neighbourhood - focus on INA Casa block (TRL 3 to 7 and SRL 3 to 7).

Table 22 summarises Demo's actions impacting proposed KPIs of the Impact Model.

Table 22. Preliminary plan for application of assessment framework to Vigne Neighbourhood.

Cate-gory	*KPI*	*Relevance to demo*	*Demo actions impacting the KPIs/Comments*	*Type of urban interventions*
Energy	Total Primary Energy	3	(n/a) > eventually A4.1 - renovation scenario simulation (focus on Vigne area)	Digital twin
	Renewable Energy Ratio (RER)	3	(n/a) > eventually A4.1 - renovation scenario simulation (focus on Vigne area)	Digital twin
	Net Energy / Net Power	3	(n/a) > eventually A4.1 - renovation scenario simulation (focus on Vigne area)	Digital twin

	Grid Delivered Factor (Optional KPI)	3	(n/a) > eventually A4.1 - renovation scenario simulation (focus on Vigne area)	Digital twin
Environment	GHG Emissions Performance	5	A2.1, A2.2, A3.1, A3.2, A4.1	Mobility, Green Infrastructures, Open Spaces, Digital twin
	Air Pollution from the Energy Consumption	4	A2.1, A2.2, A3.1, A3.2, A4.1	Mobility, Green Infrastructures, Open Spaces, Digital Twin
	Indoor Air Quality (Optional KPI)	2	(n/a)	(n/a)
	Thermal Comfort (Optional KPI)	2	(n/a)	(n/a)
	Overheating risk – Heat Index (Optional KPI)	2	(n/a)	(n/a)
Social	Democratic process	4	A1.1, A2.1, A3.1, A3.3	Mobility, Green Infrastructures, Open Spaces
	Sociability	4	A1.1, A2.1, A3.1, A3.3	Mobility, Green Infrastructures, Open Spaces
	Social engagement	4	A1.1, A2.1, A3.1, A3.3	Mobility, Green Infrastructures, Open Spaces
	Demographic composition	4	n/a > (A1.1, A2.1, A3.1, A3.3)	Mobility, Green Infrastructures, Open Spaces
	Safety and Security	4	A2.1, A3.1	Mobility, Green Infrastructures, Open Spaces
	Energy and Environmental Consciousness	5	A2.1, A3.2, A3.3	Mobility, Green Infrastructures, Open Spaces
	Cultural Sustainability (Optional KPI)	2	(n/a)	(n/a)
Socio-Economics	Access to services and Amenities	5	A1.1, A2.1, A3.1, A3.3	Mobility, Green Infrastructures, Open Spaces
	Energy Affordability (Optional KPI)	4	(n/a) > eventually A4.1 - renovation scenario simulation (focus on Vigne area)	Digital Twin
	Energy Renovation Rate (Optional KPI)	2	(n/a) > eventually A4.1 - renovation scenario simulation (focus on Vigne area)	Digital Twin
	Investments Triggered	5	A1.1, , A2.2, A3.1, A4.1	Urban Regeneration Interventions
	Global Cost (Optional KPI)	4	A2.2, A3.1, A4.1 – economic performance analysis linked to demo interventions	Urban Regeneration Interventions
Sustainable Urba	Transport Behaviour	5	A2.1, A2.2, A3.1, A3.2, A3.3	Mobility, Green Infrastructures, Open

				Spaces, Digital Applications
	Urban Accessibility	5	A1.1, A2.1, A2.2, A3.3	Built Environment, Mobility, Green Infrastructures, Open Spaces
	Multi-modality (Optional KPI)	4	A2.1, A2.2, A3.1	Mobility, Green Infrastructures, Open Spaces
	Cycling path supply	5	A2.1, A3.1	Mobility, Green Infrastructures, Open Spaces
	Renewal of Walking and Open Spaces	5	A2.1, A3.1, A3.2	Mobility, Green Infrastructures, Open Spaces
	Physical activity (Optional KPI)	5	A2.1, A3.1, A3.3	Mobility, Green Infrastructures, Open Spaces, Digital Applications
Integrated Urban Regeneration	Recycling and circular economy initiatives	4	A3.1 (physical intervention), A2.1, A3.3, A4.1 (in term of awareness rising)	Mobility, Green Infrastructures, Open Spaces
	Resource Recovery (Optional KPI)	4	A3.1	Mobility, Green Infrastructures, Open Spaces
	Urban Heat Island	5	A3.1, A3.2, A4.1	Mobility, Green Infrastructures, Open Spaces
	Flood Risk (Optional KPI)	3	A3.1, A3.2	Mobility, Green Infrastructures, Open Spaces
	Uptake of Digital Applications in Urban Regeneration Processes	5	A2.2, A3.2, A3.3, A4.1	Digital Applications
	Digital Competence (Optional KPI)	5	A3.2, A3.3 , A4.1	Digital Applications

2. Cascais Demo

The Portuguese demo case is called *Alcabideche* Neighbourhood and is located in the central-western Portuguese city of Cascais. *Alcabideche* is a diverse urban centre, which comprises various communities, including a social neighbourhood called 'Bairro de Alcabideche,' schools, a sports centre, and cultural venues. The site area has an extension of 40 ha (0.40 km^2) with a population of 2800 habitants, from which 350 are social housing residents. In addition, accounting for the neighbourhood commuters, over 2500 citizens are part of the school community, including students' parents, and 2400 citizens are monthly users of the local sports centre.

Figure 10. *Cascais Demo – map of the Alcabideche Neighbourhood*

Adopting the name "Social neighbourhood as an Active Energy Community", the main objective of this demo is to promote an urban regeneration model through the integration of the energy communities involving citizens and local stakeholders. For this, different locations have been identified for the installation of the energy communities. The Cascais Demo installations comprise several distinctive built environment typologies, such as:

- **Area 1 – Public buildings and neighbourhood facilities**, which serve as the central hubs for community activities and basic services provision.
- **Area 2 – Social housing neighbourhoods**, designed to provide affordable living spaces and support to lower-income residents.

- **Area 3 – Single-housing neighbourhoods**. Each of these typologies contributes to the overall diversity and functionality of the Cascais Demo area.

The second main Cascais Demo objective is related with integration of the digital planning and tools as part of the regeneration model. Finally, the third main objective aims to strongly engage and activate the local community in view to replicate the urban regeneration model in other similar city neighbourhoods.

As part of the City Dialogues in coordination with the Innovation Hub, Demo planned actions were revised during the first 9 month of project implementation as indicted in **Table 23**.

***Table 23**. Cascais Demo – Revised Action for Urban Regeneration of Alcabideche Neighbourhood.*

Cascais key actions
A1. Contextualization planning, impact assessment of the intervention measures. A1.1 - Assess the energy use and provide a set of retrofitting solutions A1.2 - Evaluation of the related ongoing actions in Cascais and planning of the actions to be taken within the framework of the project
A2. Evaluation of energy poverty level through survey and socio-economic-demographic characteristics analysis. A2.1 - Evaluation of energy poverty level. Conduct surveys to collect micro-data at the household level and analyse the survey data to better understand how to interact with the target community A2.2 - Evaluation of the residents' transportation needs to connect with mobility policies and evaluate where the EV chargers will be more useful A2.3 - Development of a framework for urban regeneration with input from the Innovation Hub
A3. Implement an active citizen energy community in the neighbourhood with a customised smart energy metering and management platform that allows the sharing of energy between 'prosumers', working as an urban energy lab. Task A3.1 - Assessment of Cascais' climate condition and renewable potential (Global Horizontal Irradiation in the ground and in building rooftops) Task A3.2 - Evaluation of the potential capacity to be installed in the energy communities and the sharing capacity Task A3.3 - Analysis of potential for electric mobility installations and assessment potential consumers and potential for storage solutions Task A3.4 - Raising the community (defining producer/consumer members, signing contracts, defining model of coefficients of sharing, tariffs to be applied, etc) and Education among the community of the concept of energy communities, the benefits associated, the methods for joining & building an energy community Task A3.5 - Management of the community (giving access of the platform to consumers, invoicing processes, tracking of energy flows, updates on members, updates on tariffs applied, etc)

A4. Develop and test the use of Digital Twins (e.g., PEDRERA and immersive models) in assessing the potential of creating a citizen energy community in the neighbourhood. Task A4.1 - Development of a 3D model of the neighbourhood buildings to incorporate in the Digital Twin Task A4.2 - Integration of the production and consumption data in the Digital Twin via API connecting data retrieved from Greenvolt Comunidade's platform Task A4.3- Definition of layers of data to apply (data, granularity, depth) Task A4.3 - Development of front end (App or web based) to be used by citizens and inform them of the potential and benefits of being part of an energy community in Cascais Task A4.4- Development of manual of usage for the front end platform (educating the population) Task A4.5- Initiatives for education & impact tracking of the digital twin (analysis of utilization, defining roadmap for improvements)
A5. Promoting campaigns for awareness raising and capacity building of citizens about multi-benefits of sustainable, inclusive, and accessible neighbourhoods inclusive gaming. Activities regarding awareness raising, co-creation and experimentation regarding the main topics: active energy communities, mobility, energy poverty. A5.1. Awareness raising Developing an information / awareness campaign before the implementation of the PV systems, presenting their benefits. Also, targeting specific population groups that can reach out to and help on spreading the message to the rest of the community. Training and awareness campaigns to promote participation: creating an environment that facilitates households living in energy poverty to adopt and sustain energy-saving practices. This involves enhancing energy literacy through community programmes and fostering social networks that promote collective action. A5.2. Co-creation. Evaluation of interest to join the energy community. Evaluate the residents' buildings problems and show them ways to improve their home's comfort. Obstacles identification and ideas to overcome them. Raising ideas on how to decarbonize Cascais and improve the indoor quality in Cascais' buildings. Envolve local stakeholders and citizen in specific activities based on gaming and quizzes. A5.3 Experimentation. Present possible solutions and scenarios, test the digital applications with the community.
A6. Replicate the regeneration model towards all social neighbourhoods in Cascais as well as the Lisbon Metropolitan Area in collaboration with other 17 municipalities. A6.1 - Writing of a "Good Practices Manual" to be used as a guide for the replication in other neighbourhoods (with the description of obstacles and how they were overcome). A6.2. Characterization of the different social neighbourhoods in Cascais and the Lisbon Metropololitan Area, and Identify social neighbourhoods with similar characteristics to Alcabideche. A6.3 Disseminate and engage other social communities/neighbourhoods.

Table 24 summarises Demo's actions impacting proposed KPIs of the Impact Model.

Table 24. Preliminary plan for application of assessment framework to Alcabideche Neighbourhood.

Cate-gory	KPI	Relevance to demo	Demo actions impacting the KPIs / Comments	Type of urban interventions
Energy	Total Primary Energy	5	A1: Conducting energy audits and consumption analysis; Promoting energy-saving measures and technologies; Assessing the impact of RES interventions. A3.2 - A3.5	Active Energy Community (AEC), Citizens' Engagement Strategy and Awareness campaign
	Renewable Energy Ratio (RER)	5	A1: Installing renewable energy systems solar panels; Monitoring the ratio of renewable energy production versus total energy consumption; Evaluating renewable energy integration effectiveness. A3.2 - A3.5	Digital twin, AEC
	Net Energy / Net Power	5	A1: Calculating net energy consumption and generation; Implementing net metering systems; Analysing energy balance and optimising power distribution. A3.2 - A3.5	Digital twin, AEC
	Grid Delivered Factor (Optional KPI)	5	A1: Assessing the reliability and efficiency of energy delivery from the grid; Implementing measures to improve grid resilience and reduce dependency. A3.2 - A3.5	Digital twin, AEC
Environment	GHG Emissions Performance	4	A1: Conducting energy audits and consumption analysis; Promoting energy-saving measures and technologies; Assessing the impact of RES interventions. A3.2 - A3.5	Active Energy Community (AEC), Citizens' Engagement Strategy and Awareness campaign
	Air Pollution from the Energy Consumption	5	A4: Calculating greenhouse gas emission scenarios based on KPI approach; Implementing strategies to reduce carbon footprint; Monitoring emissions in real-time.	AEC, Mobility, Green Infrastructures, Open Spaces
	Indoor Air Quality (Optional KPI)	1	A4: Analysing air quality data related to energy use; Conducting regular air quality assessments. 'Mobile' air quality sensors for PM10, CO2	Citizens' Engagement Strategy and Awareness campaign
	Thermal Comfort (Optional KPI)	4	A4: Monitoring indoor air quality parameters; Conducting indoor air quality assessments and improvements.	Citizens' Engagement Strategy and Awareness campaign
	Overheating risk – Heat Index (Optional KPI)	3	A4: Evaluating and optimising indoor thermal conditions;	Citizens' Engagement Strategy and Awareness campaign
Social	Democratic process	5	A2.1/ A3.9-A3.12/ A5: Conducting surveys to gather residents' opinions on energy initiatives; Organising public meetings and workshops; Encouraging community participation in decision-making.	Citizens' Engagement Strategy and Awareness campaign
	Sociability	5	A2.1/ A3.9-A3.12/ A5: Promoting community events and social gatherings; Facilitating forums for residents to share experiences and ideas; Strengthening community bonds through energy projects.	
	Social engagement	5	A2.1/ A3.9-A3.12/ A5 Involving residents in energy project planning and implementation; Encouraging volunteerism and community-led initiatives.	

	Demographic composition	5	A2.1 Analysing the demographic characteristics of the neighbourhood; Tailoring energy initiatives to meet diverse community needs; Monitoring changes in demographic trends.	
	Safety and Security	4	A2.1 Implementing safety measures in energy infrastructure; Conducting safety audits and risk assessments; Engaging the community in safety awareness programmes.	
	Energy and Environmental Consciousness	4	A2.1/ A3.9-A3.12/ A5: Conducting awareness campaigns on sustainable energy use; Providing educational workshops on environmental impacts; Encouraging environmentally conscious behaviours through community projects.	
	Cultural Sustainability (Optional KPI)	4	A2.1/ A3.9-A3.12/ A5 : Promoting cultural events that highlight sustainability; Encouraging the preservation of local traditions through energy projects; Engaging cultural leaders in sustainability initiatives.	
Socio-Economics	Access to services and Amenities	5	A2/A3:Improving access to energy-efficient services and amenities; Developing infrastructure that supports sustainable living; Ensuring inclusive access to energy solutions.	AEC, Digital applications, Citizens' Engagement Strategy and Awareness campaign
	Energy Affordability (Optional KPI)	5	A2/A3/A4: Monitoring and addressing energy cost burdens on residents.	AEC, Citizens' Engagement Strategy and Awareness campaign
	Energy Renovation Rate (Optional KPI)	5	A3/A4/A5: Attracting private and public investments in energy projects; Showcasing successful project outcomes to potential investors; Leveraging funding opportunities for energy initiatives.	Citizens' Engagement Strategy and Awareness campaign
	Investments Triggered	5	A3/A6: Increasing the rate of energy-efficient renovations; Monitoring Urban regeneration progress and impact.	Urban regeneration interventions
	Global Cost (Optional KPI)	2	A6 – economic performance analysis linked to demo interventions	Urban regeneration interventions
Sustainable Urban Mobility	Transport Behaviour	5	A4: Encouraging the use of sustainable transport options; Implementing public transport improvements; Conducting surveys on residents' transport habits.	Citizens' Engagement Strategy, Citizen´s awareness campaign, Mobility, Open Spaces, Green infrastructures
	Urban Accessibility	5	A4: Enhancing access to public transport and pedestrian pathways; Monitoring accessibility improvements.	
	Multi-modality (Optional KPI)	5	A4: Promoting the integration of various transport modes; Implementing multi-modal transport hubs; Encouraging seamless travel options.	
	Renewal of Walking and Open Spaces	4	A4: Developing and upgrading walking paths and public spaces; Promoting pedestrian-friendly environments; Conducting surveys on space usage.	
	Cycling path supply	4	A4: Expanding and improving cycling infrastructure; Promoting cycling as a sustainable transport option; Monitoring cycling path usage.	

	Physical activity (Optional KPI)	2	A4: Encouraging physical activity through urban design; Implementing fitness programmes and facilities; Monitoring residents' physical activity levels.	
Integrated Urban Regeneration	Recycling and circular economy initiatives	5	A3/A4/A5: Implementing community recycling programmes; Promoting circular economy practices; Conducting educational workshops on waste reduction.	Urban regeneration interventions, Citizens' Engagement Strategy and Awareness campaign
	Resource Recovery (Optional KPI)	2	A3/A4/A5: Monitoring resource recovery outcomes.	AEC, Mobility, Green Infrastructures, Open Spaces
	Urban Heat Island	4	A3/A4: Monitoring urban temperature variations; Promoting urban greening initiatives.	Green Infrastructures, Open Spaces
	Flood Risk (Optional KPI)	2	(n/a) > eventually, A1: Conducting flood risk assessments	Green Infrastructures, Open Spaces
	Uptake of Digital Applications in Urban Regeneration Processes	5	A4: Developing digital tools for urban planning; Implementing smart city technologies; Encouraging the use of digital applications for urban regeneration.	Digital applications
	Digital Competence (Optional KPI)	2	(n/a) > eventually, A3: Providing digital literacy training programmes; Encouraging the use of digital tools for energy management; Monitoring improvements in digital competence.	Green Infrastructures, Open Spaces

3. Bucharest Demo

The Romanian demo case is called 'Open Campus for Neighbourhood and Climate' Neighbourhood and is located in District 2 of the Romanian capital Bucharest. The site area has an extension of 3 ha (0.03 km^2) with a population of 4000 habitants (mixed, different ages, families, and young adults). The demo site has a mix of uses, such as residential building blocks and single-family dwellings, public schools and UTCB campus, private retail, and small business areas. It is characterised by a built environment composed of mixed architecture, including multi-family residential buildings from the communism era ,the UTCB student campus, and residential single-housing units from different construction periods.

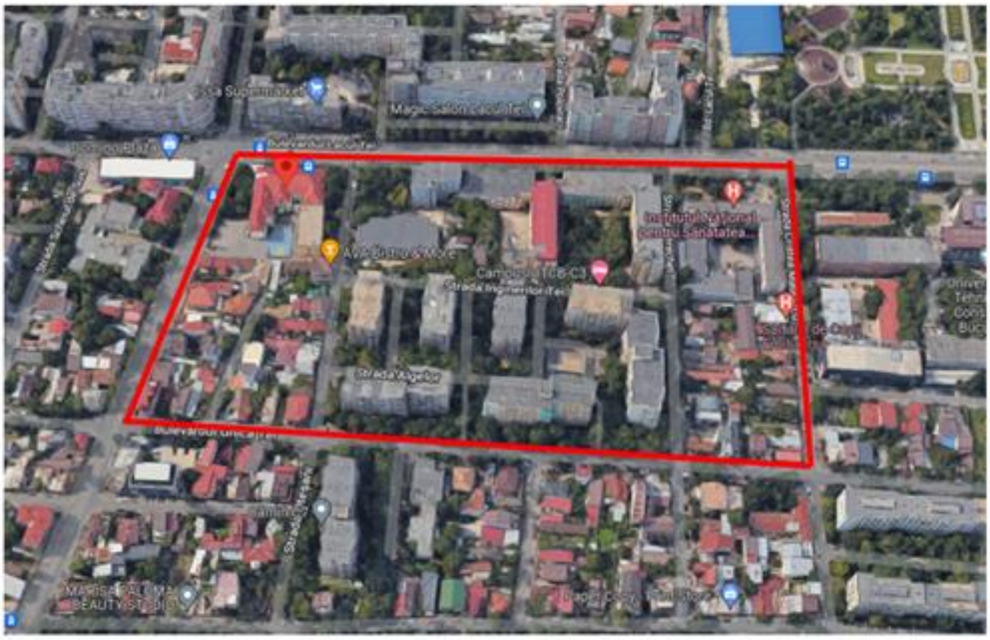

Figure 11. Bucharest Demo – 'Open Campus for Neighbourhood and Climate', in the 2nd District in Bucharest.

The Bucharest Demo case mainly consists of several distinctive areas:

- **Area 1 – University Campus and school building**
- **Area 2 – Residential large multifamily buildings**
- **Area 3 – Detached Single-Housing Neighbourhood**
- **Area 4 – Other public buildings**

As part of the City Dialogues in coordination with the Innovation Hub, Demo planned actions were revised during the first 9 month of project implementation as indicted in **Table 25**.

Table 25. *Bucharest Demo – Revised Action for Urban Regeneration of the 'Open Campus' Neighbourhood.*

Bucharest key actions
A1. Develop a co-designed deep retrofit solution for the local student canteen and energy smart building environment through urban sharing ecosystems.
A2. Smart and sustainable regeneration of local community public spaces within and outside the university campus.
A3. Develop a sharing platform (Shared Energy Centre) for sharing the energy produced in the campus with the neighbourhood.
A4. Digital Twin development and testing for assessing the potential of GHG emission reduction and the creation of an energy community in the neighbourhood.

Table 26 summarises Demo's actions impacting proposed KPIs of the Impact Model.

Table 26. *Preliminary plan for application of assessment framework to 'Open Campus' Neighbourhood.*

Cate-gory	***KPI***	***Relevance to demo***	***Demo actions impacting the KPIs/Comments***	***Type of urban interventions***
Energy	Total Primary Energy	5	A1 - Primary energy offers a comprehensive view of energy consumption, enabling efficient allocation of resources for maximum energy savings; for this reason, the indicator will be monitorised before and after the buildings (canteen and school) retrofit A3 - The total amount of primary energy will be monitorised through the energy community platform	Built Environment Interventions
	Renewable Energy Ratio (RER)	5	A1 - Solutions which involves renewable energy will be applied via buildings renovation A3 - The total amount of renewable energy will be monitorised through the energy community platform where it will result also the RER indicator	Built Environment Interventions
	Net Energy / Net Power	5	A3, A4 - beneficial for energy management systems within the energy sharing platform and digital twin data inputs	Built Environment Interventions
	Grid Delivered Factor (Optional KPI)	5	A3, A4 - the factor will be monitorised via energy sharing platform and digital twin	Built Environment Interventions
Environment	GHG Emissions Performance	5	A4 - data input validation for the digital twin and after retrofit endorsement of the building	Built Environment, Mobility and Green Infrastructure Interventions
	Air Pollution from the Energy Consumption	3	A2 - the regeneration of the demo site by creating more green spaces improve the air quality of the area and therefore decrease the air pollution	Built Environment and Mobility Interventions
	Indoor Air Quality (Optional KPI)	5	A1 - indoor air quality is improved because of the solutions applied during buildings retrofit	Built Environment Interventions / Citizens' Awareness

	Thermal Comfort (Optional KPI)	5	A1 - thermal comfort is improved because of the solutions applied during buildings retrofit	Campaigns and Engagement Strategy
	Overheating risk – Heat Index (Optional KPI)	4	A1 - overheating risk important in renovation process for the space quality and people's comfort	
Social	Democratic process	4	A2 - the regeneration of public spaces determines the community endorsement and support	Citizens' Engagement Strategy
	Sociability	4	A2 - the increase of green areas creates more spaces for people interactions within the community	
	Social engagement	5	A2 - positive impact on social communities therefore increasing the reliability of the regenerated public spaces	
	Demographic composition	3	A2 - the diversity of people engaging and benefiting from the regenerated public spaces	
	Safety and Security	2	A2 - acknowledge the level of security and safety in the regenerated area	
	Energy and Environmental Consciousness	4	A2, A3 - promote community engagement by raising awareness about sustainable practices and encouraging collective action	
	Cultural Sustainability (Optional KPI)	1	A2 - not directly applicable for the intervention area	
Socio-Economics	Access to services and Amenities	2	A2 - ensuring community accessibility to facilities and services	Digital Twin, Mobility, Green Infrastructures, Open Spaces
	Energy Affordability (Optional KPI)	2	A2/A3 - monitoring social and energy impact in terms of affordability within the engaged community	Built Environment Interventions / Citizens' Awareness Campaigns and Engagement Strategy
	Energy Renovation Rate (Optional KPI)	5	A1 - reflects the buildings stock performance improvement determined by energy renovation initiatives	Built Environment Interventions / Citizens' Awareness Campaigns and Engagement Strategy
	Investments Triggered	3	A4 – economic performance analysis linked to demo interventions	Urban Regeneration Interventions
	Global Cost (Optional KPI)	3	A4 – economic performance analysis linked to demo interventions	Urban Regeneration Interventions
Sustainable Urban Mobility	Transport Behaviour	4	A2 - promoting public transport already present (metro, tram, bus)	Mobility, Green Infrastructures, Open Spaces
	Urban Accessibility	4	A2 - ease and availability for each individual to access the area	Built Environment, Mobility, Green Infrastructures, Open Spaces
	Multi-modality (Optional KPI)	1	A2 - promoting public transport already present (metro, tram, bus)	Mobility
	Cycling path supply	4	A2 - freeing up urban areas to increase the number and length of bike lanes	Mobility, Open Spaces

	Renewal of Walking and Open Spaces	5	A2 - all actions proposed in Bucharest demo expect to renew the open space, increasing the urban green areas and its functionality A2 - more walkable areas, freeing up sidewalks for pedestrians	Mobility, Green Infrastructures, Open Spaces
	Physical activity (Optional KPI)	3	A2 - physical activity increased by regeneration of the area (bike usage, walkability)	Mobility, Green Infrastructures, Open Spaces
Integrated Urban Regeneration	Recycling and circular economy initiatives	4	A2 - a lot of R-strategy measures taken into account in the package of actions A2 which will be realised in the demo site area	Built Environment, Mobility, Green Infrastructures, Open Spaces
	Resource Recovery (Optional KPI)	4	A2/A1 - heat recovery from canteen processes via renovation, collect and waste sort	Built Environment, Mobility, Green Infrastructures, Open Spaces
	Urban Heat Island	5	A2, A4 - reduced by increased green spaces, simulated and monitorised via digital twin	Green Infrastructures, Open Spaces
	Flood Risk (Optional KPI)	1	A2 - green areas can help reduce flooding by absorbing and slowing down rainwater runoff	Green Infrastructures, Open Spaces
	Uptake of Digital Applications in Urban Regeneration Processes	5	A4 - indicator tested in developing process of digital twin	Digital Twin
	Digital Competence (Optional KPI)	5	A4 - indicator complementary to the digital twin development process	Digital Twin

4. Tampere Demo

The Finnish demo case is Tampere's City Centre and is located in the City of Tampere. The site is a mixed area composed of residential, retail, schools, and work infrastructure/facilities, including historical buildings, parks, and cultural facilities with an extension of 600 hectares. The target population is diverse as well composing of neighbourhood residents, local businesses, and visitors of city centre (Tampere has a population of around 250 000 residents with approx. 41,000 inner city inhabitants).

Figure 12. *Tampere Demo – City Centre Neighbourhood.*

The Tampere Demo case consists of several distinctive areas:

- **Area 1 – The Central Railway Station**
- **Area 2 – The Central Square**
- **Area 3 – Inner-city Business area**
- **Area 4 – Inner-city Residential area**

As part of the City Dialogues in coordination with the Innovation Hub, Demo planned actions were revised during the first 9 month of project implementation as indicted in **Table 27**.

***Table 27**. Tampere Demo – Revised Action for Urban Regeneration of the City Centre Neighbourhood.*

Tampere Demo Revised Actions
A1. Towards the metaverse – creation and utilization of digital twins
A2. Engagement of citizens in co-creation of walkable and safe city centre
A3. Use digital twins to simulate safety and CO2 emission levels related to people flows and to support walkability
A4. Measure well-being and life satisfaction, domains of Environmental, Socio-economic and Safety-related factors of well-being
A5. Economic incentives and campaigns for residents to increase walkability and reduce their own carbon footprint based on simulation results from the digital twin

Table 28 summarises Demo's actions impacting proposed KPIs of the Impact Model.

***Table 28**. Preliminary plan for application of assessment framework to Tampere City Centre.*

Cate-gory	***KPI***	***Relevance to demo***	***Demo actions impacting the KPIs/Comments***	***Type of urban interventions***
Energy	Total Primary Energy	2	(n/a) > eventually A3 and A5 to use of Digital Twins to reduce carbon footprint.	Digital Twin and, eventually, Built environment interventions (as result from Citizens' Awareness Campaigns and Engagement Strategy)
	Renewable Energy Ratio (RER)	2	(n/a) > eventually A3 and A5 to use of Digital Twins to reduce carbon footprint.	
	Net Energy / Net Power	2	(n/a) > eventually A3 and A5 to use of Digital Twins to reduce carbon footprint.	
	Grid Delivered Factor (Optional KPI)	2	(n/a) > eventually A3 and A5 to use of Digital Twins to reduce carbon footprint.	
Environment	GHG Emissions Performance	5	A1, A3, A5. Alignment of the work with the carbon-neutral roadmap of the City of Tampere. This goes in line with the SUMP goals that the city is currently updating.	Urban Regeneration Interventions
	Air Pollution from the Energy Consumption	3	A1, A3, A5. Increasing walkability aims to reduce inner city traffic pollution by some extent. Possible economic incentives may be included to encourage carbon-neutral transport and reduce inner city air pollution.	Digital Twin, Sustainable Mobility and, eventually, Built environment interventions (as result from Citizens' Awareness Campaigns and Engagement Strategy)
	Indoor Air Quality (Optional KPI)	2	(n/a) > eventually A1 use of DT	These could be partially addressed as part of Citizens' Awareness Campaigns and
	Thermal Comfort (Optional KPI)	2	(n/a) > eventually A1 use of DT	

	Overheating risk – Heat Index (Optional KPI)	2	(n/a) > eventually A1 use of DT	Engagement Strategy / DT application
Social	Democratic process	4	A1, A2, A4. Additional methods of citizen participation are being considered, such as use of the '*Maptionnaire'* resident data collection tool.	Citizens' Engagement Strategy
	Sociability	5	A1, A2, A4. This is much related to increase of walkability and to the aim to increase it. Research has been done on the connections between health, community interaction, and sustainable mobility.	
	Social engagement	5	A1, A2, A4. Digital twin will be used for this (citizen participation, surveys, pilots, simulations etc.)	
	Demographic composition	5	A1, A2, A4. This is a cross-sectional interview and participatory process done already and work continues in all action points.	
	Safety and Security	4	A1, A2, A4. The Tampere Sense of Safety survey (2021) revealed that residents felt least safe in the city centre area and in general, they found the place unattractive for pedestrians. Research is continuing on how to improve sense of safety in the city centre for residents.	
	Energy and Environmental Consciousness	3	A1, A2, A4. Related to the Tampere 2030 Carbon-neutral Roadmap development that is currently ongoing. We have regular meetings with the Climate and Environmental Policy team.	
	Cultural Sustainability (Optional KPI)	4	A1, A2, A4. A need to increase cultural happenings and cultural engagement in the Central Square and inner-city areas has been identified, which is being considered within development plans and resident engagement strategies.	
Socio-Economics	Access to services and Amenities	3	(n/a) > eventually A2	Digital Twin, Mobility, Green Infrastructures, Open Spaces
	Energy Affordability (Optional KPI)	2	(n/a) > eventually A2	These could be partially addressed as part of Citizens' Awareness & Engagement Campaigns / DT application
	Energy Renovation Rate (Optional KPI)	2	(n/a) > eventually A2	
	Investments Triggered	4	A5. Innovative new use of Digi. Twin models in the planning and decision-making process is expected to bring value to future city planning projects, across broad departments.	Urban Regeneration Interventions
	Global Cost (Optional KPI)	3	A1, A5 – economic performance analysis linked to demo interventions	Urban Regeneration Interventions
Sustainable Urban Mobility	Transport Behaviour	4	A2, A5. The Tampere Sustainable Urban Mobility Plan (SUMP) has conducted data gathering on resident transport and mobility behaviour. This data has been utilised within the demo.	Digital Twin, Mobility, Green Infrastructures, Open Spaces

	Urban Accessibility	4	A2, A4, A5. Walking paths and cycling path supply is taken into account within the Digi. Twin models.	Digital Twin, Built Environment, Mobility, Green Infrastructures, Open Spaces
	Multi-modality (Optional KPI)	2	A2, A5. The connections between walking and cycling path supply and multi-modal public transport is being evaluated through Digi. Twin modelling.	Digital Twin, Mobility
	Renewal of Walking and Open Spaces	2	A2, A5. Potential economic incentives are being considered to improve resident engagement with inner city walkability.	Digital Twin, Mobility, Green Infrastructures, Open Spaces
	Cycling path supply	5	Related to the digital twin utilization. More cycling paths are currently planned for the inner-city area around the Demo site.	Digital Twin, Mobility, Open Spaces
	Physical activity (Optional KPI)	4	A2, A5. Increased walkability of inner-city urban areas is expected with improve physical activity for residents.	Digital twin, Mobility, Green Infrastructures, Open Spaces
Integrated Urban Regeneration	Recycling and circular economy initiatives	2	A1. Circular economy tools, methods, and strategies will be evaluated for use within the Digi. Twin modelling of the Demo area.	Digital Twin and Citizens' Awareness Campaigns and Engagement Strategy
	Resource Recovery (Optional KPI)	2	A1. Circular economy tools, methods, and strategies will be evaluated for use within the Digi. twin modelling of the Demo area.	Digital Twin and Citizens' Awareness Campaigns and Engagement Strategy
	Urban Heat Island	3	A1. Digi. Twin planning will consider the heat island risk of the Demo area.	Digital Twin
	Flood Risk (Optional KPI)	3	A1. Nature-based solution pilots developed in other areas of the city may be evaluated for the demo area.	Digital Twin
	Uptake of Digital Applications in Urban Regeneration Processes	5	A1. Digital twin and other digital tool development and utilization in current urban development and regeneration activities	Digital Twin
	Digital Competence (Optional KPI)	2	A4. Activities to reduce the digital literacy gap, and the inclusion of new digital tools within the Tampere.finland application for wider resident engagement.	Digital Twin, and Citizens' Awareness Campaigns and Engagement Strategy

Appendix B – GHG Emissions in Mobility

***Table 29**. Reference data for the determination of the GHG emissions in the use stage (mobility).*

Item	Transportation data	GWP reference data	Source
External district	22 km/person/day	-	[73]
Inner district	6 km/person/day	-	[73]
Private car, medium, EURO 5 petrol	70% (α_i)	3.3221E-1 kg CO2/km	[74], [74]
Bus	5% (α_i)	1.134E-1 kg CO_2/person per km	[74], [74]
Metro/railways	10% (α_i)	4.473E-2 kg CO_2/person per km	[74], [74]
Foot/bike	15% (a_{vt})	0.00 g CO_2/km	[74]

Appendix C – Emission Factors for Air Pollutants per Energy Carrier

Enery Consumption - Built Environment

***Table 30**. Emission factors for air pollutants per energy carrier (tech: conventional boilers <50 kW). Adopted from* [75].

Energy Carrier	PM 2.5 g PM2.5/kWh	NOx g NOx/kWh	SOx g SOx/kWh
Solid fuels (hard coil)	1.22E-02	7.52E-01	2.95E+00
Natural Gas	5.03E-04	3.20E-01	8.78E-04
Liquid fuels (gas oil)	2.87E-03	2.34E-01	1.67E-01
Biomass	4.79E-01	2.91E-01	3.89E-02

***Table 31**. Reference emission factors for air pollutants low-voltage electricity from in the WeGenerate demo locations. Adopted from* [76].

Energy Carrier	GWP kg CO2eq/kWh	PM 2.5 g PM2.5/kWh	NOx g NOx/kWh	SOx g SOx/kWh
Electricity (grid – low V - Finland)	1.5353e-1	2.4848e-4	3.2697e-4	5.8465e-4
Electricity (grid – low V - Romania)	3.8737e-1	1.2206e-3	6.5100e-4	2.2588e-3
Electricity (grid – low V - Italy)	3.7215e-1	3.9402e-4	6.4614e-4	1.1025e-3
Electricity (grid – low V - Portugal)	2.7193e-1	3.5784e-4	5.8087e-4	1.0624e-3

***Table 32**. Emission factors for NOx and PM (Reference* [32]*)*

Category	Fuel	NO_x (g/kg fuel)			PM (g/kg fuel)		
		Mean	Min	Max	Mean	Min	Max
PC	Petrol	8.73	4.48	29.89	0.03	0.02	0.04
	Diesel	12.96	11.20	13.88	1.10	0.80	2.64
	LPG	15.20	4.18	34.30	0.00	0.00	0.00
LCV	Petrol	13.22	3.24	25.46	0.02	0.02	0.03
	Diesel	14.91	13.36	18.43	1.52	1.10	2.99
HDV	Diesel	33.37	28.34	38.29	0.94	0.61	1.57
	CNG (Buses)	13.00	5.50	30.00	0.02	0.01	0.04
L-category	Petrol	6.64	1.99	10.73	2.20	0.55	6.02

(i) Emission of **SO2** (Reference [32])

The emissions of SO2 per fuel-type m are estimated by assuming that all sulphur in the fuel is transformed completely into SO2, using the formula:

$$E_{SO2,m} = 2 \cdot k_{S,m} \cdot FC_m$$

Where:

$E_{SO2,m}$ – emissions of SO2 per fuel m [g],

$k_{S,m}$ – weight-related sulphur content in the fuel of type m [g/g fuel],

FC_m – fuel consumption of fuel m [g].

Typical values for fuel sulphur content are given below for the periods before mandatory improved fuel specifications, following the first improvement in fuel specification (January 2000 = Fuel 2000), the second (January 2005 = Fuel 2005) and the regulation of fuel sulphur to maximum 10 ppm by January 2009 (Fuel 2009). In addition, typical emission factors for Calculation approach proposed for a number of countries can be found in [32].

Table 33. *Typical sulphur content of the fuel (1 ppm = 10-6 g/g fuel) (Reference* [32]*)*

Fuel	1996 Base fuel (Market average)	Fuel 2000	Fuel 2005	Fuel 2009 and later
Petrol	165 ppm	130 ppm	40 ppm	5 ppm
Diesel	400 ppm	300 ppm	40 ppm	3 ppm

Appendix D – Sustainable Mobility Enablers

List of mobility enablers to allow quantifying the available factors to uptake the sustainability of urban mobility systems.

Table 34. *Enabling factors of sustainable mobility (adapted from Reference* [16]*)*

Sustainable Mobility Enablers	**Scale of application [Building (B) / Neighbourhood (N)]**	**Evaluation Format**
EV-charging stations	B/N	True/False
Sheltered bicycle parking (B/N), changing/shower facilities (B)	N	True/False
Adequate bicycle infrastructural coverage on roads where car traffic does not allow mixed-use	N	True/False
Share of population within characteristic distance of public transportation stop	N	True/False
Vehicle-calming traffic measures on lighter roads	N	True/False
Pedestrian-friendly design of junctions, signified by surface levels, fit-for-volume traffic-management facilities, surface materials	B/N	True/False
Well-lit, well-connected, easy-to-traverse, well-maintained pedestrian infrastructure leading to all building access points	B/N	True/False
Car-sharing facilities	B	True/False
Home-office space and facilities at residential buildings	B	True/False
Any additional enabler of sustainable transportation modes can be added to the checklist if the auditor deems necessary	B/N	True/False
Bike sharing/city bikes	N	True/False

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