Ref. Ares(2024)7240330 - 11/10/2024

SUPERSHINE

D3.3 Set of social, environmental, economic, and financial key performance indicators

Authors: Miguel Gomez Meiras (CIRCE), Paola Zerilli (UoY), Ahmed Djeddi (UoY), Ana Belen Gomez Minguela (CARTIF)

Funded by the European Union

Innovate UK

Technical references

Project Acronym	SUPERSHINE
Project Title	S=Smart U=Upgraded asset-values and quality of life P=Public Private Partnership E=Extended Energy Efficiency R=Renewables triggered by the project SH=Social Housing I=Investment N=Net Zero E=European
Project Duration	November 2022–March 2026

Deliverable No.	D3.3
Dissemination level	PU (Public)
Work Package	WP 3 - SUPERSHINE investments pipelines and business models
Task	Task 3.2 - Methodology for Environmental, Economic and Social LCA assessment
Lead beneficiary	CIRCE
Authors	Miguel Gomez Meiras (CIRCE), Paola Zerilli (UoY), Ahmed Djeddi (UoY), Ana Belen Gomez Minguela (CARTIF)
Due date of deliverable	31 January 2024
Actual submission date	31 January 2024

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them.

v	Date	Beneficiaries	Track changes
1.0	23/11/2023	CIRCE	First Draft
1.1	26/12/2023	CARTIF	Section 4.1
1.2	28/12/2023	UoY	Section 4.3 and 4.4
2.0	29/01/2024	UoY	Revision

2.1	31/01/2024	APRE	Revision

Table of contents

List of Tables

List of Figures

Abbreviations and Acronyms

Acronym	Description
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
KPI	Key Performance Indicator
PED	Positive Energy District
LH	Lighthouse (District)
DHW	Domestic Hot Water
DH	District Heating
GHG	Greenhouse gases emissions
RES	Renewable Energy System

Acronym	Description
ROI	Return on Investment
NPV	Net Present Value
IPV	Increase in Property Value
SME	Small Medium Enterprise
EE	Energy Efficiency
IRR	Internal Rate of Return
BCR	Benefit Cost Ratio
S&P 500	Standard and Poor’s 500 index

Keywords

Energy indicators, Environmental indicators, Financial indicators, Lighthouses, energy poverty, decarbonization

Executive Summary

This deliverable focuses on defining representative metrics and indexes for evaluating the implementation of SUPERSHINE solutions in the lighthouse districts. The work includes defining and formulating Key Performance Indicators (KPIs) at various levels of granularity, tailored to the scope of specific lighthouse interventions. Performance indicator definitions will be accompanied by case-specific data collection guidelines, assessment methods, and data requirements needed for monitoring.

To analyse the varying actions developed in each district, we structured the intervention following the energy triangle (active, passive, and renewable), taking into account customer behaviour.

Energy - Technical Key Performance Indicators (KPIs) integrate a methodology to permit the calculation of the impacts for the different improvements in light demonstrators. To calculate these parts, implement a methodology to connect the impacts developed in each different area with specifying interventions that it intends to measure.

A Life Cycle Sustainability Assessment (LCSA) will be conducted, considering the three pillars of sustainability: environment, social, and costs, at both building and district levels. A tailored approach through a weighted scoring system will be designed and developed within the project to assess the sustainable potential of each integrated solution's scalability, replicability, and profitability.

Financial - Energy efficiency renovation projects in social housing buildings and districts aim to reduce energy consumption, lower costs, and improve living conditions for residents. Measuring financial KPIs is crucial for evaluating the success and economic viability of energy efficiency renovation projects in social housing buildings and at the district level. This deliverable considers analysing the return on Investment (ROI), Net Present Value (NPV) and Payback Period among other financial KPIs so that stakeholders can make informed decisions, optimise resource allocation, and maximise the benefits of energy efficiency initiatives while ensuring long-term financial sustainability. Also, this deliverable describes the financial evaluation methodology to conduct a comprehensive cost-benefit analysis to quantify the financial impacts of the EE renovation project. Consider both direct (energy savings) and indirect benefits (e.g., improved comfort, reduced maintenance, and operating costs).

A specific online survey, integrated into the SUPERSHINE portal and tailored to the different stakeholders involved in the project has been developed to facilitate data collection and inventory assessment. Life Cycle (LC) studies will be performed, involving the definition of the goal, system boundaries, and relevant KPIs; development of the Life Cycle Inventory (LCI); performance of the impact assessment; and analysis of the results, interpretation, and conclusions.

1. Introduction

1.1. Purpose of the document:

The SUPERSHINE project is an initiative aligned with the European Green Deal, focusing on enhancing energy efficiency in social housing. We aim at alleviating energy poverty and creating sustainable, energy-efficient districts. Our approach is guided by principles such as 'Energy efficiency first', affordability, decarbonisation, and life-cycle thinking.

This deliverable is a component of our project, concentrating on the development of Key Performance Indicators (KPIs) for our lighthouse districts. These KPIs will serve as metrics for evaluating the implementation of SUPERSHINE solutions. The deliverable includes a comprehensive Life Cycle Sustainability Assessment (LCSA) and a tailored approach to assess each integrated solution's scalability, replicability, and profitability.

1.2. Scope of this document

The scope of this document is encompassing several key areas of the SUPERSHINE project. It includes an overview of the project's indicators, providing a clear understanding of the goals and targets we aim to achieve.

The document delves into technical and financial aspects and also outlines the Key Performance Indicators (KPIs), which serve as critical metrics for evaluating the implementation of SUPERSHINE solutions.

Furthermore, the document will serve as a base to carry out an environmental, economic, and financial impact analysis, providing a holistic view of the project's potential impacts and benefits.

1.3. Interdependencies with other WPs and tasks

The information contained in this deliverable serves as a fundamental basis for coordinating various activities across WP2, WP3, WP4, and WP5. Specifically, the engagement strategies detailed within each LH, along with the KPIs that will be continuously monitored, hold significant importance. The knowledge and results derived from these initiatives act as crucial elements, contributing to the progression and accomplishment of subsequent tasks within the aforementioned WPs.

2. Lighthouse Districts

Project Objectives: The project focuses on the renovation of social housing to assist households struggling to pay their energy bills including prioritising energy efficiency, affordability, decarbonizing, and integrating renewables.

Lighthouse Districts: The project has established lighthouse districts characterised by several key features such as the possibility to allow energy-efficient buildings, low carbon mobility, smart grids, efficient water and waste management, and responsive technologies. The SUPERSHINE lighthouse districts are strategically located in three cities and revolve around housing developments that are ready for transformation. As in *D1.2 Engagement strategy and social acceptance KPIs* the insights derived from a survey conducted as part of *Task 1.1 – Exploration of Pilot Sites Socio-Economic Context* have been used to collect the relevant information about each district.

Key Features of Lighthouse Districts: The buildings in these districts are designed to minimise energy use. The project promotes transportation methods that produce fewer greenhouse gas emissions. These are electricity networks that use digital technology to optimise the production and distribution of electricity.

Areas of Intervention: The project's main areas of intervention include strengthening information and incentives for public and private owners and tenants to undertake renovations, ensuring adequate and well-targeted funding, promoting comprehensive and integrated renovation interventions, and making the construction ecosystem fit to deliver sustainable renovation.

The methodology followed to select the KPIs starts with the analysis of the identified actions to be carried out in the lighthouse districts (Trieste, Riga and Herning) and their classification based on the energy efficiency triangle. The next subsections will describe the districts using the methodology shown in figure 1 below:

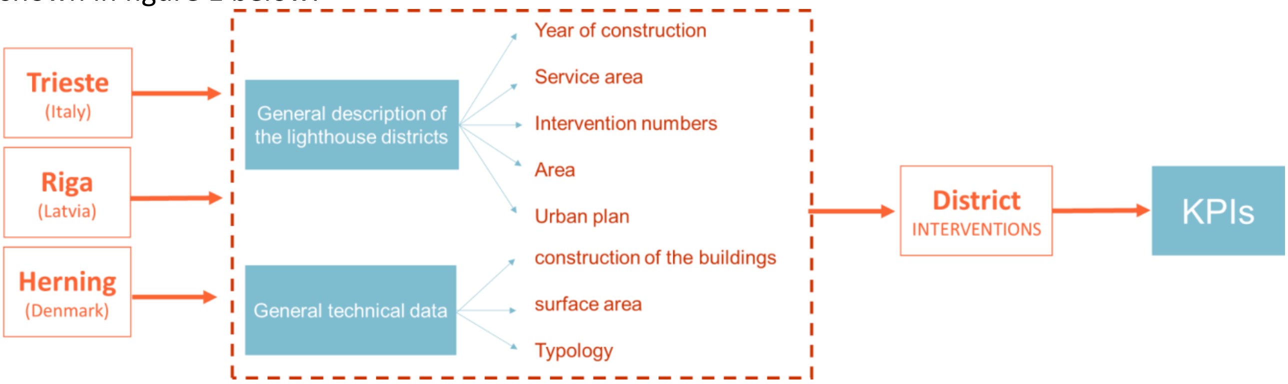


Figure 1: KPI's methodology

Before analysing the actions that will be carried out in each of the districts, a general description of the district under study is provided, along with the contribution of technical data that could be useful for the development of the project, introducing key concepts such as the year of construction of the buildings, their surface area, or their typology.

2.1.Trieste District

To describe the actions developed in the Trieste district, the methodology explained earlier has been followed. Based on these reported actions to be carried out in the demo, a selection of KPIs is specified in order to measure their impact and performance.

2.1.1.DISTRICT INFORMATION

Trieste Boito is a residential complex built in 1951 by G.M.A. Military Government of Occupied Territories in Trieste, capital of the Friuli - Venezia Giulia region. This area offers services such as primary schools, a recreation centre for children, sports facilities, a church, and commercial centres, all included in the Habitat Microaree program. The intervention focuses on numbers 1, 2, 3, 4, 5, 6, 7, and 8 on Via Boito, which has an area about 4.417,00 m2. Each building has 4 floors and 16 dwellings.

Figure 2: Intervention Area from Trieste, Boito

Trieste Boito is included in the Action Plan for Sustainability, Energy, and Climate (PAESC), initiated by the Trieste Municipality, which is currently in the approval process. Boito participated in the Habitat Microaree18 project which promotes well-being and social cohesion with the aim of improving the quality of life of the inhabitants of deprived areas.

The intervention is intended to be carried out on the buildings, providing them with larger habitable areas, as well as a comprehensive rehabilitation of the space. Within the urban scale, the goal is to renew green space networks, adapt circulation routes, and parking areas.

Before intervention, these houses will be assigned to new inhabitants under the ERP by Trieste, which includes individuals over 65 years old, families with children, and houses with rents less than €15,000.[1]

2.1.2. GENERAL INFORMATION [2]

In the case of the Trieste demo, all the buildings have the same technical data. Those common info is gathered in table 1 below.

Table 1: General common data for Trieste buildings.

Construction year	Number of dwellings	Total Floorspace (m2)	Number of dwellings per building
1951	16	552	16
Energy Performance Certificate rating	**Number of storey**	**Function**	**Energy Consumption (kWh/m2 annual)**
G	4	Social Housing	131

The complex consists of 8 buildings with 16 apartments each, resulting in a population density of 3,5 people. After the renovation, each building will have 8 apartments, maintaining a population density of 2,5 people per dwelling. The typology of the buildings is a prism with **dimensions**: Height (m) 14 m, Width (m) 20 m, Depth (m) 10 m, and a roof angle of 20º. Currently, the area has an **energy classification** of G, which is expected to transform into an A2 classification upon completion of the rehabilitation works.

2.1.3. LIST OF INTERVENTIONS IN BOITO DISTRICT

The description of the interventions is carried out taking into account the **energy efficiency triangle**, grouping the actions developed into three main pillars: passive measures, active measures, and renewable actions.

Passive measures are those aimed at reducing energy demand through the efficient construction of new buildings or the comprehensive rehabilitation and insulation of building envelopes. These passive actions include improvements to the envelope, windows, and roofs.

The **Active Measures** are related to the high efficiency of the active systems as heating and cooling that provide optimal comfort conditions to the buildings. These measures can include other active systems, through equipment improvement and lighting change.

[1] Information obtained from the municipality of Trieste and the SuperShine Grant Agreement document.
[2] Information given by Trieste municipality.

To conclude, the last step relates to trying to meet as much as possible the energy demand through **Renewable Energy**, which is to be obtained from natural resources that are practically inexhaustible on a human scale and regenerate continuously.

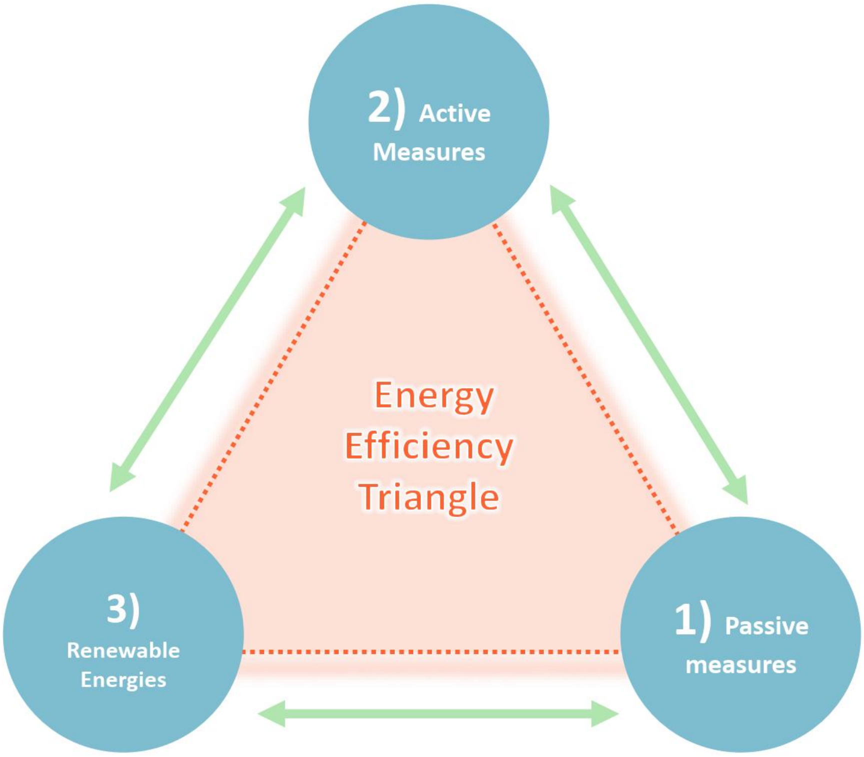


Figure 3: Energy Triangle Explanation

2.1.4. Passive Measures

Proposed Window Fittings and External/Internal Coating Renovations.

The comprehensive rehabilitation of all residential buildings is intended to eliminate their current state of disrepair by installing insulation, replacing windows and doors. Along with the comprehensive rehabilitation, a reconfiguration of the interior of the homes is proposed to meet current habitability conditions as outlined in the regulations.

Table 2: Passive Measures. WF (Window Fittings)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
T-WF	T-WF-1	External doors and windows of the housing units will be in aluminium	Boito 1 Boito 2 Boito 3 Boito 4 Boito 5 Boito 6 Boito 7 Boito 8
	T-WF-2	Doors and windows will feature a thermal break type with thermal imaging glass	
	T-WF-3	Doors and windows will be equipped with aluminium shutters with wing or book opening	
	T-WF-4	Installation of a BAPV system in the windows	

Table 3: Passive Measures. CO (External / Internal Coating renovations.)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
T-CO	T-CO-1	The building will be thermally insulated using 100 mm thick insulating panels applied externally to the walls	Boito 1 Boito 2 Boito 3 Boito 4 Boito 5 Boito 6 Boito 7 Boito 8
	T-CO-2	The building will be thermally insulated using 100 mm thick insulating panels laid on the floor on the mezzanine	
	T-CO-3	In the inter-floors, and in the attic laid panels of varying thickness in relation to the required insulation.	

2.1.5.Active Measures

Proposed Heating/Cooling Renovations.

Within the proposed renovations regarding the heating/cooling system updating, the goal is to reduce the current heat demand of 130 kWh/year, cutting heating bills by 75%, resulting in a saving of €500 per year and translating to 100 tons of CO2 per year. To achieve this, the following solutions are proposed for all buildings in the residential complex. The intention is to install a shared condensing boiler through geothermal heat pumps, given the high likelihood of reduced heat loads following the installation of insulation as part of the comprehensive rehabilitation of the buildings.

Table 4: Active Measures. HC (Heating/Cooling renovations)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
T-HC	T-HC-1	Centralised heating and hot water production system using a natural gas condensing boiler	Boito 1 Boito 2 Boito 3 Boito 4 Boito 5 Boito 6 Boito 7 Boito 8
	T-HC-2	Installation of consumption metering system for each housing unit	
	T-HC-3	Heating systems with heating elements for each housing unit	

Proposed Lighting renovations.

Innovations in the field of urban lighting allow for energy savings that can exceed 80%, considering that lighting accounts for 19% of the total urban energy consumption. New technologies based on LED and a lighting management system represent a viable alternative to reduce the energy footprint and consequently lower $CO2$ emissions. Unlike traditional light sources such as sodium lamps or fluorescent tubes, the installation of LED luminaires can result in a savings of up to 50% compared to other traditional alternatives, reducing energy expenditure and emissions.

Table 5: Active Measures. LG (Lighting renovations)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
T-LG	T-LG-1	The lamps will be low-consumption	Boito 1 Boito 2 Boito 3 Boito 4 Boito 5 Boito 6 Boito 7 Boito 8
	T-LG-2	The external lighting bodies with low light pollution	

2.1.6. Renewable Measures

Proposed Energy from Renewable Energy Sources Renovations.

Due to the comprehensive rehabilitation that will be carried out, as well as the typology of the buildings (height and compactness of the geometry), along with the lack of obstacles that could cast shadows, the installation of a photovoltaic system is intended to reduce electricity consumption in the area. Currently, residential electricity costs in Italy amount to €0.18/kWh. Users would reduce their energy bills and recover installation costs within 4.5 years.

Table 6: Renewable Measures. RE (Renewable Energy sources renovations)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
T-RE	T-RE-1	Installation on the roof of solar panels	Boito 1 Boito 2 Boito 3 Boito 4 Boito 5 Boito 6 Boito 7 Boito 8
	T-RE-2	Installation of flow and return circuits for solar panels	

2.2. Riga District

To describe the actions that will be developed in the "Āgenskalna priedes" District of Riga, the methodology indicated before in this section has been also applied.

2.2.1. DISTRICT INFORMATION

Āgenskalna priedes" is a residential area in the city of Riga, consisting of residential buildings from the years 1959-1961 and a new residential building constructed in the year 2020. This area offers services such as multi-apartment residential buildings, family housing areas, offices, retail spaces, public services, universities, schools, and kindergartens. The main inhabitant groups are newcomers (new families, students) and elderly (singles and families).

This area belongs to the district of Āgenskalns (the historical neighbourhood of Riga), is best known for its extensive architecture and landscaped parks, ponds, and waterfront of the river Daugava.

This area is a truly diverse neighbourhood, a balanced mix of historical buildings and new developments. In addition, it has been marked by the municipality as the renovation wave pilot in its Sustainable Development Programme 2021-2027.

The intervention focuses on numbers 14, 16, 18, and 20 on Dreiliņu iela street; 16, 16A, 16B, 16C, 12, 8, 8A, 8B 10, 12, 14, 16, 18, and 20 on Kristapa iela street; 19, 21, 23, and 25 on Melnsila iela street; and 22, 22A, 22B, 22C and 24 on Āgenskalna Street, covering an area of about 461.3 hectares with 1,283 apartments/households.

Figure 4: Intervention Area from Riga, Āgenskalna priedes

Riga is the capital of Latvia and the largest city in the Baltic states. In beginning of 2020, the Latvian government adopted two major energy and climate planning; the first one denominated like "*country's Strategy for Achieving Climate Neutrality by 2050*" and second "*Latvia's national energy and climate plan 2021-2030*" focusing on the development of a sustainable, competitive and climate neutral economy.

In addition to Latvian government plan, Riga city elaborated the "Blod City Vision-2050" for energy transformation, decarbonisation and positive energy districts. In October 2020, the new term of the Riga City Council began to work, declaring climate-smart urban development and achieving climate neutrality goals as their key strategic priorities. Riga city has made a strong political commitment towards climate neutrality by signing the Paris climate declaration "Cities Leading the Way to Climate Neutrality" in 2021.

The Āgenskalns neighbourhood is known for its active, motivated to take part in development of their neighbourhood and willing to contribute to green and smart transformation of their urban and living space.

2.2.2.GENERAL INFORMATION [3]

In the case of Riga's "Āgenskalns" neighbourhood, buildings feature different technical specifications. Therefore, in the following tables, each building is categorised based on its typology and location within the neighbourhood. In order to facilitate searching for information, the buildings have been classified by street and then by numbers.

Dreiliņu Street:

Table 7: Data related to building nº 20

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	2164.2	55	G
Number of storey	**Energy Consumption, DH (kWh/m2 annual)**	**Energy Consumption, DHW (kWh/m2 annual)**	**Energy Consumption, DH+DHW (kWh/m2 annual)**
5	169.96	42.98	212.94

Table 8: Data related to building nº 18-16-14

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1961	1530.60	40	G
Number of storey	**Energy Consumption, DH (kWh/m2 annual)**	**Energy Consumption, DHW (kWh/m2 annual)**	**Energy Consumption, DH+DHW (kWh/m2 annual)**
5	170.18 (nº18) 164.48 (nº16) 184.52 (nº14)	30.26 (nº18) 39.43 (nº16) 43.13 (nº14)	200.44 (nº18) 203.91 (nº16) 227.65 (nº14)

[3] Information given by Trieste municipality.

Kristapa Street:

Table 9: Data related to building nº8 - 8A - 8B

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	954.40 (nº8) 948.20 (nº8A) 946.90 (nº8B)	62 (nº8) 64 (nº8A) 63 (nº8B)	- (nº8) G (nº8A) G (nº8B)
Number of storey	**Energy Consumption, DH (kWh/m2 annual)**	**Energy Consumption, DHW (kWh/m2 annual)**	**Energy Consumption, DH+DHW (kWh/m2 annual)**
4	- (nº8) 221,40 (nº8A) 221,40 (nº8B)	- (nº8) 49,70 (nº8A) 49,70 ((nº8B)	- (nº8) 271,10 (nº8A) 271,10 (nº8B)

Table 10: Data related to building nº10

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	1902.3	128	G
Number of storey	**Energy Consumption, DH (kWh/m2 annual)**	**Energy Consumption, DHW (kWh/m2 annual)**	**Energy Consumption, DH+DHW (kWh/m2 annual)**
4	227.78	36.97	264.75

Table 11: Data related to building nº12

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	2747.20	70	G
Number of storey	**Energy Consumption, DH (kWh/m2 annual)**	**Energy Consumption, DHW (kWh/m2 annual)**	**Energy Consumption, DH+DHW (kWh/m2 annual)**
5	186.50	27.59	214.09

Table 12: Data related to building nº14

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	943.10	62	G

Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
4	215.16	23.50	238.66

Table 13: Data related to building nº16 - 16A - 16B - 16C

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	1547.00 (nº16) 1731.70 (nº16A) 1736.40 (nº16B) 1520.40 (nº16C)	40 (nº16) 44(nº16A) 44 (nº16B) 40 (nº16C)	G (nº16) F (nº16A) F (nº16B) F (nº16C)
Number of storey	**Energy Consumption, DH (kWh/m2 annual)**	**Energy Consumption, DHW (kWh/m2 annual)**	**Energy Consumption, DH+DHW (kWh/m2 annual)**
5	185.61 (nº16) 166.26 (nº16A) 165.24 (nº16B) 173.05 (nº16C)	26.24 (nº16) 29.87 (nº16A) 32.99 (nº16B) 25.87 (nº16C)	211.85 (nº16) 196.13 (nº16A) 198.23 (nº16B) 198.92 (nº16C)

Table 14: Data related to building nº18

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1959	2147.10	55	G
Number of storey	**Energy Consumption, DH (kWh/m2 annual)**	**Energy Consumption, DHW (kWh/m2 annual)**	**Energy Consumption, DH+DHW (kWh/m2 annual)**
5	184.16	27.07	211.23

Table 15: Data related to building nº20

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1959	2145.80	55	G

Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
5	208.56	29.15	237.71

Melnsila Street:

Table 16: Data related to building nº19

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	1517.90	39	G
Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
5	206.48	29.14	235.62

Table 17: Data related to building nº21

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	1526.39	39	G
Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
5	172.61	27.86	200.47

Table 18: Data related to building nº23

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	1840.60	41	G
Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
5	174.71	26.02	200.73

Table 19: Data related to building nº25

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating

1960	1790.60	41	F
Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
5	169.21	23.26	192.47

Āgenskalna Street:

Table 20: Data related to building nº22 - 22B - 22C

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	1550.20 (nº22) 1554,20 (nº22A) 1616,10 (nº22C)	40 (nº22) 40 (nº22A) 41 (nº22C)	G (nº22) G (nº22A) G (nº22C)
Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
5	182,51 (nº22) 180,43 (nº22A) 179,85 (nº22C)	31,27 (nº22) 28,54 (nº22A) 25,94 (nº22C)	213,78 (nº22) 208,97 (nº22A) 205,79 (nº22C)

Table 21: Data related to building nº 22A

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
1960	2826.50	71	G
Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)
5	169.80	41.84	211.64

Table 22: Data related to building nº 24

Construction year	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating
2020	1675,30	29	A+
Number of storey	Energy Consumption, DH (kWh/m2 annual)	Energy Consumption, DHW (kWh/m2 annual)	Energy Consumption, DH+DHW (kWh/m2 annual)

5	34.53	4.56	39.09

The complex consists of 25 multi-apartment residential buildings and public space. All "Āgenskalna priedes' ' buildings are connected to centralised district heating (DH) & domestic hot water (3rd DHW with high operational temperatures "*in 120°C, out 80°C*") system, supplying the area with cogeneration thermal energy.

All households have access to a high-speed internet connection; however, no specific smart ICT applications have been introduced in the district.

2.2.3.LIST OF INTERVENTIONS IN ĀGENSKALNS DISTRICT

For the Riga demo, in addition to the three pillars previously described for the **energy efficiency triangle**, it is necessary to include one more pillar we have called 'customers.' This group, in some cases, modifies the rest of the options based on their behaviour and habits.

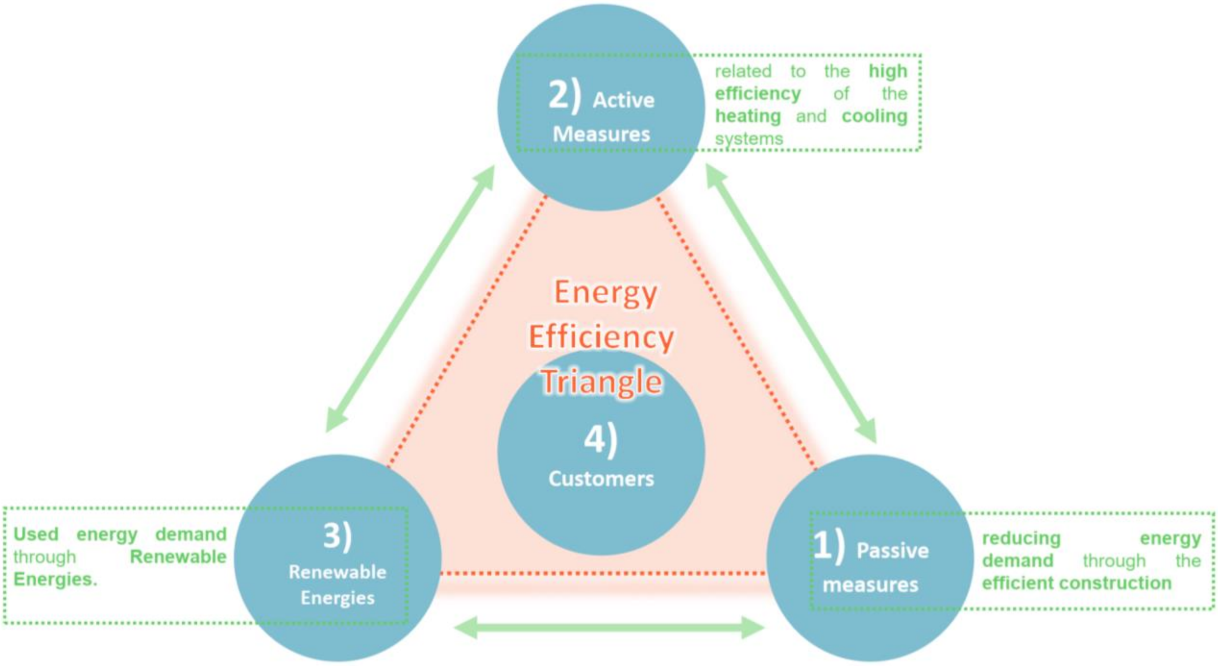


Figure 5: Energy Triangle Explanation

2.2.4. Passive Measures

Proposed Window Fittings

About 90% of our time, we are users of some building that consumes energy both to heat and light its spaces, as well as to ventilate them or produce hot water. This means that 40% of the world's energy consumption is derived from the energy demand of buildings (heating or cooling systems).

By ASEFAVE, the biggest losses or gains of heat have been produced by building openings, which account for about 25% to 30% of our heating needs. In this case, improved building facades have reduced the overall thermal transmittance by incorporating solutions for solar control and minimising thermal bridges in the carpentry.

Table 23: Passive Measures. WF (Window Fittings)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
R-WF	R-WF-1	Replacement of Window Fittings	Dreiliņu Street (nº20, 18, 16 and 14) Kristapa Street (nº8A, 8B, 10, 12, 14, 16A, 16B, 16C and 20) Melnsila Street (nº19, 21, 23 and 25) Āgenskalna Street (nº22, 22B, 22C, 22A)

External / Internal Coating renovations [4]

The energy retrofit of a building's thermal envelope can achieve an average reduction of 64% in the energy demand for heating and cooling by reducing the heat transfer between the interior and exterior. This entails a significant improvement in heat and cold resistance properties, as well as a decrease in energy demand.

Table 24: Passive Measures. CO (External / Internal Coating renovations)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
R-CO	R-CO-1	external/internal coating (insulation)	Dreiliņu Street (nº20, 18, 16 and 14) Kristapa Street (nº8A, 8B, 10, 12, 14, 16A, 16B, 16C and 20)

[4] Building Control Laboratory of the Basque Government and ENEDI Research Group at the University of the Basque Country (UPV/EHU). (2023). Decarbonizing Rehabilitation (Deliverable). Basque country (Spain): Basque Government.

			Melnsila Street (nº19, 21, 23 and 25) Āgenskalna Street (nº22, 22B, 22C, 22A)

2.2.5.Active Measures

Proposed Heating/Cooling Renovations

An improvement in thermal performance is intended by reducing the temperature of the heating network, paving the way for the inclusion of increasing the efficiency of heat production, and reducing losses. This could reduce carbon emissions, which are currently around 2,700 tons of CO_2 per year.

Table 25: Active Measures. HC (Heating/Cooling renovations)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
R-HC	R-HC-1	heating/cooling updating	Dreiliņu Street (nº20, 18, 16 and 14) Kristapa Street (nº8A, 8B, 10, 12, 14, 16A, 16B, 16C and 20) Melnsila Street (nº19, 21, 23 and 25) Āgenskalna Street (nº22, 22B, 22C, 22A)

Proposed Lighting renovations.

This action destined to improve the functionality, efficiency or aesthetic of lighting.

Table 26: Active Measures. LG (Lighting renovations)

TYPE	ID	DESCRIPTION	BUILDING DETAILS

R-LG	R-LG-1	Lighting Renovation to Enhance Energy Efficiency	Dreiliņu Street (nº20, 18, 16 and 14) Kristapa Street (nº8A, 8B, 10, 12, 14, 16A, 16B, 16C and 20) Melnsila Street (nº19, 21, 23 and 25) Āgenskalna Street (nº22, 22B, 22C, 22A)

2.2.6. Renewable Measures

Proposed Energy from renewable energy sources renovations.

The capacity factors of photovoltaic (PV) solar energy in Riga are similar to those in Denmark, around 13%. Electricity prices are relatively low in Latvia, approximately €0.15/kWh, so the payback periods for rooftop solar energy are likely to exceed 5 years. This is also an effort to reduce the annual electrical demand of 7,500 MWh from the scheme, which is approximately 7,600 tons. These emissions could be substantially or completely offset through on-site generation.

Table 27: Renewable Measures. RE (Renewable Energy sources renovations)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
R-RE	R-RE-1	Installation of solar panels	Dreiliņu Street (nº20, 18, 16 and 14) Kristapa Street (nº8A, 8B, 10, 12, 14, 16A, 16B, 16C and 20) Melnsila Street (nº19, 21, 23 and 25) Āgenskalna Street (nº22, 22B, 22C, 22A)

2.3. Customers

Energy Audits

Energy Audits is a process of evaluating the energy usage within a building, facility, or system. The primary goal of an energy audit is to identify opportunities for improving energy efficiency, reducing energy consumption, and optimising overall energy performance.

Table 28: Customers. EA (Energy Audits)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
R-EA	R-EA-1	Energy Audits is a process to identify opportunities for improving energy efficiency, reducing energy consumption, and optimising overall energy performance.	Dreiliņu Street (nº20, 18, 16 and 14) Kristapa Street (nº8A, 8B, 10, 12, 14, 16A, 16B, 16C and 20) Melnsila Street (nº19, 21, 23 and 25) Āgenskalna Street (nº22, 22B, 22C, 22A)

Information Awareness

This concept emphasises the importance of disseminating information and knowledge about energy-related practices, technologies and behaviours.

Table 29: Customers. IA (Information Awareness)

TYPE	ID	DESCRIPTION	BUILDING DETAILS
R-IA	R-IA-1	Allows measuring the energy savings that occur after obtaining sufficient knowledge on a subject, in this case, it would be energy consumption and savings.	Dreiliņu Street (nº20, 18, 16 and 14) Kristapa Street (nº8A, 8B, 10, 12, 14, 16A, 16B, 16C and 20) Melnsila Street (nº19, 21, 23 and 25) Āgenskalna Street (nº22, 22B, 22C, 22A)

2.4. Herning District, FællesBo, Denmark

To describe the actions that will be developed in the "Herning" District of FællesBo , the methodology described in the first part of this section has been applied, which was also used in the Trieste area, the first district described.

2.4.1. DISTRICT INFORMATION

The SUPERSHINE Danish lighthouse district is in Herning Municipality (part of the Midtjylland Region). The residential demonstration buildings are in the south-eastern part of Herning in a mixed-use area (see Figure 6), which includes a large school, a shopping centre, residential villas and residential blocks.

There are four residential buildings (identified as Afd. 16, 19, 21, and 24) that have been earmarked as ready-to-go renovation projects. These buildings collectively encompass 692 flats with a total area of 55,101 square metres. Notably, these buildings, constructed between 1954 and 1965, have not undergone any refurbishment to date. In terms of while each building has its unique requirements, there is a general consensus that envelope renovation, insulation enhancements, and upgrades to energy systems are imperative. It's worth mentioning that none of these buildings currently utilise renewable energy generation methods.

Figure 6: Intervention Area from Herning, FællesBo

The district's residents are characterised by low income and financial capacity, lower education levels despite good access to education, convenient access to local services, and a need for social support, with about 50% requiring some form of assistance. Among the Faelles Bo tenants, 68% live in single-person households, including 12% single parents, 26% are over 60 years old, half lack formal education, 53% are employed, and 20% are immigrants, indicating cultural diversity. These characteristics highlight the community's unique challenges and opportunities.

2.4.2.GENERAL INFORMATION [5]

As shown in the following table, all buildings have similar technical characteristics.

[5] Information given by Herning municipality.

Building Name	Construction year	Number of dwellings	Total Floorspace (m2)	Number of dwellings per building	Energy Performance Certificate rating[6]	Number of storey	Function	Energy Consumption (kWh/m2 annual)
D 16	1958	89	6,470	18	No	4	Residential	122
D 19	1956	210	16,443	35	No	3	Residential	175
D 21	1954	123	9,596	41	No	3	Residential	163
D 24	1965	270	22,592	25	No	3	Residential	176

Table 30: Building information about Herning, FællesBo

Building Property	Quantity
Number of tenants	160
Number of apartments	89
Average size	74 m^2
Density	41 m^2/ tenant
Location	Longitude: 8.98, Latitude: 56.13, 58 metres above sea level
Total building land area	2,192 m^2
Height	8 m
Depth	14 m
Envelope surface	6000 m^2
Walls	
Description	Façades with hollow brick cavity wall without insulation/smaller unknown insulation for some gables.
Surface	381 m^2

[6] The Certificate (EPC) rating of the building before the deep building renovation that is currently taking place(April 2023 – October 2024)

Thermal Performance	1,25 W/m²K
Thickness	0,3 m
Roofs	
Description	Gable tiled roof on timber frame with 200 mm mineral wool insulation.
Roof angle	35º
Roof surface	2192 m²
Thermal Performance	0,2 W/m²K
Windows	
Description	Wooden 2-layers thermo window
Surface	380 m²
Percentage of glazed surface	10%
Thermal Performance	1,3 W/m²K
Floors	
Description	Wooden joists over 80mm not insulated concrete floor
Surface	2192 m²
Thermal Performance	2 W/m²K
Heating and HDW Systems	
Annual Energy consumption	122 kWh/m2
Annual Energy Consumption after renovation	103 kWh/m2
District Heating COP	2.0

Water consumption per dwelling	1,000 litre/m2/year.
DHW	500 litre/m2/year.

Table 31: Extended Building information about Department 16

2.4.3.LIST OF INTERVENTIONS IN THE HERNING DISTRICT

The proposed interventions at the Danish lighthouse encompass improvements to the building envelope, interior renovations, and energy efficiency systems. The building envelope will be enhanced with better insulation and reduced heat loss through various measures, including roof replacement, attic re-insulation, facade insulation, and more. Interior renovations aim to improve living spaces with a new bathroom, floor heating, a revamped kitchen, and improved acoustics. Energy efficiency will be boosted through the maintenance of a biomass cogeneration district heating system and potential installation of a rooftop PV system. These interventions collectively aim to enhance environmental sustainability, comfort, and aesthetics.

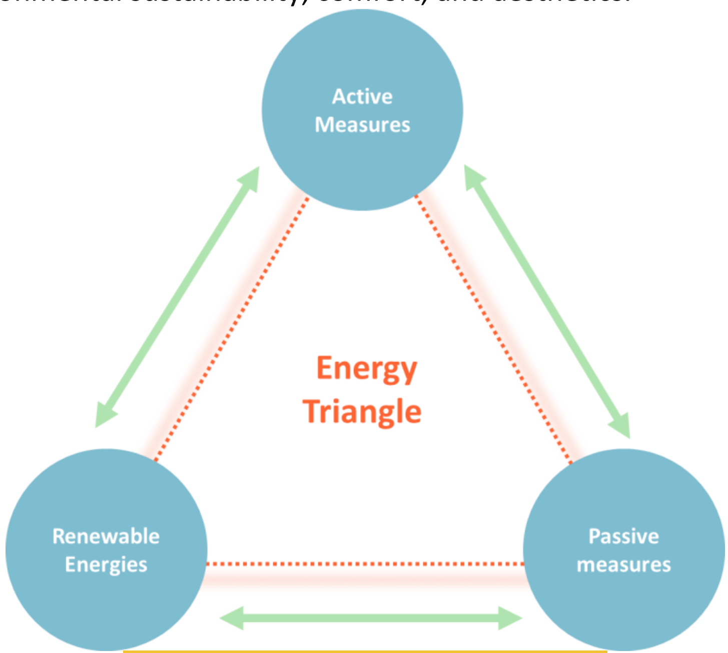


Figure 7: Energy Triangle Explanation

2.4.4.Active Measures

Proposed HVAC renovations.

Within the proposed renovations regarding the heating/cooling system updating, the intention is to adapt the pipes to reduce the energy loss. The heating systems are currently in good condition and far from the end of their lifecycle. Also, with a COP of around 2 the District Heating System is already more efficient than other more polluting alternatives such as a natural gas boiler.

TYPE	ID	DESCRIPTION	BUILDING DETAILS
H-HC	HC-1	New thermostat	
	HC-2	New floor heating system	
	HC-3	New balanced ventilation	

Proposed Lighting renovations.

Lighting is already rather efficient in the buildings due to the extended use of LED.

TYPE	ID	DESCRIPTION	BUILDING DETAILS
H-LG	LG-1	New LED lighting in common areas	

2.4.5. Pasive Measures

Proposed Window Fittings and external/internal Coating renovations.

The renovation fully commits to insulate the building to reduce the energy demand considerably. All surfaces in contact with the exterior are properly addressed from façade to the roof.

TYPE	ID	DESCRIPTION	BUILDING DETAILS

H-WF	WF-1	New 3-layer low energy windows	
	WF-2	New doors in balconies and at the entrance	

TYPE	**ID**	**DESCRIPTION**	**BUILDING DETAILS**
H-CO	CO-1	Insulation of division between floors towards cellar	
	CO-2	Pipe insulation of heating and DHW	
	CO-3	Insulation of roof (400 MM RockWOOL granulate)	
	CO-4	New insulation of the façade	

2.4.6. Renewable Measures

Proposed Energy from renewable energy sources renovations.

Due to the comprehensive rehabilitation that will be carried out, as well as the typology of the buildings (height and compactness of the geometry), along with the lack of obstacles that could cast shadows, the installation of a photovoltaic system is intended to reduce electricity consumption in the area. Currently, residential electricity costs in Denmark amount to €0.38/kWh. Users would reduce their energy bills and recover installation costs within 10 years.

TYPE	**ID**	**DESCRIPTION**	**BUILDING DETAILS**
H-RE	RE-1	Installation on the roof of PV solar panels for the departments' common electricity consumption (lightning on common areas, washing machines).	

	RE-2	Under consideration - Rooftop PV systems for electricity supply to the tenants having individual electricity supply for each flat.	

3. Key Performance Indicators (KPIs)

3.1. Introduction to SUPERSHINE KPIs

The European project SUPERSHINE aims to provide a comprehensive set of indicators to measure the performance and impact of energy, environmental, and financial aspects. These indicators are designed to provide a holistic view of the project's progress and effectiveness.

The indicators of the SUPERSHINE project play a crucial role in implementing solutions in the lighthouses. They provide a comprehensive framework to measure and monitor the performance of various aspects such as energy consumption, renewable energy production, energy efficiency, environmental impact, waste management, indoor air quality, construction materials, land use, water resources, and financial aspects. This allows for a systematic and data-driven approach to implementing and improving solutions, ensuring they are effective, sustainable, and aligned with the project's goals.

Moreover, the indicators can help in realising the NEB's goals by providing a means to measure and monitor the impact of the implemented solutions. They can help ensure that the solutions are not only effective and efficient but also sustainable and inclusive, in line with the NEB's principles. Furthermore, the indicators can aid in identifying areas for improvement and innovation, thereby contributing to the continuous development and evolution of the solutions in line with the NEB's objectives.

Lastly, these and the SLCA (Social Life Cycle Assessment) indicators described in *D1.2 engagement strategy and social acceptance KPIs* complement each other to provide a holistic assessment of the project. They mutually reinforce each other, with positive social acceptance leading to better implementation of technical solutions, and effective technical solutions enhancing social acceptance. These KPIs ensure a balanced assessment of the project, taking into account all important aspects - social, technical, environmental, and financial. Furthermore, they contribute to the continuous improvement of the project, providing valuable feedback for refinement and improvement.

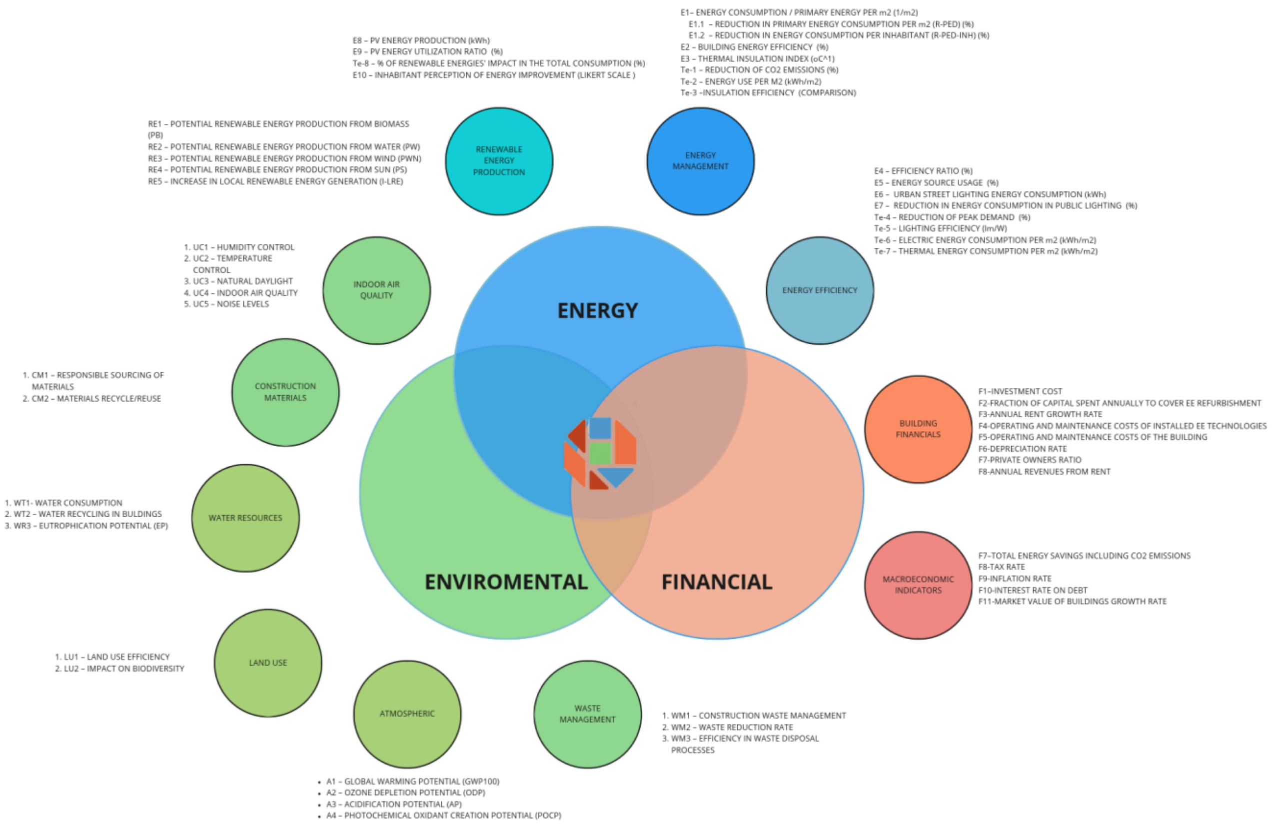


Figure 8: SUPERSHINE D3.3 KPIs map

3.2. Energy - Technical KPIs

To select the energy KPIs, it establishes a relationship between the interventions that will be developed in the three lighthouses (Riga, Trieste, and Herning) and what needs to be measured in each intervention area.

The solution will be developed and structured into four different categories: Passive measures, Active measures, Renewable measures, and, in only one city, including customer measures. The customer category is added because in Riga, there will be intervention to consider the customers behaviour. This final category (customer measure) is crucial in defining the role of consumers in the energy transition and how it could change the operability for consumption, climate control systems, and energy consumption.

For example, in a behavioural science experiment in one neighbourhood from San Marcos, California. The study aims to measure the importance of consumers' knowledge about energy data and how it could influence energy savings. Therefore, the population of the neighbourhood has been divided into four different groups, each receiving a different message with alternative objectives.

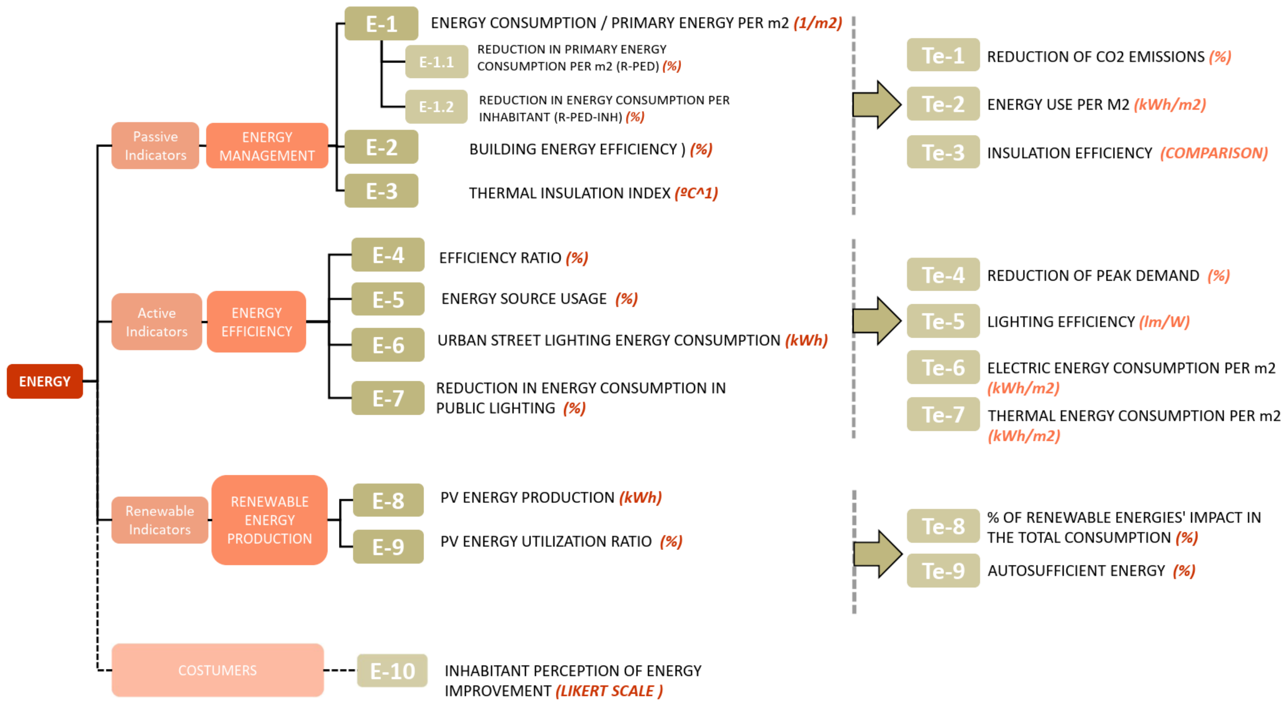
1. If you turn off your air conditioner you will save money
2. If you turn off your air conditioner you save the planet and environment.
3. The three group received one message for instance people will be a good citizen
4. The last group message compared the energy consumption among the different neighbours.

This science experiment could support the idea of taking into consideration the importance of consumers in measuring energy savings.

With reference to the other three categories, it will be connected to the Key Performance Indicators (KPIs) following the next classification:

INTERVENTION CLASSIFICATION	KPIs CLASSIFICATION
Passive Indicators	Energy Management
Active Indicators	Energy Efficiency
Renewable Indicators	Renewable energy production

Passive measures connect with the KPIs that provide information about energy management. Active measures relate to those KPIs in charge of energy efficiency, and renewable energy measures join those that measure renewable resources and their impact.



Moreover, to complete energy analyses it included some "final KPIs" that could measure the impact of interventions. These KPIs cannot be applied in the baseline step because it needs to compare two energy data. In addition, these KPIs permit measuring global, specific concepts for each category, allowing for a complete energy analysis. For this reason, those "final KPIs" have a separate in overall analysis. These KPIs are designed within the TE classification and specifying our concrete details at the end of each category.

3.2.1.List of energy KPIs

ENERGY MANAGEMENT

- E1– ENERGY CONSUMPTION / PRIMARY ENERGY PER m2 ***(1/m2)***
  - E1.1 – REDUCTION IN PRIMARY ENERGY CONSUMPTION PER m2 (R-PED) ***(%)***
  - E1.2 – REDUCTION IN ENERGY CONSUMPTION PER INHABITANT (R-PED-INH) ***(%)***
- E2 – BUILDING ENERGY EFFICIENCY ***(%)***
- E3 – THERMAL INSULATION INDEX ***(ºC^1)***

- Te-1 – REDUCTION OF CO2 EMISSIONS **(%)**
- Te-2 – ENERGY USE PER M2 **(kWh/m2)**
- Te-3 –INSULATION EFFICIENCY **(COMPARISON)**

ENERGY EFFICIENCY

- E4 – EFFICIENCY RATIO ***(%)***
- E5 – ENERGY SOURCE USAGE ***(%)***
- E6 – URBAN STREET LIGHTING ENERGY CONSUMPTION ***(kWh)***
- E7 – REDUCTION IN ENERGY CONSUMPTION IN PUBLIC LIGHTING ***(%)***

- Te-4 – REDUCTION OF PEAK DEMAND **(%)**
- Te-5 – LIGHTING EFFICIENCY **(lm/W)**
- Te-6 – ELECTRIC ENERGY CONSUMPTION PER m2 **(kWh/m2)**
- Te-7 – THERMAL ENERGY CONSUMPTION PER m2 **(kWh/m2)**

RENEWABLE ENERGY PRODUCTION

- E8 – PV ENERGY PRODUCTION ***(kWh)***
- E9 – PV ENERGY UTILISATION RATIO ***(%)***

- Te-8 – % OF RENEWABLE ENERGIES' IMPACT IN THE TOTAL CONSUMPTION **(%)**
- Te-9 – AUTO SUFFICIENT ENERGY **(%)**

COSTUMERS

- E10 – INHABITANT PERCEPTION OF ENERGY IMPROVEMENT ***(LIKERT SCALE)***

- *PASSIVE INDICATORS - ENERGY MANAGEMENT*

E1- ENERGY CONSUMPTION / PRIMARY ENERGY PER m2 (1/m2)

Defining name	Action name
Category pillar	ENERGY CONSUMPTION
Definition	This KPI allows for the measurement of the total energy consumed in its original form, without undergoing any conversion or transformation. It encompasses various energy sources, including crude oil, natural gas, coal, nuclear energy, and renewable energies (such as solar, wind, hydroelectric, among others), as well as any other energy source in its original state.
Reference	Joud Al Dakheel, Claudio Del Pero, Niccolò Aste, Fabrizio Leonforte, Smart buildings features and key performance indicators: A review, Sustainable Cities and Society,

	Volume 61,2020,102328,ISSN 2210-6707,https://doi.org/10.1016/j.scs.2020.102328. Balaras, C. A., Dascalaki, E. G., Droutsa, K. G., Kontoyiannidis, S., Guruz, R., & Gudnason, G. (2014). Energy and other key performance indicators for buildings–Examples for Hellenic buildings. Global Journal of Energy Technology Research Updates, 1(2), 71-89. European project - MAtchUP
Formula	$E1 = \frac{ENERGY\ CONSUMPTION\ (kWh)}{PRIMARY\ ENERGY\ (kWh)} * AREA\ m^2$
Unit of measurement	(1/m2)
Data source	Energy Consumption Records
Actions/ Interventions	T-WF-1 T-CO-1 WF-1 H-CO-3 T-WF-2 T-CO-2 WF-2 H-CO-4 T-WF-3 T-CO-3 H-CO-1 T-WF-4 R-WF-1 H-CO-2
Variable / Parameter	Relationship between energy consumption and primary energy
Monitoring Interval	In the baseline period and when executing the interventions.
Target (Lighthouse)	Reducing the KPI by a certain percentage compared to a baseline period.
Building or District Level	District Level

Relationship with other KPIs	E1.1 E1.2 E-2 E-5 TE-6 TE-7 TE-9
NEB	Efficiency of energy use

Following KPIs (E1.1-E1.2) depending on E1, for that reason; in the next tables only the main information about these indicators are included.

E1.1- REDUCTION IN PRIMARY ENERGY CONSUMPTION PER m2 (R-PED) (%)

Defining name	Action name
Category pillar	ENERGY CONSUMPTION
Definition	Reduction in Primary Energy Consumption per m2 (R-PED) (%) measures the percentage decrease in primary energy consumption per square metre of the building, reflecting improvements in energy efficiency.
Reference	Crețu, M., Czumbil, L., Bârgăuan, B., Ceclan, A., Berciu, A., Polycarpou, A., ... & Micu, D. D. (2020). Modelling and evaluation of the baseline energy consumption and the key performance indicators in technical university of Cluj-Napoca buildings within a demand response programme: A case study. IET Renewable Power Generation, 14(15), 2864-2875.
Formula	$E1.1 = \frac{Energy\ Consumption\ (_{Baseline}) - Energy\ Consumption\ (_{Current})}{Energy\ Consumption\ (_{Baseline})} * 100$
Unit of measurement	%

E1.2- REDUCTION IN ENERGY CONSUMPTION PER INHABITANT (R-PED-INH) (%)

Defining name	Action name
Category pillar	REDUCTION IN ENERGY CONSUMPTION PER INHABITANT (R-PED-INH) (%)
Definition	Measure the percentage decrease in energy consumption per inhabitant compared to a reference period.
Reference	Villamor, E., Akizu-Gardoki, O., Azurza, O., Urkidi, L., Campos-Celador, A., Basurko, I., & Barcena Hinojal, I. (2020). European cities in the energy transition: a preliminary analysis of 27 cities. Energies, 13(6), 1315.
Formula	$E1.2 = \frac{E\ Consumption\ per\ inhabitant\ _{(Baseline)} - E\ Consumption\ per\ inhabitant\ _{(Current)}}{Energy\ Consumption\ per\ inhabitant\ _{(Baseline)}} * 100$
Unit of measurement	%

*In the formula cell, the letter E indicates Energy.

E2- BUILDING ENERGY EFFICIENCY

Defining name	Action name
Category pillar	ENERGY EFFICIENCY
Definition	Effective utilisation of energy resources within a building to meet operational needs while minimising waste and environmental impact.
Reference	Li, H., Johra, H., de Andrade Pereira, F., Hong, T., Le Dréau, J., Maturo, A., ... & Dong, B. (2023). Data-driven key performance indicators and datasets for building energy flexibility: A review and perspectives. Applied Energy, 343, 121217.

Formula	$$E2 = \frac{USEFUL\ ENERGY\ OUTPUT}{TOTAL\ ENERGY\ INPUT} * 100$$
Unit of measurement	%
Data source	Energy audits Utility bills or sensors Building management systems
Actions/ Interventions	T-WF-1 T-CO-1 WF-1 H-CO-3 T-WF-2 T-CO-2 WF-2 H-CO-4 T-WF-3 T-CO-3 H-CO-1 T-WF-4 R-WF-1 H-CO-2
Variable / Parameter	Relationship between useful energy output and total energy input
Monitoring Interval	In the baseline period and when executing the interventions.
Target (Lighthouse)	Improve building energy efficiency, often set as a percentage increase in efficiency or a reduction in energy consumption.
Building or District Level	Building
Relationship with other KPIs	E4 E8 E9 TE-3 TE-4 TE-9
NEB	Efficiency of energy use

E3- THERMAL INSULATION INDEX

Defining name	Action name
Category pillar	ENERGY EFFICIENCY
Definition	Assesses the effectiveness of a building's thermal insulation, which is crucial for maintaining desired indoor temperatures while minimising energy consumption.
Reference	Angelakoglou, K., Chatzigeorgiou, E., Lampropoulos, I., Giourka, P., Martinopoulos, G., & Nikolopoulos, N. (2023). Monitoring the Sustainability of Building Renovation Projects—A Tailored Key Performance Indicator Repository. Buildings, 13(8), 2046.
Formula	$E3 = \frac{DESIRED\ INDOOR\ TEMPERATURE\ DIFFERENCE}{HEAR\ TRANSFER\ BUILDING\ ENVELOPE}$
Unit of measurement	ºC-1
Data source	building energy audits Thermal imaging
Actions/ Interventions	T-WF-1 T-CO-1 WF-1 H-CO-3 T-WF-2 T-CO-2 WF-2 H-CO-4 T-WF-3 T-CO-3 H-CO-1 T-WF-4 R-WF-1 H-CO-2

Variable / Parameter	Representing the efficiency of the building's thermal envelope.
Monitoring Interval	In the baseline period and when executing the interventions.
Target (Lighthouse)	TII value or to exceed regional energy efficiency standards.
Building or District Level	Building
Relationship with other KPIs	E2 E4 E5 TE-1 TE-3 TE-8
NEB	energy efficiency improvements, contributing to a positive energy balance.

The following KPIs are centred around measuring general concepts in energy terms, focusing on baseline measures. These KPI groups are defined as TE and often require values from the previously described KPIs. The template for these KPIs has been modified because our details are the same as the preceding information, and we have decided to summarise the information to avoid repeating concepts and details.

TE.1-REDUCTION OF CO2 EMISSIONS (%)

Defining name	Action name
Category pillar	ENERGY EFFICIENCY
Definition	Measures the amount of energy consumed per unit of floor area.
Formula	$TE.1 = \frac{CO2\ Emissions\ (Baseline) - CO2\ Emissions\ (Current)}{CO2\ Emissions\ (Baseline)} * 100$

Unit of measurement	%
Data source	Use the European coefficient to calculate all the CO2 values.
Actions/ Interventions	T-WF-1 T-CO-1 WF-1 H-CO-3 T-WF-2 T-CO-2 WF-2 H-CO-4 T-WF-3 T-CO-3 H-CO-1 T-WF-4 R-WF-1 H-CO-2
Variable/ Parameter	Reduction of CO2 Emissions, representing the percentage decrease in carbon dioxide emissions achieved through interventions.
Monitoring Interval	Assess the impact of interventions and track changes in CO2 emissions.
Building or District Level	District Level

TE.2-ENERGY USE PER M2 (kWh/m2)

Defining name	Action name
Category pillar	ENERGY CONSUMPTION
Definition	Measures the percentage decrease in carbon dioxide emissions compared to a baseline period.
Formula	$TE.2 = \frac{Total\ Energy\ Consumption}{Total\ floor\ area}$

Unit of measurement	kWh/m²
Data source	Energy bills Building management systems.
Actions/ Interventions	T-WF-1 T-CO-1 WF-1 H-CO-3 T-WF-2 T-CO-2 WF-2 H-CO-4 T-WF-3 T-CO-3 H-CO-1 T-WF-4 R-WF-1 H-CO-2
Variable/ Parameter	Indicating the energy efficiency of the space.
Monitoring Interval	Regular monitoring
Building or District Level	District Level

TE.3-INSULATION EFFICIENCY

Defining name	Action name
Category pillar	ENERGY EFFICIENCY
Definition	Evaluates the effectiveness of insulation in minimizing heat transfer within a building.
Formula	$TE.3 = \frac{tHERMAL\ rESISTANCE\ OF\ INSULATION}{Total\ Wall\ Area}$

Unit of measurement	Specific metric used for thermal resistance
Data source	Insulation specifications, or energy audits.
Actions/ Interventions	T-WF-1 T-CO-1 WF-1 H-CO-3 T-WF-2 T-CO-2 WF-2 H-CO-4 T-WF-3 T-CO-3 H-CO-1 T-WF-4 R-WF-1 H-CO-2
Variable/ Parameter	effectiveness of insulation in reducing heat transfer.
Monitoring Interval	Regular monitoring.
Building or District Level	Building Level

- *ACTIVE INDICATORS - ENERGY EFFICIENCY*

E4- EFFICIENCY RATIO

Defining name	Action name
Category pillar	ENERGY EFFICIENCY
Definition	It measures the ratio of useful output to the energy input, providing insights into how

	efficiently energy is utilised to achieve desired outcomes.
Reference	Shaw, H. J., & Lin, C. K. (2021). Marine big data analysis of ships for the energy efficiency changes of the hull and maintenance evaluation based on the ISO 19030 standard. Ocean Engineering, 232, 108953.
Formula	$E4 = \frac{USEFUL\ OUTPUT}{ENERGY\ INPUT}$
Unit of measurement	%
Data source	Energy Efficiency Ratio KPI is obtained from operational data, production records, and energy consumption metrics.
Actions/ Interventions	T-HC-1 T-HC-2 T-HC-3 T-LG-1 T-LG-2 R-HC-1 R-LG-1 H-HC-1 H-HC-2 H-HC-3 H-LG-1
Variable / Parameter	Energy Efficiency Ratio,
Monitoring Interval	In the baseline period and when implementing the interventions.
Target (Lighthouse)	Energy Efficiency Ratio value that reflects optimal energy utilisation.
Building or District Level	District
Relationship with other KPIs	E2 E4 E5 TE-1 TE-3 TE-8

NEB	energy efficiency improvements, contributing to a positive energy balance.

E5- ENERGY SOURCE USAGE

Defining name	Action name
Category pillar	ENERGY MANAGEMENT
Definition	The Energy Source Usage KPI evaluates the distribution and efficiency of different energy sources employed within an organisation or system.
Reference	Airò Farulla, G., Tumminia, G., Sergi, F., Aloisio, D., Cellura, M., Antonucci, V., & Ferraro, M. (2021). A review of key performance indicators for building flexibility quantification to support the clean energy transition. *Energies*, *14*(18), 5676.
Formula	$E5 = \frac{ENERGY\ CONSUMED\ /\ EACH\ SOURCE}{TOTAL\ ENERGY\ CONSUMPTION} * 100$
Unit of measurement	%
Data source	Energy consumption records utility bills Monitoring systems.
Actions/ Interventions	T-HC-1 T-HC-2 T-HC-3 T-LG-1 T-LG-2 R-HC-1 R-LG-1 H-HC-1 H-HC-2 H-HC-3 H-LG-1

Variable / Parameter	Represented the percentage contribution of each energy source to the total energy consumption.
Monitoring Interval	In the baseline period and when implementing the interventions.
Target (Lighthouse)	Energy sources aligned with organisational goals, environmental considerations, or cost-efficiency objectives.
Building or District Level	Building
Relationship with other KPIs	E2 E4 E5 TE-1 TE-3 TE-8
NEB	Utilisation of various energy sources and contributing to a positive energy balance.

E6- URBAN STREET LIGHTING ENERGY CONSUMPTION

Defining name	Action name
Category pillar	Urban Infrastructure
Definition	Measures the total energy consumed by street lighting systems in urban areas. It evaluates the efficiency of energy use in illuminating public spaces
Reference	Beccali, M., & Bonomolo, M. (2020). Special Issue "Smart Urban Lighting Systems". Applied Sciences, 10(10), 3627.

Formula	$E6 = \frac{TOTAL\ ENERGY\ CONSUMPTION}{NUMBER\ OF\ STREET\ LIGHTS}$
Unit of measurement	kWh
Data source	Energy bills Smart metering systems Municipal records
Actions/ Interventions	T-LG-1 T-LG-2 R-LG-1 H-HC-1 H-LG-1
Variable / Parameter	Representing the efficiency of energy use in illuminating each street light.
Monitoring Interval	In the baseline period and when implementing the interventions.
Target (Lighthouse)	Energy Consumption per Street Light value
Building or District Level	District Level
Relationship with other KPIs	E1 E7 E9 TE-2 TE-5 TE-6
NEB	Energy-efficient street lighting, contributing to a positive urban energy balance.

E7- REDUCTION IN ENERGY CONSUMPTION IN PUBLIC LIGHTING

Defining name	Action name

Category pillar	ENERGY CONSUMPTION
Definition	Measure the percentage decrease in energy consumption for illuminating public spaces,
Reference	Quevedo, T. C., Geraldi, M. S., Melo, A. P., & Lamberts, R. (2023). Benchmarking Energy Consumption in Universities: A review. Journal of Building Engineering, 108185.
Formula	$E7 = \frac{E\ CONSUMPTION(BL) - E\ CONSUMPTION(CT)}{E\ CONSUMPTION\ (CT)} * 100$
Unit of measurement	%
Data source	energy bills Smart metering systems Municipal records
Actions/ Interventions	T-LG-1 T-LG-2 R-LG-1 H-HC-1 H-LG-1
Variable / Parameter	Reduction in Energy Consumption, representing the percentage decrease in energy consumption achieved through interventions.
Monitoring Interval	In the baseline period and when implementing the interventions.
Target (Lighthouse)	Reduction in Energy Consumption percentage, aiming for continuous improvement.

Building or District Level	District Level
Relationship with other KPIs	E1 E7 E9 TE-2 TE-5 TE-6
NEB	Achieving a reduction in energy consumption

TE.4-REDUCTION OF PEAK DEMAND (%)

Defining name	Action name
Category pillar	ENERGY MANAGEMENT
Definition	Measures the percentage decrease in the highest level of electricity demand during a specific period. It focuses on strategies to manage and reduce peak electricity consumption, contributing to a more stable and efficient power grid.
Formula	$TE.4 = \frac{Peak\ Demand\ before\ Intervention - Current\ Peak\ Demand}{Peak\ Demand\ before\ Intervention} * 100$
Unit of measurement	%
Data source	Electricity grid records Utility reports
Actions/ Interventions	T-HC-1 T-HC-2 T-HC-3 T-LG-1 T-LG-2 R-HC-1 R-LG-1 H-HC-1 H-HC-2 H-HC-3 H-LG-1
Variable / Parameter	representing the percentage decrease in peak electricity demand achieved through interventions.

Monitoring Interval	Regular monitoring
Building or District Level	Building Level

TE.5-LIGHTING EFFICIENCY (lm/W)

Defining name	Action name
Category pillar	ENERGY EFFICIENCY
Definition	measures the luminous efficacy of a lighting system, representing the amount of visible light (lumens) produced per unit of electrical power consumed
Formula	$TE.5 = \frac{Total\ Luminous\ Flux\ (lm)}{Total\ Power\ Consumption\ (W)}$
Unit of measurement	lm/W
Data source	Energy bills Lighting audit reports.
Actions/ Interventions	T-LG-1 T-LG-2 R-LG-1 H-HC-1 H-LG-1
Variable / Parameter	Representing the luminous efficacy of the lighting system.
Monitoring Interval	In the baseline period and when implementing the interventions.
Building or District Level	District Level

TE.6- X

ELECTRIC ENERGY CONSUMPTION PER m2

Defining name	Action name
Category pillar	ENERGY MANAGEMENT
Definition	Measures the amount of electrical energy used per unit of floor area. It assesses the efficiency of electrical energy utilisation within a given space
Formula	$TE.6 = \frac{Total\ Electric\ Energy\ Consumption}{Total\ Floor\ Area}$
Unit of measurement	kWh/m²
Data source	Energy bills Utility records Building management systems.
Actions/ Interventions	T-LG-1 T-LG-2 R-LG-1 H-HC-1 H-LG-1
Variable / Parameter	Representing the efficiency of electrical energy use in the specified area
Monitoring Interval	In the baseline period and when implementing the interventions.
Building or District Level	District Level

TE.7-THERMAL ENERGY CONSUMPTION PER m2 (%)

Defining name	Action name

Category pillar	ENERGY MANAGEMENT
Definition	Measures the amount of thermal (heat) energy used per unit of floor area. It assesses the efficiency of thermal energy utilisation within a given space, providing insights into heating and cooling practices and efficiency.
Formula	$TE.7 = \frac{Total\ Thermal\ Energy\ Consumption}{Total\ Floor\ Area} * 100$
Unit of measurement	kWh/m²
Data source	Heating and cooling system records Energy bills Building management systems.
Actions/ Interventions	T-HC-1 T-HC-2 T-HC-3 T-LG-1 T-LG-2 R-HC-1 R-LG-1 H-HC-1 H-HC-2 H-HC-3 H-LG-1
Variable / Parameter	Representing the efficiency of thermal energy use in the specified area.
Monitoring Interval	Regular monitoring
Building or District Level	Building Level

- *RENEWABLE ENERGY PRODUCTION*

E8- PV ENERGY PRODUCTION

Defining name	Action name
Category pillar	SUSTAINABILITY
Definition	measures the electricity generated by solar panels or photovoltaic systems. It assesses the effectiveness of solar energy utilisation in contributing to a sustainable and renewable energy
Reference	Hoffmann, M., Puranik, S., Juanpera, M., Martín-Rapún, J. M., Tuiskula, H., & Blechinger, P. (2020, September). Investment planning in multi-vector energy systems: definition of key performance indicators. In CIRED 2020 Berlin Workshop (CIRED 2020) (Vol. 2020, pp. 158-161). IET.
Formula	$E8 = Total\ Electricity\ Generated\ by\ PV\ System$
Unit of measurement	kWh
Data source	Solar panel monitoring systems Energy metres Renewable energy certificates.
Actions/ Interventions	T-RE-1 T-RE-2 R-RE-1 H-RE-1 H-RE-2
Variable / Parameter	representing the total electricity generated by the photovoltaic system.
Monitoring Interval	Regular monitoring
Target (Lighthouse)	Targets may be set to achieve a specific amount of PV Energy Production

Building or District Level	Building level
Relationship with other KPIs	E2 E7 E9 TE-8 TE-9
NEB	Sustainability

E9- SOLAR ENERGY UTILIZATION RATIO

Defining name	Action name
Category pillar	SUSTAINABILITY
Definition	Energy Utilisation Ratio KPI measures the efficiency with which the generated solar energy is utilised within a system or facility.
Reference	Hoffmann, M., Puranik, S., Juanpera, M., Martín-Rapún, J. M., Tuiskula, H., & Blechinger, P. (2020, September). Investment planning in multi-vector energy systems: definition of key performance indicators. In CIRED 2020 Berlin Workshop (CIRED 2020) (Vol. 2020, pp. 158-161). IET.
Formula	$E9 = \frac{ENERGY\ CONSUMED\ FROM\ PV\ SYSTEM}{TOTAL\ OF\ ENERGY\ PRODUCTION} * 100$
Unit of measurement	%
Data source	Energy monitoring systems Metres Building management systems.

Actions/ Interventions	T-RE-1 T-RE-2 R-RE-1 H-RE-1 H-RE-2
Variable / Parameter	Representing the efficiency of utilising solar energy within the system.
Monitoring Interval	Regular monitoring
Target (Lighthouse)	PV Energy Utilisation Ratio, aiming for optimal utilisation of solar energy.
Building or District Level	Building Level
Relationship with other KPIs	E2 E7 E9 TE-8 TE-9
NEB	Sustainability and Positive energy balance

TE.8-% OF RENEWABLE ENERGIES' IMPACT IN THE TOTAL CONSUMPTION (%)

Defining name	Action name
Category pillar	SUSTAINABILITY
Definition	The Percentage of Renewable Energies' Impact in the Total Consumption KPI measures the proportion of energy consumption that is derived from renewable sources.
Formula	$TE.8 = \frac{Renewable\ Energy\ Consumption}{Total\ Energy\ consumption} * 100$
Unit of measurement	%

Data source	Utility records Renewable energy certificates
Actions/ Interventions	T-RE-1 T-RE-2 R-RE-1 H-RE-1 H-RE-2
Variable / Parameter	Representing the contribution of renewable energy to the total energy consumption.
Monitoring Interval	Regular monitoring
Building or District Level	Building Level

TE.9-AUTOSUFFICIENT ENERGY

Defining name	Action name
Category pillar	SUSTAINABILITY
Definition	measures the degree to which a system or organisation is capable of meeting its energy needs independently, without relying on external sources.
Formula	$TE.9 = \frac{Internally\ Generated\ Energy}{Total\ Energy\ consumption} * 100$
Unit of measurement	%
Data source	Monitoring systems Metres Renewable energy certificates.

Actions/ Interventions	T-RE-1 T-RE-2 R-RE-1 H-RE-1 H-RE-2
Variable / Parameter	Representing the percentage of energy needs met through internal generation.
Monitoring Interval	Regular monitoring
Building or District Level	Building Level

- *COSTUMERS*

E10- INHABITANT PERCEPTION OF ENERGY IMPROVEMENT

Defining name	Action name
Category pillar	ENERGY EFFICIENCY
Definition	Assesses the perception and awareness of building or district inhabitants regarding energy efficiency measures and improvements.
Reference	Witkowski, S., Plummer, R., & Dale, G. (2022). Inter-group perceptions of key performance indicators for monitoring and evaluating scenic viewpoints. Society & Natural Resources, 35(7), 725-744.
Formula	Collecting feedback through surveys

Data source	Surveys or Interviews
Actions/ Interventions	R-EA-1 R-IA-1
Variable / Parameter	Inhabitant Perception of Energy Improvement
Monitoring Interval	Then, to implement the interventions.
Target (Lighthouse)	Achieve specific satisfaction levels or awareness scores
Building or District Level	District Level
Relationship with other KPIs	E1 E2 E3 E8 E9 TE-3 TE-4 TE-6
NEB	Sustainability

3.2.2. Environmental Impact Metrics and Indexes

These KPIs have been carefully selected based on their relevance and effectiveness in assessing environmental impact from a holistic perspective including atmospheric, waste management, indoor air quality, construction materials and land use. These KPIs are backed by scientific research and are widely recognized for their effectiveness in evaluating environmental performance. They provide a comprehensive framework for assessing the SUPERSHINE project's environmental impact and sustainability practices, thereby contributing to its goal of enhancing energy efficiency in districts. Other European projects that have served as a basis for the development of these KPIs are SUPER- I, NEUTRAL PATH, CHRONICLE, RINNO, INCUBE.

The standard for Life Cycle Assessment (LCA) of construction products is the *European Standard EN 15804:2012+A2:2019*. This standard provides the core rules for the product category of construction products. An Environmental Product Declaration (EPD) contains information related to the product's environmental performance obtained using LCA methodology.

The LCA study follows four main phases:

- **Goal and Scope Definition:** This phase involves defining the purpose of the study and the system boundaries.
- **Inventory Analysis:** This phase involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system.
- **Impact Assessment:** This phase involves evaluating the significance of potential environmental impacts using the results of the inventory analysis.
  - **A1-A3 (Product Stage):** This includes raw material extraction and processing (A1), transport to the manufacturer (A2), and manufacturing (A3). All stages include the provision of all materials, products, and energy, as well as waste processing up to the end-of-waste state or disposal of final residues during the product stage.
  - **A4-A5 (Construction Process Stage):** This includes transport to the building site (A4) and installation into the building (A5). These stages include all impacts and aspects related to any losses during this construction process stage.
  - **B1-B7 (Use Stage):** This includes use or application of the installed product (B1), maintenance (B2), repair (B3), replacement (B4), refurbishment (B5), operational energy use (B6), and operational water use (B7).
  - **C1-C4 (End of Life Stage):** This includes de-construction, demolition (C1), transport to waste processing (C2), waste processing for reuse, recovery and/or recycling (C3), and disposal (C4). All C stages include provision and transport, provision of all materials, products and related energy and water use.
  - **D (Benefits and Loads Beyond the System Boundary):** This includes reuse, recovery and/or recycling potentials, expressed as net impacts and benefits.

  It is noteworthy to highlight that all construction products and materials now need to declare modules A1-A3, C1-C4 and D. Only under very specific conditions is it still possible to do a cradle-to-gate (A1-A3) EPD assessment. In all other cases, the end-of-life (EOL) and more specifically the loads and benefits to end-of-life recycling need to be included.

- **Interpretation:** This phase involves analysing results, drawing conclusions, and providing recommendations.

It's important to note that the environmental performance of construction products across their life cycle in the building or construction works depends on the design, installation, operation, demolition, etc. Therefore, the environmental performance assessment must be carried out at the building and district level. The European methodology for the assessment of the environmental performance of buildings – Level(s) is based on EN 15978 and therefore also on EPD information.

Regarding the scope of the SUPERSHINE PROJECT, the main reason why only the environmental impact of the building from the use phase is measured, including operation data and future renovations, but not the impact made when the building was constructed, is due to the lack of updated and accurate data.

When the building was originally constructed, detailed data on the embedded carbon in the construction materials and emissions generated during the construction process wasn't collected. In addition, construction practices and materials used have significantly changed since then, making old data less relevant for current assessments. Finally, since the environmental impact can be modified for these previous phases the analysis of these metrics will be based on what is called "gate to cradle" which means that only actual (operational) and future impacts will be measured.

On the other hand, operation data and future renovations are easier to accurately measure and document. These data are also critical for understanding the environmental impact of the building over its lifespan, as the operation of the building and renovations can significantly contribute to total carbon emissions.However, it's important to note that this approach may underestimate the total impact of the building on the environment. Ideally, a complete lifecycle analysis of the building would consider all phases, from initial construction to final demolition, but this is often not practical due to data limitations.

List of environmental KPIs

ATMOSPHERIC

- A1 – GLOBAL WARMING POTENTIAL (GWP100)
- A2 – OZONE DEPLETION POTENTIAL (ODP)
- A3 – ACIDIFICATION POTENTIAL (AP)
- A4 – PHOTOCHEMICAL OXIDANT CREATION POTENTIAL (POCP)

WASTE MANAGEMENT

- WM1 – CONSTRUCTION WASTE MANAGEMENT
- WM2 – WASTE REDUCTION RATE
- WM3 – EFFICIENCY IN WASTE DISPOSAL PROCESSES

INDOOR AIR QUALITY

- UC1 – HUMIDITY CONTROL
- UC2 – TEMPERATURE CONTROL
- UC3 – NATURAL DAYLIGHT
- UC4 – INDOOR AIR QUALITY
- UC5 – NOISE LEVELS

CONSTRUCTION MATERIALS

- CM1 – RESPONSIBLE SOURCING OF MATERIALS
- CM2 – MATERIALS RECYCLE/REUSE

LAND USE

- LU1 – LAND USE FOR TEMPORARY SITE FACILITIES
- LU2 – IMPACT ON BIODIVERSITY

WATER RESOURCES

- WT1- Water Consumption
- WT2 – Water Recycling in Buildings
- WT3 - Eutrophication potential (EP)

KPI definition

Defining name	A1-GWP (GWP100)
Category pillar	Atmospheric
Definition	GWP100 (Global Warming Potential over 100 years) is an index that measures the amount of infrared thermal radiation a greenhouse gas would absorb over a 100-year timescale after it has been added to the atmosphere. It is expressed as a multiple of the radiation that would be absorbed by the same mass of added carbon dioxide (CO2), which is taken as a reference gas. For the SUPERSHINE project
Reference	Understanding Global Warming Potentials | US EPA https://www.environdec.com/resources/indicators
Formula	$$GWP = \sum_{i=1}^{n} (Quantity \times \ Emission\ Factor)$$ **GWP**: Global Warming Potential in Kg CO_2 eq.

	Quantity: Total amount of product or process used during the building lifecycle **Emission Factor:** Total amount of emissions given in Kg CO_2 eq per product or process measured in their declared unit
Unit of measurement	Kg of Co2 Eq
Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	CO2 emissions.
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Atmospheric, Construction Materials LCA
NEB	Sustainability

Defining name	A2- OZONE DEPLETION POTENTIAL (ODP)

Category pillar	Atmospheric
Definition	The Ozone Depletion Potential (ODP) is a Key Performance Indicator (KPI) that measures the relative amount of degradation a chemical compound can cause to the ozone layer[6]. It is defined as the ratio of global loss of ozone due to a given substance to the global loss of ozone due to trichlorofluoromethane (R-11 or CFC-11) of the same mass[6]. For example, chlorodifluoromethane (R-22) has an ODP of 0.05[6]. Therefore, understanding the ODP of materials used in a building can help in making more environmentally friendly choices in building design and construction.
Reference	https://www.environdec.com/resources/indicators
Formula	$$ODPtotal = \sum_{i=1}^{n} (ODPi \times Mi$$ **ODP_{total}** is the total Ozone Depletion Potential for the building. **ODP_i** is the ODP of the Ith substance **M_i** is the mass of the Ith substance used in the building The sum is over all n substances used in the building materials
Unit of measurement	Kg CFC-11 eq
Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Avoid Ozone-Depleting Substances: Use materials and technologies that do not contain substances with high

	ozone depletion potential (ODP), such as certain refrigerants and aerosols. opt for alternatives like Hydrochlorofluorocarbons (HCFCs) and Hydrofluorocarbons (HFCs) which have lower ODPs.
Variable / Parameter	Reduction in the use of Ozone Depleting Substances
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Construction Materials
NEB	Sustainability

Defining name	A3 ACIDIFICATION POTENTIAL (AP)
Category pillar	Atmospheric
Definition	Environmental impact indicator that measures the potential of a building or a product to contribute to acid rain. the assessment of environmental quality of buildings. This indicator is defined as the sum of the acidification potential of various stages such as feed, farm, processing, transportation, storage, and retail for each individual commodity. It is typically measured in kilograms of sulphur

	dioxide equivalents (SO2 eq.) per kilogram of edible weight produced
Reference	https://www.environdec.com/resources/indicators Acidification Potential – AgImpacts (mit.edu) NS2019.041.pdf (uns.ac.rs)
Formula	$AP = \sum_{i} (APi \times Qi)$ **AP** is the total Acidification Potential. **APi** is the acidification potential for each released component. This is expressed in terms of their potential to form relative to SO2. **Q** $_i$ is the quantity of the i-th component released.
Unit of measurement	Kg SO2 eq
Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Passive Measures: Use of materials that are low emitting in terms of acidification potential
Variable / Parameter	Reduction of Acidification Potential by the building industry
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level

Relationship with other KPIs	Waste Management, Construction Materials
NEB	Sustainability

Defining name	A4 PHOTOCHEMICAL OXIDANT CREATION POTENTIAL (POCP)
Category pillar	Atmospheric
Definition	This indicator assesses the impact of construction and miscellaneous products that may cause emissions of volatile organic compounds (VOCs), nitrogen oxides (NOx), and other substances that contribute to ozone formation in the lower layers of the atmosphere. These photochemical oxidants (like ozone) form in the presence of sunlight and can cause health problems such as respiratory issues among other impacts.
Reference	https://www.environdec.com/resources/indicators VOCs and POCPs - Fluorocarbons Photochemical ozone creation potentials | The International Journal of Life Cycle Assessment (springer.com)
Formula	$$POCP = \sum_{i=1}^{n} (Quantity \times \ POPC\ Factor)$$ **POCP:** Photochemical Oxidant Creation Potential
Unit of measurement	kg C2H4 eq.

Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Passive Measures: Use materials that are Active Measures: Low emitting refrigerants for HVAC systems
Variable / Parameter	Reduction in the use of substances that contribute to increasing the amount of Ozone in the lower layers of the atmosphere
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Atmospheric
NEB	Sustainability

Defining name	WM1 CONSTRUCTION WASTE MANAGEMENT
Category pillar	Waste Management
Definition	This indicator measures the total amount of Construction and Demolition Waste (CDW) generated by different activities during the life cycle of the building. This indicator

	is subdivided in the following sub indicators when possible, Recycling, Incineration, Landfill.
Reference	UM3 Indicator 2.2 v1.1 40pp.pdf (europa.eu) Levels Waste Management
Formula	$$CDW = \sum Wr + \sum Wi + \sum Wl$$ **CDW:** Construction and Demolition Waste **Wr:** Construction waste which End of Life Scenario is Recycling **Wi**: Construction waste which End Of Life Scenario is Incineration **Wl:** Construction waste which End Of Life Scenario is Incineration
Unit of measurement	Kgs of CDW
Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Passive Measures: Materials that have a longer life cycle can reduce the amount of generated waste during the life cycle.
Variable / Parameter	Reduction in the generation of Construction Waste
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All

Building or District Level	Building and district level
Relationship with other KPIs	Waste reduction rate
NEB	Sustainability

Defining name	WM2 WASTE REDUCTION RATE
Category pillar	Waste Management
Definition	This indicator measures waste management in a building during the use phase, it is defined as a metric that analyses and monitors the potential environmental impacts, benefits, and improvements associated with waste management.
Reference	[Waste Management Indicators and Policies | UNECE] [Life cycle indicators for resources, products and waste: waste management (europa.eu)]
Formula	$$WRR = \frac{IWp - FWp}{No} \times 100$$ **WRR:** Waste Reduction Rate **IWp:** Initial Waste per building **FWp:** Final Waste per building **No:** Number of Occupants
Unit of measurement	% of reduction (Kg of Waste per person)

Data source	Data from the lighthouses public data for each region or country.
Actions/ Interventions	Passive Measures: Appropriate waste categorization may require dedicated spaces in buildings or residential units.
Variable / Parameter	Reduction in waste generation
Monitoring Interval	Twice a year
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Waste Management
NEB	Sustainability

Defining name	WM3 EFFICIENCY IN WASTE DISPOSAL PROCESSES
Category pillar	Waste Management
Definition	This indicator assesses how efficient the disposal process is in the lighthouses. The following end of life scenarios are evaluated according to their respective impact. The following scenarios are considered: Landfill, Incineration, Recycling, Composting, Biomass, Reusing. A scoring system has been created to evaluate each scenario from more to less harmful (The more harmful the scenario, the fewer points it should receive.)

	• Landfilling (1 point): The percentage of waste materials that are landfilled contributes up to 1 point of the total. • Incineration (2 points): The percentage of waste materials that are incinerated contributes up to 2 points of the total. • Recycling (3 points): The percentage of waste materials that are recycled contributes up to 3 points of the total. • Biomass/Composting/Reusing (4 points): The percentage of waste materials that are used for Biomass, Composting or Reusing contributes up to 4 points of the total.
Reference	http://edgeservices.bing.com/edgesvc/redirect?url=https%3A%2F%2Fwww.epa.gov%2Fsmm%2Fmanaging-and-reducing-wastes-guide-commercial-buildings&hash=bpNYRFlrS%2Fdrz5W8pzfllpWvRCVEIfgtd5DKn2iMBac%3D&key=psc-underside&usparams=cvid%3A51D%7CBingProd%7C066F10478AEF7E6FC5B46C16600508B92AA93CC5B303BD8A8A812C46146FDC90%5Ertone%3APrecise Waste Management Indicators and Policies | UNECE Solid waste indicators and their implications for management practice | International Journal of Environmental Science and Technology (springer.com)
Formula	$P = \frac{L1 + I2 + R3 + BCR4}{100}$ **L:** Percentage of waste materials that are landfilled, **I**: Percentage of waste materials that are incinerated, **R**: Percentage of waste materials that are recycled, **BCR:** Percentage of waste materials that are used for Biomass, Composting or Reusing.

	*Please note that this formula obtains a result that will be between 1 (least efficient) and 4 (most efficient)
Unit of measurement	From 1 to 4
Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Implement waste segregation at the source to streamline collection and disposal. Consider outsourcing waste collection and disposal to specialists for improved service quality. Standardise secondary raw materials to boost waste prevention and enhance the quality of recycling. Foster open communication among all stakeholders, sharing best practices and data to drive waste reduction and recycling. Embrace a circular economy approach to waste management, focusing on waste reduction, energy efficiency, and environmentally friendly disposal methods.
Variable / Parameter	Waste Disposal Efficiency
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	All Waste Management KPIs
NEB	Sustainability

Defining name	LU1 LAND USE EFFICIENCY

Category pillar	Land use
Definition	Land use efficiency is an indicator that shows how efficient the land is used in the district. It is based on two main principles: • **Compact Cities:** Cities that are compact use land more efficiently and are better placed to provide public goods and basic services at a lower cost1. Therefore, a higher weight might be given to the residential built area ratio in compact cities. • **Public Space:** Public open spaces usually take 15-30% of a city's land cover, but in some cases up to 50%, with major impacts on land value and the urban economy2. Therefore, the weight given to the public space ratio should reflect the importance of public spaces in the urban environment. Based on these principles, one possible approach could be to assign a weight of 0.7 to the residential built area ratio and a weight of 0.3 to the public space ratio.
Reference	08 Land Use and Ecology - BREEAM Knowledge Base Level(s) - European Commission (europa.eu) indicator 11.3.1 training module land use efficiency.pdf (unhabitat.org) Discussion Paper - Developing Public Space and Land Values in Cities and Neighbourhoods.pdf (unhabitat.org)
Formula	$LUE = \frac{Residential\ Built\ Area}{Total\ Built\ Area} \times 0{,}7 + \frac{Public\ Space\ Area}{Total\ Area}$ **LUE:** Land Use Efficiency
Unit of measurement	None

Data source	Plans and other information provided about the districts / buildings
Actions/ Interventions	At the building level, implementing space-saving designs and multi-purpose spaces can increase the residential built area ratio. This could include vertical construction, shared amenities, and efficient use of space within buildings. At the district level, careful urban planning can optimise the allocation of public spaces. This could involve creating multi-functional public spaces that serve various community needs, thereby maximising the utility of the land
Variable / Parameter	Demand for residential space and public amenities
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	District level
Relationship with other KPIs	Land Use
NEB	Sustainability

Defining name	LU2 IMPACT ON BIODIVERSITY
Category pillar	Land use
Definition	This indicator is based on a series of questions that assess the impact on biodiversity of the buildings and districts. It can be calculated as the sum of scores assigned to each

	positive response to the survey questions. Each positive response contributes to the overall impact score, indicating the potential impact on biodiversity. A higher number indicates a higher potential impact on biodiversity based on the survey responses. The maximum possible score is 5 (if all responses are "Yes"), indicating a higher potential impact on biodiversity. The minimum possible score is 0 (if all responses are "No"), indicating a lower potential impact on biodiversity. This Biodiversity Impact Score provides a quantitative measure that summarises the potential impact on biodiversity based on the survey results. It allows stakeholders to quickly assess and compare the biodiversity impact of different development projects. ● **P1 - Biodiversity Value Assessment:** ○ Have any of the following local entities identified potential biodiversity value on the site? (Contact all relevant entities before answering this question.) ■ A competent public entity ■ Any nature preservation or conservation group ● **P2 - Proximity to Protected Biodiversity Spaces:** ○ Is the development located within 2 km of a clearly defined, recognized, declared, and managed geographical space aimed at achieving long-term conservation of nature with associated ecosystem services (e.g., a Ramsar site)? Verify using local sources such as: ■ Wetlands of International Importance (Ramsar Convention) ■ Natural sites on the World Heritage List (UNESCO) ■ Protected areas under the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)

	■ Other internationally recognized areas for biodiversity conservation ● **P3 - Proximity to Declared Biodiversity Zones:** ○ Is the development located within 500 m of a declared biodiversity zone? Verify using local sources similar to those listed in P2. ● **P4 - Presence of Biodiverse Habitats:** ○ Are any of the following habitats present in the construction zone or within 100 metres of it? (While the list is not exhaustive, it serves as a guide for assessing habitats with biodiversity value for BREEAM ES.) ■ Forests (e.g., high and low woodlands, shrublands) ■ Watercourses (e.g., rivers, streams, or channels) ■ Wetlands (e.g., swamps, marshes, wet meadows, peatlands, oases, estuaries, deltas, tidal flats, marine coastal areas, mangroves, coral reefs, and human-made sites like fish ponds, reservoirs, and saltpans) ■ Pastures (e.g., steppes, meadows, pampas, grasslands, savannahs, heaths, bogs) ● **P5 - Presence of Biodiversity Elements:** ○ Are any of the following elements present in the construction zone or within its boundaries? ○ Mature or semi-mature trees ○ Mature green hedge plantations/plants establishing a boundary (hedges over 1 m high and 0.5 m wide) ○ Existing buildings (occupied or abandoned) that could serve as refuge for flora and fauna
Reference	https://breeam.es/categorias-breeam-suelo-ecologia/

Formula	BIS=P1_Score+P2_Score+P3_Score+P4_Score+P5_Score
Unit of measurement	1 to 5
Data source	Plans, reports and other information provided about the districts / buildings
Actions/ Interventions	Users, owners, and facility managers can improve the Biodiversity Impact Score in buildings and districts by understanding their impact on biodiversity and identifying priority species, habitats, and ecosystem services. Implementing practices that reduce harm to biodiversity, such as minimising disruption to natural habitats, using sustainable materials, and managing waste responsibly, can also be beneficial. Promoting the use of green infrastructure within the building or district, such as green roofs, living walls, and green spaces, can contribute to biodiversity. Additionally, engaging in conservation efforts, such as supporting local biodiversity projects or initiatives, can help to minimise the impact on biodiversity and contribute to a more sustainable built environment.
Variable / Parameter	Potential biodiversity impact based on site conditions.
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Land use.
NEB	Sustainability

Defining name	WT1 WATER CONSUMPTION
Category pillar	Water Resources
Definition	This indicator measures the total amount of water used per unit area over a year in residential units.
Reference	https://kb.breeam.com/wp-content/plugins/breeamkb-pdf/pdf/?c=4442 https://kb.breeam.com/section/new-construction/uk/2014-uk/water-breeam_uk_nc_2014/wat01/
Formula	$Yearly\ Water\ Consumption = \frac{Total\ Water\ Consumed}{Number\ of\ residents}$
Unit of measurement	m³ year
Data source	Water consumption provided by the Lighthouses
Actions/ Interventions	**Passive Measures:** Low-Consumption Sanitary Fittings: Installing low-flow faucets, showerheads, and toilets can significantly reduce water consumption. Sustainable Urban Drainage Systems (SUDS): These systems manage rainfall close to where it falls, reducing the demand for mains water for landscape irrigation. Rainwater Harvesting: Collecting and storing rainwater for use in irrigation or toilet flushing can reduce the demand for mains water.

	Active Measures: Metering: Water metering can help monitor water usage and identify areas for improvement. Water Recycling: Treating and reusing greywater (from sinks, showers, etc.) can reduce the demand for mains water. Leak Detection and Repair: Regularly checking for and repairing leaks can prevent water wastage. **RES (Renewable Energy Sources):** Solar Water Heaters: These systems use solar energy to heat water, reducing the need for gas or electric water heaters, which can save water by reducing the time it takes for water to heat up. Energy-Efficient Appliances: Appliances that use less energy often use less water as well. For example, energy-efficient dishwashers and washing machines typically use less water than their conventional counterparts.
Variable / Parameter	Yearly consumption in regards to geographical information
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Water Recycling in Buildings
NEB	Sustainability

Defining name	WT2 WATER RECYCLING INDEX
Category pillar	Water Resources
Definition	This indicator is based on a two-question survey about the presence of water recycling in public spaces and residential buildings. Please note that this is a simple indicator and does not take into account the extent or effectiveness of the water recycling practices. For a more detailed assessment, additional data would be needed. ● Question 1: Is there any water recycling in public spaces? ● Question 2: Is there any water recycling in residential buildings? For each question, a response of "Yes" is assigned a score of 1, and a response of "No" is assigned a score of 0. The WRI is then calculated by summing the scores for the two questions.
Reference	05 Water - BREEAM Knowledge Base
Formula	WRI= Score for Question 1+ Score for Question 2 **WRI:** Water Recycling Index
Unit of measurement	1 to 2
Data source	Survey
Actions/ Interventions	Passive Water Recycling Strategies: ● Rainwater Harvesting: Captures and stores rainwater for later use in non-potable applications. ● Greywater Systems: Utilises gravity or simple filtration to redirect and treat greywater for reuse.

	• Permeable Surfaces: Uses design elements to allow rainwater to naturally infiltrate the soil. Reduces stormwater runoff by promoting groundwater recharge. Active Water Recycling Strategies: • Onsite Wastewater Treatment: Involves mechanical systems for treating wastewater at the local level. • Dual Plumbing Systems: Involves separate plumbing systems for potable and non-potable water. • Smart Irrigation Systems: Utilises technology to adjust irrigation based on real-time data. • Metering and Monitoring: Involves the use of water metres and smart metering technology.
Variable / Parameter	The Index measures whether water is recycled or not in the district and its buildings
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Water Consumption
NEB	Sustainability

Defining name	WT3 EUTROPHICATION POTENTIAL (EP)
Category pillar	Water Resources

Definition	Eutrophication Potential (EP) is an environmental performance indicator used to assess the potential impact of a building or construction product on eutrophication, which is the excessive richness of nutrients in a body of water, frequently due to runoff from the land, causing a dense growth of plant life.
Reference	https://www.environdec.com/resources/indicators EN 15804 Technical Doc (europa.eu) Eutrophication potential (EP) calculation (cheminfo.org)
Formula	EP=(Vref/mwref)(V/mw) $EP = \frac{\frac{Vref}{MWref}}{\frac{V}{mw}}$ where: $V = P + \frac{N}{16} + \frac{ThOD}{138}$ $ThOD = C + \frac{H - 3N}{4} - \frac{O}{2}$ **P** is the number of phosphorus atoms, **N** is the number of nitrogen atoms, **O** is the number of oxygen atoms, **ThOD** is the theoretical oxygen demand. **Mw_{ref}** Molecular weight for phosphate anion **Mw_{ref}** Molecular weight of the compound
Unit of measurement	Kg PO4,3- eq

Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Selection of materials with low eutrophication potential and the reuse of existing materials. Effective waste and water management strategies can minimise nutrient release, while water-saving measures and wastewater treatment systems can reduce nutrient runoff. Energy efficiency improvements and the installation of renewable energy systems can indirectly reduce eutrophication. Incorporating green spaces into the district design can help absorb and filter nutrients, reducing runoff into local water systems.
Variable / Parameter	Efficient Water Management, Sustainable Material Selection
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Water Resources, Construction Materials, Waste Management
NEB	Sustainability

Defining name	CW1 RESPONSIBLE SOURCING OF MATERIALS
Category pillar	Construction Materials

Definition	The indicator measures the proportion of materials used in a project that are sourced responsibly, considering environmental, social, and economic impacts of the materials' production and supply chains. Responsible sourcing often involves certification schemes that provide third-party verification of responsible practices. Key certifications include: ● PEFC (Programme for the Endorsement of Forest Certification) ● FSC (Forest Stewardship Council) ● C2C (Cradle to Cradle) These certifications provide assurance of responsible sourcing practices across a range of material types. EPDs (Environmental Product Declarations) are also valid for this index; they don't directly prove responsible sourcing but provide detailed, transparent information about the environmental impacts of a product throughout its lifecycle.
Reference	163_IP3_13.pdf (bre.co.uk) BES 6001 Standard for Responsible Sourcing - BRE Group
Formula	$RSM = \frac{Volume\ of\ Responsibly\ Sourced\ Materials}{Total\ Volume\ of\ Materials}$
Unit of measurement	Percentage, volume in M_3
Data source	Certificates provided
Actions/ Interventions	All measures can used this KPIs to assess responsible sourcing

Variable / Parameter	Amount of environmentally friendly materials in construction processes
Monitoring Interval	Whole Life Cycle of the Building / District including renovations
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Construction materials
NEB	Sustainability

Defining name	CW2 MATERIALS LIFECYCLE ANALYSIS
Category pillar	Construction Materials
Definition	The indicator measures the environmental impact of a construction product throughout its life cycle, from the extraction and processing of raw material to its end-of-life and management of waste disposal. This indicator reflects the sustainability of the materials used in the project throughout its life cycle. This can be measured using carbon emissions as explained in the GWP(100) indicator. However as opposed to the GPW indicator for each material the whole life cycle of the product is considered from "cradle to grave" meaning it should include all of the phases in which an impact has been measured according to the respective input source.

Reference	Life-cycle assessment for green buildings | EEBGUIDE Project | Results in brief | FP7 | CORDIS | European Commission (europa.eu)
Formula	$Materials\ LCA(GWP = \sum_{I=1}^{N} GWPi$ **LCA:** Life Cycle Analysis **GWP:** Global Warming Potential
Unit of measurement	kg CO2 eq
Data source	Life Cycle Assessment using EPDs and other information provided about the districts / buildings
Actions/ Interventions	Active measures: Choose materials with low carbon impact such as biogenic or recycled. RES: Renewable Energy Systems may offset their embodied carbon producing clean energy.
Variable / Parameter	Embodied Carbon in Building Construction Products
Monitoring Interval	Every time there is a renovation this should be calculated
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	GPW(100) Waste Management
NEB	Sustainability

Defining name	UC1 HUMIDITY CONTROL
Category pillar	User Comfort
Definition	Relative Humidity is a measure of the amount of moisture present in the air compared to the maximum amount the air can hold at a given temperature expressed as a percentage.
Reference	Humidity Control, Well Building Standard
Formula	**RH=Pw/Pws** **RH:** Relative Humidity **Pw:** Vapour pressure **Pws** Saturation pressure
Unit of measurement	%
Data source	Sensors
Actions/ Interventions	Passive Measures: Use of appropriate insulation material according the climate Active measures: Heating and ventilation systems improve humidity levels and can be used to prevent
Variable / Parameter	Humidity Control in interior spaces
Monitoring Interval	Use Stage

Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	User Comfort
NEB	Sustainability

Defining name	UC2 TEMPERATURE CONTROL
Category pillar	User Comfort
Definition	This indicator controls whether the thermal comfort of the user is being addressed according to the Well Being Standard. Different users may have different comfort levels regarding temperature so thermal comfort conditions should create baseline satisfaction for the largest number of people.
Reference	Well Building Standard V2 Thermal Comfort ASHRAE 55 2017
Formula	The indicator should be at least 90% of the measured time inside the accepted threshold according to each lighthouse national regulations
Unit of measurement	Cº
Data source	Sensors

Actions/ Interventions	Passive Measures: Insulation, Natural Ventilation, Shading, Window to Wall Ratio improvement Active measures: HVAC Systems inclusion or improvement, High Efficiency appliances RES: Use of Heat Recuperators
Variable / Parameter	Indoor Air Temperature
Monitoring Interval	Use Stage
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	Use Comfort
NEB	Sustainability

Defining name	UC3 NATURE DAYLIGHT
Category pillar	User Comfort
Definition	This indicator measures the Residential Access to Daylight expressed in a percentage compared to the amount of unobstructed daylight available outside under identical meteorological conditions.
Reference	https://v2.wellcertified.com/en/wellv2/light/feature/1

	https://www.sciencedirect.com/science/article/pii/S1878029617301202 https://ucm.buildingsmart.org/use-case-details/2437/en https://www.researchgate.net/publication/316052727_Daylighting_and_Visual_Comfort_in_Buildings'_Environmental_Performance_Assessment_Tools_A_Critical_Review
Formula	$DF = \frac{Ei}{Eo} 100\%$ **Ei:** Illuminance at the indoors working plane **Eo:** Illuminance at the outdoor on a horizontal plane
Unit of measurement	%
Data source	Plans, reports or photographs of the building
Actions/ Interventions	This indicator can be improved through a variety of strategies. These include taking into account the climate and latitude of the building site, considering external obstructions like surrounding buildings or vegetation, optimising the building's geometry to enhance its capacity to deliver adequate levels of daylight to interior spaces, and selecting materials with properties that enhance light reflection. On the other hand, too much daylight can lead to issues such as glare and overheating. To mitigate this, strategies such as careful window positioning, the use of shading devices, and the selection of appropriate glazing types can be employed. These strategies help control the amount of light entering the building, ensuring a balance between adequate natural light and comfort.
Variable / Parameter	Appropriate amount of daylight in interior spaces

Monitoring Interval	Use Stage
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	User comfort
NEB	Sustainability

Defining name	UC4 INDOOR AIR QUALITY
Category pillar	User Comfort
Definition	**Part I Measurement Evaluation** This part of the KPI evaluates whether the parameters (indoor air quality, CO2, PM, and VOCs) are being measured. This can be assessed by checking if the following conditions are met: **Part II Benchmark Achievement** This part of the KPI measures whether the well-being standards for each parameter are reached. This can be assessed by comparing the measured values against the recommended thresholds: • CO2 levels should ideally be at or below 1000 ppm. • PM2.5 levels should ideally be below 15 µg/m³. • Total VOC levels should ideally be below 500 µg/m³

Reference	https://v2.wellcertified.com/en/performance-rating/indoor%20air%20quality
Formula	**Part I: Measurement Evaluation** This part of the KPI evaluates whether the parameters (CO_2, PM, and VOCs) are being measured. This can be represented as a binary score for each parameter: ● CO2 Measurement (CO2M): 1 if measured, 0 if not ● PM Measurement (PMM): 1 if measured, 0 if not ● VOC Measurement (VOCM): 1 if measured, 0 if not The score for Part I can then be calculated as the sum of these binary scores divided by the total number of parameters (3 in this case), giving a score between 0 and 1: $Part\ I = \frac{CO2+PPM+VOCs}{3}$ **Part II: Benchmark Achievement** This part of the KPI measures whether the well-being standards for each parameter are reached or exceeded. This can also be represented as a binary score for each parameter: $Part\ II = \frac{CO2 + PPM + VOCs}{3}$ $CO2 > 900\ pms$ $VOCs > 900\ pms$ $ppm > 900\ pms$ CO2 Benchmark (CO2B): 1 if the measured value is equal to or less than the standard, 0 if not PM Benchmark (PMB): 1 if the measured value is equal to or less than the standard, 0 if not

	VOC Benchmark (VOCB): 1 if the measured value is equal to or less than the standard, 0 if not The score for Part II can then be calculated as the sum of these binary scores divided by the total number of parameters (3 in this case), giving a score between 0 and 1: The overall KPI can then be calculated as the sum of both scores. This will give an overall KPI score between 0 and 6, where 6 indicates that all parameters are being measured and are within the well-being standards, and 0 indicates that none of the parameters are being measured or are within the standards. This scoring system allows for a simple, yet comprehensive evaluation of indoor air quality.
Unit of measurement	CO2 levels: ppm2. PM2.5 levels: µg/m³3. VOC levels: µg/m³.
Data source	Sensors / Performing Test
Actions/ Interventions	Passive Measures: Use low VOCs options for materials, improve building airtightness to reduce the ingress of outdoor pollutants Active measures: Filter air using filtered mechanical ventilation to improve air quality, monitor indoor and outdoor air quality to enhance ventilation system functioning.
Variable / Parameter	Indoor Air Quality
Monitoring Interval	Use stage

Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	User Comfort
NEB	Sustainability

Defining name	UC5 NOISE LEVELS
Category pillar	Indoor Air Quality
Definition	This indicator measures the time-averaged sound pressure level (8-hour average) that is used to indicate the sound level over a time period of occupancy. The objective is the Space average of the A-weighted sound pressure level in dB over an 8-hour period within the centre of the receiving room. The average of the A- weighted sound pressure level within residentials must be compliant with the World Health Organization acoustic class limits either considering daytime or nighttime.
Reference	https://v2.wellcertified.com/en/wellv2/sound/feature/2 EN ISO 12354-3:2017
Formula	Acceptable bounds of time averaged SPL acoustic levels proposed from World Health Organization and literature Noise levels ≤ 35 dB Acceptable indoor levels during daytime

	Noise levels ≤ 30 dB Acceptable indoor levels during night-time
Unit of measurement	dB
Data source	Decibel sound level metre per room specific
Actions/ Interventions	Passive Measures: materials and design elements to absorb or block sound Active measures: Use of masking systems
Variable / Parameter	Noise level inside buildings and districts
Monitoring Interval	TBD
Target (Lighthouse)	All
Building or District Level	Building and district level
Relationship with other KPIs	User Comfort
NEB	Sustainability

Life Cycle Assessment (LCA)

A Life Cycle Assessment (LCA) methodology for the SUPERSHINE project, based on ISO sustainability standards (ISO 15392:2019, ISO 20887:2020, ISO 21930:2017,ISO 14025) and the Levels framework, would involve a systematic analysis of the environmental impacts associated with all stages of the project. The first step is to define the scope, which includes the system boundaries, the functional unit, and the environmental issues to be addressed. The next step is to conduct a Life Cycle Inventory (LCI), collecting data on all inputs and outputs associated with each stage of the project. This data is then used in the Life Cycle Impact Assessment (LCIA) to evaluate potential environmental impacts, such as those related to climate change, ozone depletion, and water usage.

Finally, the results are interpreted to draw conclusions and provide recommendations, which could include identifying opportunities to reduce environmental impacts and improve efficiency. This process ensures a comprehensive understanding of the project's environmental footprint and provides a basis for continuous improvement.

The LCA should follow the ISO 14040 and ISO 14044 standards, which provide principles, requirements, and guidelines for conducting an LCA. The Levels framework can be used to set performance targets and monitor progress in key areas such as greenhouse gas emissions, life cycle cost and resource efficiency.

It's important to note that the LCA should be conducted in a transparent and rigorous manner, with results communicated clearly to all stakeholders. This will ensure that the SUPERSHINE project not only achieves its environmental goals, but also gains credibility and support from the public and other stakeholders.

The described KPIs are based on this methodology and help to ensure that the renovation of social housing aligns with the principles of the European Green Deal, including energy efficiency, affordability, decarbonisation, integration of renewables, life-cycle thinking and circularity, high health and environmental standards, and respect for aesthetics and architectural quality. By measuring these KPIs, the SUPERSHINE project can identify areas for improvement and track progress towards its objectives.

This methodology will be updated and further developed in *D3.4 LCA and SLCA - Part 1 And D3.5 LCA and SLCA - Part 2*

3.3. Financial Impact Metrics and Indexes

This section discusses the identified financial Key Performance Indicators (KPIs) that measures the impact of SUPERSHINE proposed EE renovations, required information to measures these KPIs at the beginning of the project, mid-way and end of the project, how to collect the required information and the formula of each financial KPI. The identified financial KPIs are grouped into 4 groups:

- Financial profitability and cost reduction KPIs
- Funding sources KPIs
- Impact on SMEs and local businesses KPIs
- Energy Poverty KPIs

By monitoring these KPIs for SUPERSHINE proposed EE renovations in social housing, the stakeholders can make informed financial decisions, justify future investments, and assess the overall economic impact of sustainable and energy-efficient initiatives.

3.3.1. Financial profitability and cost reduction

Defining name	Return on Investment (ROI)
Category pillar	Financial profitability
Definition	This KPI evaluates the financial returns generated from investing in the proposed SUPERSHINE EE renovations to the social housing association at district and building level. By monitoring the ROI for EE renovations in social housing, Social housing associations can make informed financial decisions, justify future investments, and demonstrate the economic viability of sustainable and energy-efficient initiatives. The ROI results are reported regularly to inform stakeholders about the financial success of the EE renovation project and provide insight into the specific areas contributing to positive or negative ROI trends. Also, the ROI data help identify opportunities for improving the financial outcomes of future EE renovation projects.
Reference	Dadd, D. and Hinton, M. (2023), "Performance measurement and evaluation: applying return on investment (ROI) to human capital investments", International Journal of Productivity and Performance Management, Vol. 72 No. 9, pp. 2736-2764. https://doi.org/10.1108/IJPPM-10-2021-0573
Formula	$ROI = \frac{\sum_{t=1}^{T} \frac{total\ revenue}{(1+WACC)^t} - \sum_{t=1}^{T} \frac{total\ cost_t}{(1+WACC)^t}}{Investment\ cost}$
Unit of measurement	Percentage
Data source	• **Group one** obtained from SUPERSHINE survey: ○ Investment cost ○ fraction of capital spent annually to cover costs EE refurbishment ○ Annual rent growth rate

	○ Operating and maintenance costs of installed EE technologies ○ Operating and maintenance cost of the building ○ Depreciation rate ○ private owners ratio ○ Annual revenues from rent ● **Group two** obtained from publicly available financial datasets: ○ Total energy savings including CO2 emissions ○ Tax rate ○ Inflation rate ○ interest rate on debt ○ market value of buildings growth rate
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Revenue from Energy savings By monitoring the ROI for EE renovations in social housing, the stakeholders can make informed financial decisions, justify future investments, and assess the overall economic impact of sustainable and energy-efficient initiatives.
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	Building level
NEB	Economic/Financial

Defining name	Net Present Value (NPV)
Category pillar	Financial profitability
Definition	This KPI measures the present value of all future annual cash flows coming from the EE renovation energy savings, considering the time value of money. The annual cash flows are all the positive cash flows generated by the EE renovation project including energy cost savings, increased property value, and other financial benefits minus the negative cash flows representing the initial investment costs and ongoing operational expenses associated with the EE renovations. We report the NPV results periodically to inform stakeholders about the financial success of the SUPERSHINE EE renovation project. Also, this KPI will be compared against the NPV of S&P500 to determine whether investing in EE renovation is worth it financially.
Reference	Stenström, Christer & Aditya, Parida & Kumar, Uday & Galar, Diego. (2013). Performance indicators and terminology for value driven maintenance. Journal of Quality in Maintenance Engineering. 19. 10.1108/JQME-05-2013-0024.
Formula	$NPV = \sum_{t=0}^{T} \frac{in\ cashflow_t - out\ cashflow_t}{(1 + WACC)^t}$
Unit of measurement	EUR
Data source	• **Group one** obtained from **SUPERSHINE survey to partners**: ○ Investment cost ○ fraction of capital spent annually to cover costs EE refurbishment ○ Annual rent growth rate ○ Operating and maintenance costs of installed EE technologies ○ Operating and maintenance cost of the building ○ Depreciation rate ○ private owners ratio

	- Annual revenues from rent - Equity fraction - Debt fraction • **Group two** obtained from publicly available financial datasets (LSEG https://www.lseg.com/en/data-analytics (previously called Refinitiv) and FRED (Federal Reserve Bank of St. Louis): - Total energy savings including CO2 emissions - Tax rate - Inflation rate - Interest rate on debt - Market value of buildings growth rate - WACC
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Revenue from Energy savings By monitoring the Net Present Value for EE renovations in social housing, the stakeholders can make informed financial decisions, justify future investments, and assess the overall economic impact of sustainable and energy-efficient initiatives.
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	Building level
NEB	Economic/Financial

Defining name	Payback period
Category pillar	Financial profitability
Definition	This KPI measures the duration required for the cumulative net cash inflows to equal the initial investment cost of the EE renovation project. This KPI expresses the payback period in terms of years to provide a clear understanding of how long it takes to recover the initial investment. This KPI considered several factors such as energy market price and project scope. Furthermore, this KPI will be reported periodically to inform stakeholders about the financial efficiency of the EE renovation project.
Reference	Frank Lefley (1996), The payback method of investment appraisal: A review and synthesis, International Journal of Production Economics, Volume 44, Issue 3,Pages 207-224,ISSN0925-5273,https://doi.org/10.1016/0925-5273(96)00022-9.
Formula	$Payback\ period\ = \frac{initial\ investment\ cost}{annual\ net\ cash\ flows}$
Unit of measurement	Number of Years
Data source	• **Group one** obtained from **SUPERSHINE survey to partners:** ○ Investment cost ○ fraction of capital spent annually to cover costs EE refurbishment ○ Annual rent growth rate ○ Operating and maintenance costs of installed EE technologies ○ Operating and maintenance cost of the building ○ Depreciation rate ○ private owners ratio ○ Annual revenues from rent ○ Equity fraction ○ Debt fraction

	• **Group two** obtained from publicly available financial datasets (LSEG https://www.lseg.com/en/data-analytics (previously called Refinitiv) and FRED (Federal Reserve Bank of St. Louis): ○ Total energy savings including CO2 emissions ○ Tax rate ○ Inflation rate ○ interest rate on debt ○ market value of buildings growth rate
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Number of years to payback the investment By monitoring the Net Present Value for EE renovations in social housing, the stakeholders can make informed financial decisions, the duration of recouping the initial investment, justify future investments, and assess the overall economic impact of sustainable and energy-efficient initiatives.
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	Building and district level
NEB	Economic/Financial

Defining name	Operating Cost reduction
Category pillar	Financial profitability
Definition	This KPI measures the total monetary savings achieved through efficiency measures that reduce the ongoing operational expenses of managing and maintaining social housing units. This KPI will be reported regularly to inform stakeholders about the financial benefits of the EE renovation project and to provide insight into the specific areas contributing to the cost reduction in maintenance and operating expenses. By monitoring this KPI for EE renovations in social housing, stakeholders can demonstrate the broader financial benefits beyond direct energy savings, make informed decisions for future projects, and contribute to long-term operational efficiency and cost-effectiveness.
Reference	McGinley, O.; Moran, P.; Goggins, J. An Assessment of the Key Performance Indicators (KPIs) of Energy Efficient Retrofits to Existing Residential Buildings. Energies 2022, 15, 334. https://doi.org/10.3390/en15010334
Formula	$Operating\ Cost\ Reduction = Annual\ O\&M_{before\ EE} - Expected\ annual\ O\&M_{after\ EE}$
Unit of measurement	EUR
Data source	• **Group one** obtained from **SUPERSHINE survey to partners:** ○ Operating and maintenance costs of installed EE technologies ○ Operating and maintenance cost of the building ○ private owners ratio • **Group two** obtained from publicly available financial datasets (LSEG https://www.lseg.com/en/data-analytics (previously called Refinitiv) and FRED (Federal Reserve Bank of St. Louis):

	○ Inflation rate ○ interest rate on debt
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Revenue from Energy savings/ By monitoring the Net Present Value for EE renovations in social housing, the stakeholders can make informed financial decisions, the duration of recouping the initial investment, justify future investments, and assess the overall economic impact of sustainable and energy-efficient initiatives.
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	Building and district level
NEB	Economic/Financial

Defining name	***Increase in Property value (IPV)***
Category pillar	Financial profitability
Definition	This KPI quantifies the growth in the market value of social housing buildings resulting from energy-efficient renovations. It reflects the positive financial impact on property values. It is measured as the net monetary gain in the market value of the housing units attributable to EE

	renovation upgrades. This KPI will be reported annually to the stakeholders to track the annual increase in property value due to EE renovations.
Reference	Davis, P.T.; McCord, J.A.; Mccord, M.J.; Haran (2015), M. Modelling the effect of energy performance certificate rating on property value in the Belfast housing market. Int. J. Hous. Mark. Anal. 8, 292–317.
Formula	$$IPV = \frac{\text{Expected market value of the building} - \text{current market value of the building}}{\text{Current market value of the building}} * 100\%$$
Unit of measurement	Percentage
Data source	• market value of the building • property appraisals, market analyses to quantify the expected market value of the building after EE renovations.
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Increase in building market value due to EE renovations
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	Building and district level
NEB	Economic/Financial

3.3.2. *Funding sources*

- **Cumulative investments made by European stakeholders in EE projects in the social housing sector:** this KPI refers to the total amount of money invested over a specific time frame. It includes all capital injections, contributions, or expenditures made in various assets, projects, or ventures. Understanding and monitoring this KPI is crucial for stakeholders as it provides insights into the financial health and performance of the EE renovation project in social housing. A consistent increase in cumulative investments may indicate a sector's expansion, improved profitability, or successful capital allocation strategies. Conversely, a decline in this KPI may prompt a closer examination of investment decisions, market conditions, or overall financial strategies. Required information to calculate this KPI is the annual investments made by stakeholders in the EE refurbishment projects in social housing buildings for the past 5 years. This KPI can be monitored annually.

- ***Number of available innovative funding sources:*** This KPI measures the quantity of funding contracts specifically designed for energy-efficient renovation projects in social housing. The information required to measure this KPI, can be obtained using publicly available datasets from government agencies, financial institutions, non-profit organisations, and other relevant stakeholders involved in providing funding for EE renovation projects in social housing.

- ***Capital investment attraction:*** This KPI quantifies the amount of external capital successfully attracted for funding energy-efficient renovation projects in social housing. It reflects the financial support gained from investors, grants, loans, or other sources. This KPI sums the total value of external capital secured for energy-efficient renovation projects during a specific period and is reported to stakeholders annually. The data collected are the external capital raised for energy-efficient renovation projects which can be obtained from the SUPERSHINE survey questionnaire to partners, and publicly available financial datasets such as grants, or loans to quantify the capital investment attraction. By monitoring the Capital Investment Attraction for energy-efficient renovations in social housing, stakeholders can gauge their financial sustainability, make informed decisions for future projects, and strengthen relationships with investors, lenders, and grant providers.

3.3.3. Impact on SMEs and job creation

Defining name	***District transformation impact on SMEs and local business***
Category pillar	Impact on SMEs and job creation

Definition	This KPI evaluates the influence of EE renovation projects on the district, specifically focusing on the engagement, growth, and transformation of SMEs providing products and services related to energy efficiency.
Reference	Agrawal, R., De Tommasi, L., Lyons, P. et al. Challenges and opportunities for improving energy efficiency in SMEs: learnings from seven European projects. Energy Efficiency 16, 17 (2023). https://doi.org/10.1007/s12053-023-10090-z. Johannes Fresner, Fabio Morea, Christina Krenn, Juan Aranda Uson, Fabio Tomasi, (2017), Energy efficiency in small and medium enterprises: Lessons learned from 280 energy audits across Europe, Journal of Cleaner Production, Volume 142, Part 4, Pages 1650-1660,ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2016.11.126.
Formula	MEs Growth rate = SMEs market value after the EE renovation - SMEs current market value -- *100% SMEs current market value
Unit of measurement	Growth rate of SMEs
Data source	SME engagement **(Survey questionnaire for SMEs and local businesses)** SME growth rate **(available financial datasets such as orbis dataset)** Transformation impact **(Survey questionnaire for SMEs and local businesses)**
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All

Building or District Level	District level
NEB	Economic/Financial

Defining name	**Job Creation**
Category pillar	Impact on SMEs and job creation
Definition	This KPI measures the total count of new jobs generated as a result of the SUPERSHINE EE renovation projects in each lighthouse country
Reference	https://betterbuildingssolutioncenter.energy.gov/sites/default/files/IB_Using%20Data%20to%20Set%20Priorities_Final.pdf
Formula	$Job\ creation\ rate\ = \frac{Number\ of\ new\ jobs\ created}{Existing\ workforce} * 100\%$
Unit of measurement	percentage
Data source	The project reports produced by stakeholders involved in the EE renovation project such as construction companies, ESCOs, social housing associations, among others. SUPERSHINE survey on employment data from relevant government agencies and statistical offices about the residents in the district.
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity

Variable / Parameter	Participation of low-income residents in the energy efficiency and renewable energy workforce (number of local workers trained and placed into energy efficiency and renewable energy jobs)
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	Building & District level
NEB	Economic/Financial

3.3.4. Energy Poverty

Defining name	***Energy cost savings***
Category pillar	Energy poverty
Definition	This KPI quantifies the monetary savings resulting from EE renovations and reflects the reduction in energy-related costs due to the installed efficiency measures. The energy cost savings is achieved through reduced energy consumption and improved energy efficiency. This KPI assesses directly the financial impact of the installed EE renovations and will be reported annually. By monitoring this KPI for EE renovations in social housing, the stakeholders can demonstrate the financial benefits of sustainability initiatives, make informed decisions for future projects, and contribute to long-term cost reduction and environmental sustainability

Reference	https://betterbuildingssolutioncenter.energy.gov/sites/default/files/IB_Using%20Data%20to%20Set%20Priorities_Final.pdf
Formula	$Energy\ Cost\ Savings = Previous\ Energy\ costs - Energy\ costs\ after\ EE\ renovations$
Unit of measurement	EUR
Data source	• **Group 1** (information will be obtained from financial datasets (LSEGhttps://www.lseg.com/en/data-analytics (previously called Refinitiv) and FRED (Federal Reserve Bank of St. Louis)) o The CO2 emission savings o Savings in electricity consumption o Savings in heat consumption o Market price of electricity o market price of CO2 emission per tonne • **Group 2** (technical information to be obtained from **SUPERSHINE surveys**): o Heating demand o North, east, west and south facade glazing fraction o North, east, west and south facing facade area o Wall U value o Window U value o Roof U value o Floor U value o ground floor area o number of storeys o storey height o building height o building width o roof area
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity

Variable / Parameter	Energy savings (EUR/MWh) for customers in aggregate or by low-income household served
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	Building & District level
NEB	Economic/Financial

Defining name	**Energy Expenditure as a percentage of income**
Category pillar	Energy poverty
Definition	This KPI measures the proportion of the total energy consumption cost in relation to the household total income. This KPI will be measured annually to observe the impact of SUPERSHINE EE renovations on energy poverty in each of SUPERSHINE lighthouses and fellow countries. A decreasing percentage will indicate a positive impact on the energy poverty in the building/district suggesting improved energy efficiency.
Reference	https://betterbuildingssolutioncenter.energy.gov/sites/default/files/IB_Using%20Data%20to%20Set%20Priorities_Final.pdf
Formula	$Energy\ cost\ per\ resident\ \ income = \frac{average\ energy\ expenditure}{Average\ income} * 100\%$
Unit of measurement	Percentage

Data source	• average energy expenditure per household if available or building (to be collected from **SUPERSHINE Survey)** • Average income per household in the building or district. (to be collected from the **SUPERSHINE Survey)**
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Cost savings (EUR) for customers in aggregate or by low-income household served
Monitoring Interval	At the beginning of the SUPERSHINE project, during the SUPERSHINE project (Half way), and end of the SUPERSHINE project
Target (Lighthouse)	All
Building or District Level	District level
NEB	Economic/Financial

Defining name	**Energy consumption per Sqm**
Category pillar	Energy poverty
Definition	This KPI provides a quantitative measure of the efficiency of energy use in renovated social housing units and can be valuable for evaluating the success of energy efficiency initiatives in the European Union. This KPI will be reported annually to keep track

	of SUPERSHINE impact on energy poverty in the lighthouses and fellow countries.
Reference	https://www.turnkey-retrofit.eu/wp-content/uploads/energies-15-00334.pdf
Formula	$$Energy\ consumption\ per\ Sqm = \frac{Total\ energy\ consumption}{Total\ renovated\ floor\ area}$$
Unit of measurement	Kwh/m2
Data source	• Total energy consumption: which is the Sum of energy consumed by households in social housing including heating, cooling, lighting, and other relevant energy consumption **(to be collected from the SUPERSHINE Survey)** • Total floor area of the building to be renovated or district **to be collected from the SUPERSHINE Survey**
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Energy consumption per meter squared for buildings and district
Monitoring Interval	Note that this KPI will be reported annually to measure the impact of the SUPERSHINE project during the implementation of EE renovations and after the implementation of EE renovations.
Target (Lighthouse)	All
Building or District Level	Building & District level
NEB	Economic/Financial

Defining name	**Arrears on Utility bills**
Category pillar	Energy poverty
Definition	This KPI is designed to measure the financial impact of energy efficiency renovations within a social housing building/district in the SUPERSHINE lighthouses and fellow countries. It specifically focuses on assessing the extent of arrears on utility bills among households prior to, during and after the EE renovations, with the aim of understanding the economic well-being of residents and identifying potential energy poverty indicators.
Formula	$\text{Total arrears on Utility bills} = \frac{\text{Total arrears on utility bills}}{\text{Total Number of households in building/district}}$
Unit of measurement	EUR/dwelling
Data source	• **Total arrears on Utility bills:** The cumulative amount of outstanding payments on utility bills (e.g., electricity, gas, water) for households within the social housing district. **(to be collected from the SUPERSHINE survey)** • Total number of households in the building/district: The total count of residential units within the social housing district **(to be collected from the SUPERSHINE survey)**
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	Arrears on utility bills
Monitoring Interval	Note that this KPI will be reported annually to measure the impact of the SUPERSHINE project during the implementation of EE renovations and after the implementation of EE renovations.
Target (Lighthouse)	All

Building or District Level	Building level could be extended to District level if SMEs and local businesses provide their financial information on energy consumption and arrears on utility bills
NEB	Economic/Financial

Defining name	**Energy access**
Category pillar	Energy poverty
Definition	This KPI is designed to evaluate the effectiveness of energy efficiency renovations in social housing by assessing the level of energy access for residents. The goal is to ensure households have improved and equitable access to reliable and affordable energy sources
Reference	Angelakoglou, K.; Chatzigeorgiou, E.; Lampropoulos, I.; Giourka, P.; Martinopoulos, G.; Nikolopoulos, N. Monitoring the Sustainability of Building Renovation Projects—A Tailored Key Performance Indicator Repository. *Buildings* **2023**, *13*, 2046. https://doi.org/10.3390/buildings13082046 https://assets.publishing.service.gov.uk/media/635beb98d3bf7f20de4a721c/shdf-wave-2.1-competition-guidance.pdf
Formula	$Energy\ access = \frac{Number\ of\ households\ with\ improved\ energy\ access}{Total\ number\ of\ households\ in\ the\ district}$
Unit of measurement	percentage
Data source	• Number of households with improved energy access in the building/district **(to be collected from the SUPERSHINE partners)** • Total number of households in the district **(to be collected from the SUPERSHINE partners)**

Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	A higher value for this KPI indicates a positive impact on energy poverty in the district.
Monitoring Interval	Note that this KPI will be reported annually to measure the impact of the SUPERSHINE project during the implementation of EE renovations and after the implementation of EE renovations.
Target (Lighthouse)	All
Building or District Level	District level
NEB	Economic/Financial

Defining name	**Energy disconnection rate**
Category pillar	Energy poverty
Definition	This KPI is designed to assess the impact of energy efficiency renovations on energy disconnection rates within social housing in the SUPERSHINE lighthouse and fellow countries. The goal is to assess the effectiveness of renovations in mitigating energy poverty by reducing instances of energy disconnections.
Reference	Bal M., F. Marijn, Van Hemel C., De Wit J. (2021), Including Social Housing Residents in the Energy Transition: A Mixed-Method Case Study on Residents' Beliefs, Attitudes, and Motivation Toward Sustainable Energy Use in a Zero-Energy Building Renovation in the Netherlands, Frontiers in Sustainable Cities, Vol 3, URL=https://www.frontiersin.org/articles/10.3389/frsc.2021.656781, DOI=10.3389/frsc.2021.656781

Formula	$Energy\ disconnection\ rate = \frac{Number\ of\ households\ with\ energy\ disconnections}{Total\ number\ of\ households\ in\ the\ building/district} * 100\%$
Unit of measurement	percentage
Data source	• Number of households with energy disconnections **(to be collected from the SUPERSHINE partners)** • Total number of households in the building/district **(to be collected from the SUPERSHINE partners)**
Actions/ Interventions	Passive Measures: Insulation improvement Active measures: Energy-Efficient Lighting RES: Solar Panels for electricity
Variable / Parameter	A decreasing value of this KPI indicates a positive impact of the SUPERSHINE proposed EE renovation on the energy poverty in the lighthouse and fellow countries.
Monitoring Interval	Note that this KPI will be reported annually to measure the impact of the SUPERSHINE project during the implementation of EE renovations and after the implementation of EE renovations.
Target (Lighthouse)	All
Building or District Level	Building level
NEB	Economic/Financial

3.4. Cost-Benefit Analysis Extension (CBAE)

This deliverable adopts financial evaluation methods to carry out the economic cost-benefit analysis of the impact of SUPERSHINE proposed Energy Efficiency project in social housing buildings and district. The costs or benefits refer to the increased costs or benefits due to the implementation of Energy Efficiency projects. This evaluation methodology will analyse the costs and benefits with and without the EE renovations respectively in order to show the economic effects of EE renovations. The lifetime of EE renovations project includes decision-making prior to retrofit, the EE renovations implementation stage, and existing building operation stage after the EE renovations. The static investment payback period, Internal Rate of Return (IRR), Net Present Value (NPV), Return on Investment (ROI) and benefit costs ratio (BCR) are selected for implementing the cost benefit analysis.

Investment payback period: The investment payback period refers to the time required to recover the investment cost by the profits from energy savings and CO2 emission reductions with taking into account the time value of money. It can be described using the following formula:

$$Payback\ period\ = \frac{Investment\ cost}{annual\ cash\ inflow}$$

The annual cash inflows are accumulated, and the year determined when the cumulative inflows equal the investment expenditure. The method is sometimes seen as a measure of the risk involved in the project. The two major weaknesses of the payback method is that it doesn’t take in account the cash flows after the investment cost is recovered. The payback period approach is a relatively simple technique for social housing managers to use and for this reason it remains very popular.

Internal rate of return (IRR)

The IRR refers to the discount rate when project's financial NPV is zero, and it can be calculated by the following equation:

$$0 = NPV\ = \sum_{t=1}^{T} \frac{Net\ cash\ inflow_t}{(1+IRR)^t} - \ total\ investment\ cost$$

where T represents a project's lifetime, project financial viability can be evaluated by comparing the IRR and the hurdle cut-off rate which is the WACC plus the risk-free rate. If IRR > hurdle cut-off rate, it means that the project is economically acceptable. If IRR < hurdle cut-off rate, it suggests that the project should be rejected.

Net Present Value (NPV)

NPV measures the actual or real net economic benefit of a project. While the BCR provides a ratio of benefits to costs, NPV measures the absolute net economic gain. NPV is calculated by subtracting the discounted costs from the discounted benefits. All projects with a positive NPV provide a net economic benefit.

$$NPV\ = \sum_{t=1}^{T} \frac{(Cash\ inflow_t\ -\ cash\ outflow_t)}{(1+discount\ rate)^t}$$

Where the discount rate is continuous:

$$Discount\ rate\ =\ e^{(real\ interest\ rate_t * T}$$

$$Real\ interest\ rate = \frac{(nominal\ interest\ rate_t + 1)}{(inflation\ rate_t + 1)} - 1$$

Return on investment (ROI):

The ROI is a ratio that compares the gain or loss from an investment relative to its cost. It is useful in evaluating the current and potential financial benefits from an investment. The ROI is given by:

$$ROI \ = \frac{\sum_{t=1}^{T} \frac{cash\ inflow_t}{(1+discount\ rate)^t} - \sum_{t=1}^{T} \frac{cash\ outflow_t}{(1+discount\ rate)^t}}{Investment\ cost}$$

A positive ROI indicates a positive net profit from the investment, and a negative ROI refers to a loss. In the evaluation methodology, we will compare the EE renovation project ROI with that of the S&P500 index for the next 20 years. This comparison will assist the stakeholders on whether to consider investing in the SUPERSHINE proposed EE renovations in social housing buildings and districts.

Benefit Cost Ratio (BCR)

Calculating the benefit-cost ratio (BCR) for an energy efficiency project in a social housing building involves comparing the total benefits derived from the project to the total costs incurred. The BCR is given by:

$$BCR \ = \frac{\sum_{t=1}^{T} ash\ inflow_t}{\sum_{t=1}^{T} cash\ outflow_t}$$

Where:

$$Cash\ inflow \ = Energy\ cost\ savings + increased\ property\ value + increased\ income\ from\ rent$$

$$Cash\ outflow \ = investment\ cost + maintenance\ and\ operating\ costs + financing\ cost$$

Note that if BCR > 1, then the project benefits outweigh its costs, indicating it is financially viable. If the BCR < 1, then the project's costs exceed its benefits, suggesting it may not be economically feasible without further adjustments.

3.5. Life Cycle Costing (LCC)

The real cost method is used for different goals in different methodologies and certificates such as RICS or BREEAM where Life Cycle Costs are calculated , based on nominal values updated with the expected average inflation rate and discounted at a rate equal to the average inflation of the period, estimated at 3% per year (constant currency value). A 60-year analysis has been considered. If there are any, a proportional residual value is considered for the elements that exceed the duration of the study.

It is important to note that the economic life cycle analysis does not include the environmental costs derived from monetizing the environmental impacts calculated in an LCA. The reason is that these costs are arbitrary and dependent on the source used, where there is no consensus among the scientific community about these costs. Considering these costs would also mask the rest of the conclusions associated with the traditional real costs of the different decisions made in the design of the building and the selection of materials and technological solutions.

The life cycle inventory contains the costs of materials, energies, and waste treatment evaluated in current euros. These costs discounted at a discount rate equal to the expected average inflation for the life period of the building will give us the life cycle cost analysis of the same. This value represents the cost associated with the building during all its life cycle phases,
The economic feasibility analysis of the improvement measures will be based on simple payback. As the recurring costs are given in monetary units corresponding to different periods, the currency depreciates annually in usually inflationary environments. For this, the use of a discount rate factor of the annual recurring costs equal to inflation is foreseen. We are going to assume a constant inflation of 2% per year for the next 60 years.

The total costs over the life cycle require converting all recurring costs, maintenance, and operation of the building, into addable units in current currency.

4. Conclusions

Key Performance Indicators (KPIs) have been developed in alignment with the project's vision and in a holistic manner. This approach ensures that all aspects of the project are considered and evaluated.

Some indicators were challenging to obtain, necessitating adaptations to ensure the most accurate and relevant data is captured. The scope of responses varied across different districts, resulting in some indicators only being calculable in certain lighthouses. This highlights the importance of context-specific data in performance evaluation.

Two types of data are considered for inputs: statistical data and direct data from pilots. Measures have been implemented to ensure that personal or sensitive data from various stakeholders is not collected, prioritising privacy and confidentiality. A survey has been designed to assist the pilots in providing the necessary data. This data will enable technical partners to perform accurate and meaningful calculations.

The project draws on previous reference projects, which have been adapted to align with the SUPERSHINE objective. This includes scaling indicators from buildings to districts and incorporating additional human-centric indicators in the environmental category, which typically focuses on the impacts of products and buildings. The project aims to achieve technical, financial, and environmental ambitions within a comprehensive framework. This includes renovation objectives and alignment with the New European Bauhaus (NEB) initiative.

The indicators may undergo adaptation and refinement as the implementation progresses. This flexibility allows for adjustments based on real-time insights and evolving project needs.

Life Cycle Costing (LCC) can vary significantly based on assumptions related to interest and other factors. Therefore, it's crucial to consider these variables when performing LCC analysis. LCC can be evaluated using the same phases used for Life Cycle Assessment (LCA). This approach ensures a balanced and optimised solution, considering both the economic and environmental impacts of the project.

5. References

'EUROPEAN COMMISSION Horizon 2020 H2020-SCC-2016 GA No. 731198 - RUGGEDISED'. Available at: https://ruggedised.eu/fileadmin/repository/Publications/Lessons_learned_on_the_implementation_of_smart_solutions_in_the_Lighthouses_1_out_of_3.pdf.

'Lighthouses boost sustainability with Fourth Industrial Revolution'. Available at: https://www.weforum.org/press/2021/09/lighthouses-boost-sustainability-with-fourth-industrial-revolution-transformation/.

'Lighthouses – BlueMissionAA'. Available at: http://bluemissionaa.eu/lighthouses/.

'New European Bauhaus: beautiful, sustainable, together'. Available at: https://new-european-bauhaus.europa.eu/index_en.

'REPORT FROM THE COMMISSION TO THE EUROPEAN ... - New European Bauhaus'. Available at: https://new-european-bauhaus.europa.eu/system/files/2023-01/CP-039%20-%20Annex%20to%20another%20act%20to%20be%20approved%20by%20the%20Commission%20%281%29%20%28EN%29%20Part%201.pdf.

'What is the New European Bauhaus? - Renewable Matter'. Available at: https://www.renewablematter.eu/articles/article/what-is-the-new-european-bauhaus.

'What is an EPD and how to use it? - Rockpanel'. Available at: https://www.rockpanel.co.uk/product-benefits/sustainability/what-is-an-epd/.

'ADDRESSING THE HIDDEN EMISSIONS IN BUILDINGS - BPIE'. Available at: https://www.bpie.eu/wp-content/uploads/2021/12/EPD-Factsheet.pdf.

'Environmental Product Declarations - Construction Products'. Available at: https://www.construction-products.eu/publications/environmental-product-declarations/.

'Sustainability | Free Full-Text | The Use of Environmental Product'. Available at: https://www.mdpi.com/2071-1050/15/2/1284.

'Environmental product declarations (EPDs) for ... - EnergyVille'. Available at: https://www.energyville.be/en/research/environmental-product-declarations-epds-construction-products.

'Scientific Assessment of Ozone Depletion: 2022 - National Oceanic and'. Available at: https://csl.noaa.gov/assessments/ozone/2022/executivesummary/.

'ozone depleting potential | UNEP Law and Environment Assistance Platform'. Available at: https://leap.unep.org/en/knowledge/glossary/ozone-depleting-potential.

'CONSUMPTION OF OZONE DEPLETING SUBSTANCES Atmosphere Ozone Layer'. Available at: https://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/atmosphere/ozone_depleting_substance.pdf.

'Ozone-depleting potential - Oxford Reference'. Available at: https://www.oxfordreference.com/view/10.1093/oi/authority.20110803100259631.

'Life Cycle Assessment Guide - KPMG Global'. Available at: https://kpmg.com/xx/en/home/insights/2023/10/life-cycle-assessment-guide.html.

'Life cycle-based standards and guidelines - PRé Sustainability'. Available at: https://pre-sustainability.com/articles/lca-standards-and-guidelines/.

'A framework for implementing a holistic and integrated life cycle'. Available at: https://link.springer.com/article/10.1007/s11367-021-01983-1.

'What is life cycle assessment (LCA)? | Golisano Institute for'. Available at: https://www.rit.edu/sustainabilityinstitute/blog/what-life-cycle-assessment-lca.

'Life Cycle Assessment (LCA) explained - PRé Sustainability'. Available at: https://pre-sustainability.com/articles/life-cycle-assessment-lca-basics/.

'Environmental Product Declarations – Construction Products Europe'. Available at: https://www.construction-products.eu/publications/environmental-product-declarations/.

'Environmental Product Declaration (EPD) EN 15804 - BRE Group'. Available at: https://bregroup.com/services/testing-certification-verification/en-15804-environmental-product-declarations/.

'Life Cycle Assessment (LCA) - europa.eu'. Available at: https://eplca.jrc.ec.europa.eu/lifecycleassessment.html.

'Life Cycle Assessment: Products and Services | SpringerLink'. Available at: https://link.springer.com/referenceworkentry/10.1007/978-3-031-25984-5_323.

'PEFC is raising awareness on responsible sourcing at ... - FashionUnited'. Available at: https://fashionunited.com/news/fashion/pefc-is-raising-awareness-on-responsible-sourcing-at-the-36th-iaf-world-fashion-convention/2021110543450.

'Life-cycle assessment for green buildings | EEBGUIDE Project | Results'. Available at: https://cordis.europa.eu/article/id/92955-lifecycle-assessment-for-green-buildings.

'Level(s) - European Commission - Environment'. Available at: https://environment.ec.europa.eu/topics/circular-economy/levels_en.

'The European construction sector'. Available at: https://eurocodes.jrc.ec.europa.eu/sites/default/files/2021-12/2016-09-06_The-European-construction-sector-brochure_WEB.pdf.

'EUROPEAN PUBLIC POLICIES, TOOLS AND MARKET INITIATIVES - BPIE'. Available at: https://www.bpie.eu/wp-content/uploads/2022/01/SPIPA-LCA-2022FINAL.pdf.

'Monitoring the Sustainability of Building Renovation Projects—A'. Available at: https://www.mdpi.com/2075-5309/13/8/2046.

'Building renovation: where circular economy and climate meet'. Available at: https://www.eea.europa.eu/publications/building-renovation-where-circular-economy.

'Life Cycle Assessment Benchmark for Wooden Buildings in Europe - Springer'. Available at: https://link.springer.com/chapter/10.1007/978-3-030-77127-0_13.

'Environmental benchmarks for buildings - europa.eu'. Available at: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC110085/deliverable-2-report_d2_online.pdf.

'Life Cycle Stages – One Click LCA Help Centre'. Available at: https://oneclicklca.zendesk.com/hc/en-us/articles/360015064999-Life-Cycle-Stages.

'What the revised EN 15804 EPD standard means for you'. Available at: https://pre-sustainability.com/articles/what-the-revised-en15804-epd-standard-means-for-you/.

'Whole Life-Cycle Carbon Assessments guidance - London City Hall'. Available at: https://www.london.gov.uk/publications/whole-life-cycle-carbon-assessments-guidance.

'The Importance of Environmental Product Declarations (EPDs)'. Available at: https://www.klassegroup.co.uk/blogs/insights/the-importance-of-epds.

'THE VALUE OF FSC FOR - Forest Stewardship Council'. Available at: https://fsc.org/sites/default/files/2021-03/The%20Value%20of%20FSC%20for%20CONSTRUCTION%20MARCH%2021%20WEB%20VERSION.pdf.

'Materials - Supply Chain Sustainability School'. Available at: https://www.supplychainschool.co.uk/topics/sustainability/materials/.

'Responsible Packaging - a new, forest centric way to look at ... - PEFC'. Available at: https://www.pefc.org/what-we-do/our-collective-impact/our-campaigns/responsible-packaging-a-new-forest-centric-way-to-look-at-sustainable-packaging.

'THE VALUE OF FSC FOR - Forest Stewardship Council'. Available at: https://fsc.org/sites/default/files/2020-09/The%20Value%20of%20FSC%20for%20PACKAGING%20JULY%202020%20WEB%20VERSION.pdf.

'The growing importance of EPDs. Why it matters and how you use them'. Available at: https://vestre.com/uk/news/the-growing-importance-of-epds-why-it-matters-and-how-you-use-them.

'THE VALUE OF FSC FOR'. Available at: https://fsc.org/sites/default/files/2020-09/The%20Value%20of%20FSC%20for%20RETAIL%20JULY%202020%20WEB%20VERSION.pdf.

'Sourcing of Raw Materials-Biobased Materials & FSC Wood'. Available at: https://getgreenbadger.com/sourcing-raw-materials-biobased-fsc/.

'Fibre | Forest Stewardship Council'. Available at: https://fsc.org/en/businesses/fibre.

'Key Performance Indicators for Responsible Sourcing - BSR'. Available at: https://www.bsr.org/reports/BSR_Responsible_Sourcing__KPIs_Summary.pdf.

'Responsible Nestlé responsible sourcing KPIs 2020 ... - Nestlé Global'. Available at: https://www.nestle.com/sites/default/files/2021-03/creating-shared-value-appendix-2020-responsible-sourcing-kpis_0.pdf.