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SUPER·i

D3.2 Promoting feasibility assessments for the investment pipelines in 3 SUPER-i partner countries

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2. Technical references

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PP = Restricted to other programme participants (including the Commission Services)

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CO = Confidential, only for members of the consortium (including the Commission Services)

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0.1	20/12/2023	UoY	First Draft
0.2	15/01/2024	UoY	Second Draft
0.3	29/02/2024	UoY	Final review

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Executive summary

This deliverable presents a comprehensive feasibility assessment for an investment pipeline spanning Italy, Denmark, and Slovenia, focusing on energy efficiency renovations in social housing. The assessment covers technical, financial, and environmental aspects crucial for the success and sustainability of the SUPER-i project.

Technical Aspect:

The development and application of an energy-saving model for the SUPER-i project pipeline buildings. This model evaluates current energy efficiency and proposes improvements, estimating potential savings in energy, costs, and carbon emissions. It predicts space heating demand before and after retrofit, utilising thermal performance metrics to calculate energy, fuel, and emissions savings associated with retrofitting.

Financial Aspect:

The Financial Key Performance Indicators (KPIs) for the SUPER-i Energy Efficiency (EE) renovation project in social housing. It covers KPIs related to financial profitability and cost reduction, funding sources, and mitigation of energy poverty. Key metrics include Return on Investment (ROI), Net Present Value (NPV), Payback Period, Operating Cost Reduction (OCR), Increase in Property Value (IPV), Cumulative Investments by European Stakeholders, Optimal Leverage Ratio, Number of Available Innovative Funding Sources, Capital Investment Attraction (CIA), Energy Cost Savings (ECS), Energy Expenditure as Percentage of Income, Energy Consumption per Sqm, Arrears on Utility Bills, and Energy Disconnection Rate. These KPIs provide insights into financial impact, funding sustainability, and energy poverty reduction, crucial for the success of the SUPER-i project.

The financial analysis of social housing renovations in Italy, Slovenia, and Denmark highlights significant disparities in energy efficiency needs and funding availability. In Italy and Slovenia, ageing infrastructure necessitates substantial investments for renovations, while Denmark's buildings require comparatively less extensive upgrades. Despite significant funding from both EU and national levels, there remains a financial gap in all three countries, emphasising the need for strategic planning and collaboration to bridge shortfalls. Effective coordination and prudent resource allocation will be crucial to maximise the impact of energy efficiency initiatives and address energy poverty concerns across these nations.

The available funding sources for social housing energy efficiency (EE) renovation projects encompass a variety of EU-level initiatives and country-specific programs. At the EU level, funding sources include the Cohesion Fund, Connecting Europe Facility, European Investment Bank, InvestEU, Just Transition Mechanism, LIFE: Clean Energy Transition, Modernisation Fund, Recovery and Resilience Facility, and the Innovation Fund. These programs provide financial support for sustainable development, renewable energy, energy efficiency, and transitioning to a greener economy. In the SUPER-i pilot countries of Denmark, Italy, and Slovenia, funding sources vary but often include national funds, incentive programs, public-private partnerships (PPPs), and support from entities like the National Building Fund (Denmark), National Energy Efficiency Fund (Italy), and Eco Fund (Slovenia). Innovative financing solutions such as PPP contracts, direct credit lines, guaranteed savings contracts, shared savings contracts, and energy supply contracts offer mechanisms for financing EE renovation projects, each with its own benefits and considerations. These funding options aim to bridge financial gaps and promote energy efficiency improvements in social housing across Europe.

Environmental and Social Aspect:

The deliverable also highlights the use of Life Cycle Assessment (LCA) and Social Life Cycle Assessment (SLCA) methodologies to evaluate the environmental and social impacts of refurbishment and renovation strategies for social housing. ISO sustainability standards and Social Key Performance Indicators (KPIs) are integrated to measure occupants' well-being and satisfaction, promoting replicability and scalability of investment models. Environmental KPIs and Social KPIs monitor key metrics, fostering collaboration among stakeholders and ensuring equitable access to energy resources. This comprehensive approach enhances understanding of the social impact of building renovations and contributes to sustainability goals.

3. Introduction

The SUPER-i initiative constitutes a transformative and pivotal project that closely aligns with the objectives outlined in the European Green Deal by the European Commission. Fundamentally, the project seeks to address the urgent challenges associated with the affordability of energy for households while concurrently addressing the issue of energy poverty.

3.1. Overview of energy poverty in the social housing

More than 50 million individuals in the European Union experience energy poverty, signifying that 7% of the EU population grapple with the elevated expenses of energy bills, adversely impacting their physical and mental well-being (Gangale and Mengolini (2019)[1]). Additionally, the energy consumption of social and affordable buildings in the EU contributes to 40% of the total energy consumption in Europe and 34% of greenhouse gas emissions. The prevailing energy crisis, coupled with political turmoil in Eastern Europe, has substantially heightened electricity and gas prices, affecting the livelihoods of millions of EU households. The global expansion of the COVID-19 pandemic since early 2020 has further exacerbated energy poverty issues in social and affordable housing. Residents in EU countries under lockdowns spent more time at home, leading to increased energy consumption and heightened vulnerability to energy poverty. A recent study by Siksnelyte-Butkiene (2022)[2] reveals that the COVID-19 pandemic has intensified energy poverty in Europe by diminishing disposable income and escalating energy costs. Addressing the energy-income ratio, the European Commission proposed a recovery plan for Europe in 2020, aiming to fund the Renovation Wave and enhance the energy infrastructure of EU buildings and densely populated areas.

At the European level, various initiatives are underway to reduce the net greenhouse gas emissions and break the link between economic growth and resource use. These programs make sure that people who cannot afford a sustainable lifestyle that meets the environmental goals are not left behind (European Commission, (2023)[3]). Moreover, the European Council in 2022 has launched the updated 'Fit for 55' program, which sets bold goals for cutting down greenhouse gas (GHG) emissions in the European Union and boosting the use of renewable energy sources. The SUPER-i project concentrates on building renovations, with the purpose of improving energy efficiency in social housing. The integration of affordable and sustainable energy sources is a key part of the overall objectives set by the United Nations in 2022, which have three specific targets. These targets are to achieve universal access to modern energy services, to increase the share of renewable energy sources, and to improve energy efficiency by 2030. However, to reach these targets, funding for energy research, technological innovations, infrastructure development, and renovation is essential. Furthermore, residents in social housing buildings who are suffering from energy poverty often face two problems. First, they have poor heating/cooling or electrical systems that waste energy at a low rate, leading to overuse of energy resources. Second, they bear the cost of high expenses due to energy overuse. In other words, those who already live in unstable conditions

[1] Gangale, F., & Mengolini, A. (2019). *Energy poverty through the lens of EU research and innovation projects*. Publication Office of the European Union.

[2] Indre Siksnelyte-Butkiene, Dalia Streimikiene, Tomas Balezentis, (2022). Addressing sustainability issues in transition to carbon-neutral sustainable society with multi-criteria analysis, Energy, Volume 254, Part A, 124218, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2022.124218.

[3] https://commission.europa.eu/system/files/2023-06/SDG-Report-WEB.pdf

have to deal with additional difficulties. Thomson et al. (2019)[4] state that people living in such situations may use too much energy, leading to unpayable utility bills. Alternatively, they may try to save energy to reduce financial stress, resulting in poor heating during winter months, poor cooling during summer months, or insufficient energy supply for daily needs. These actions put a mental and emotional strain on the residents. The commonness of energy poverty often comes from the condition of older housing stock in Europe, especially those built in the 1970s and 1980s. This situation leads to a large share of energy-inefficient homes, especially within the social housing sector. According to the European Commission's findings, a large share of buildings in the European Union, specifically 75%, have been rated as having poor energy efficiency (European Commission (2020)[5]).

The lack of sustainable housing has harmful effects on all other aspects of human life. Several recent studies have shown that the COVID-19 pandemic has affected disadvantaged families more than others in terms of energy poverty, thus emphasising the importance of improving energy efficiency as both an environmental issue and a matter of social justice (Siksnelyte-Butkiene, (2022)[6]). The efforts to improve energy efficiency in social housing are a reaction to the social, environmental, and economic challenges caused by the energy crisis in Europe. These efforts consider the needs of vulnerable households who gain from such initiatives, the financial obligations of the city and its residents, and the lasting environmental impacts of energy production and consumption. The application of energy-efficient measures in social housing offers a feasible way to deal with the root causes of energy poverty, rather than just giving financial support for existing energy systems or applying superficial solutions that may offer short-term relief but fail to solve the problem in the long term (Vurro et al., 2022[7]). Therefore, the SUPER-i project aims to improve the well-being of individuals by simultaneously improving the living conditions of households and lowering the environmental footprint related to home energy consumption, especially in terms of greenhouse gas emissions. Through this action, the project actively helps the gradual change of the discourse around social housing and the issue of energy poverty in Europe.

Finally, the European Commission provides financial support for energy retrofit initiatives through various means, such as the European Regional Development Fund (ERDF) and Cohesion Funds. The financial support provided under the framework of the European Structural and Investment (ESI) funds is aimed at creating "sustainable and healthy European economies and environments" (European Commission, (2022)[8]). The focus of the ERDF 2021-2027 is on improving a competitive and smart European territory, while also promoting a greener and low-carbon transition towards achieving a net zero carbon economy. This strategic approach intends to help the development of a more resilient Europe. In practical terms, it is expected that around 30% of money allocated by the European Regional Development Fund (ERDF) and 37% of funding offered by the Cohesion Fund will be used towards climate-related objectives. These objectives include tackling energy poverty, implementing energy saving initiatives, and switching to energy-efficient technologies.

[4] Thomson, H., Simcock, N., Bouzarovski, S., & Petrova, S. (2019). Energy poverty and indoor cooling: An overlooked issue in

[5] European Commission. (2020). In focus: Energy efficiency in buildings. https://ec.europa.eu/info/news/focus-energy-e"ciency-buildings-2020-lut-17_en

[6] Siksnelyte-Butkiene, Indre. 2022. "Combating Energy Poverty in the Face of the COVID-19 Pandem

[7] https://projects2014-2020.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1663935629.pdf

[8] https://ec.europa.eu/commission/presscorner/detail/en/IP_24_163

3.2. Purpose of deliverable D3.2

This deliverable is about the feasibility assessment of investments in EE renovation projects in selected SUPER-i pilot countries (Italy, Denmark, and Slovenia). In this comprehensive feasibility assessment, we investigate the current state of energy consumption of the social housing buildings in pilot countries, propose energy efficiency (EE) renovations to improve the energy consumption status, the financial cost of implementing the proposed EE renovations and available funding sources (at EU level and regional level) and the financial solutions with a focus on the Public Private Partnership contracts. Finally, in this deliverable we will investigate the environmental impact of the EE renovations in each pilot country with a focus on CO_2 emission savings.

4. Assessments of social housing provider needs

4.1. Model for energy savings and application to the pilot schemes

In this section, we discuss:

- the current energy efficiency of the SUPER-i project pipeline buildings,
- the effect of the proposed improvements on the energy use, fuel costs and GHG emissions of those buildings (in some cases, more speculative improvements are also assessed), and
- how those were modelled

The savings we calculate are used to inform the remainder of the analysis.

4.1.1. The Super-i energy saving model

A range of retrofits and upgrades is proposed to the buildings across the SUPER-i pipelines. As part of the project, we have developed, tested, and validated a building energy model in Python, which assesses potential savings that might be achieved by the pipeline schemes through their proposed improvements in terms of:

- fuel saved - the kWh of gas not burned, or electricity not used.
- cost - the price of the saved fuel, and
- carbon - the CO_2 emissions avoided[9].

In future, the model may be deployed by other housing associations (HAs) to establish the economic case for renovations to their stock. This model draws on ERM's extensive experience of developing buildings energy models, and has been designed so that that it:

- returns meaningful results given basic information, requiring no technical expertise or training
- can be run for specific years, allowing calibration of the model and assessment of inter-annual variation
- allows calculation of heating and cooling demand using the same architecture.

4.1.1.1. Template Development

Our first step was to determine a minimum dataset needed to model the energy demand for space heating and cooling of a given building, and from that to produce a data template HAs could complete simply, requiring little technical expertise, that would capture sufficient information about their buildings to give meaningful estimates of the space heating demand and - after updating the building fabric in line with a proposed set of improvements - savings. This tool examines only the effect of thermal performance - that is, heating and cooling; appliance savings and those associated with upgrading hot water and cooking appliances are simple for the HAs to calculate themselves. This model draws on Element Energy's deep understanding of energy use in buildings and the real-world impact of energy efficiency and fuel-switching measures.

[9] No monetary value is assigned to the carbon savings, though where policy instruments are predicated on emissions savings this is qualitatively discussed.

4.1.1.2. Methodology

Our model calculates the hourly quantity of heat lost (or, in the case of cooling, gained) per unit temperature difference between the environment and the building. We use a comfort range, by default this is set to between 15.5° and 22°, though we see variation across Europe in thermal comfort expectations) to model the temperature range in which no heating or cooling is required. Ambient air temperature time series data then allow us to determine the total annual heating demand.

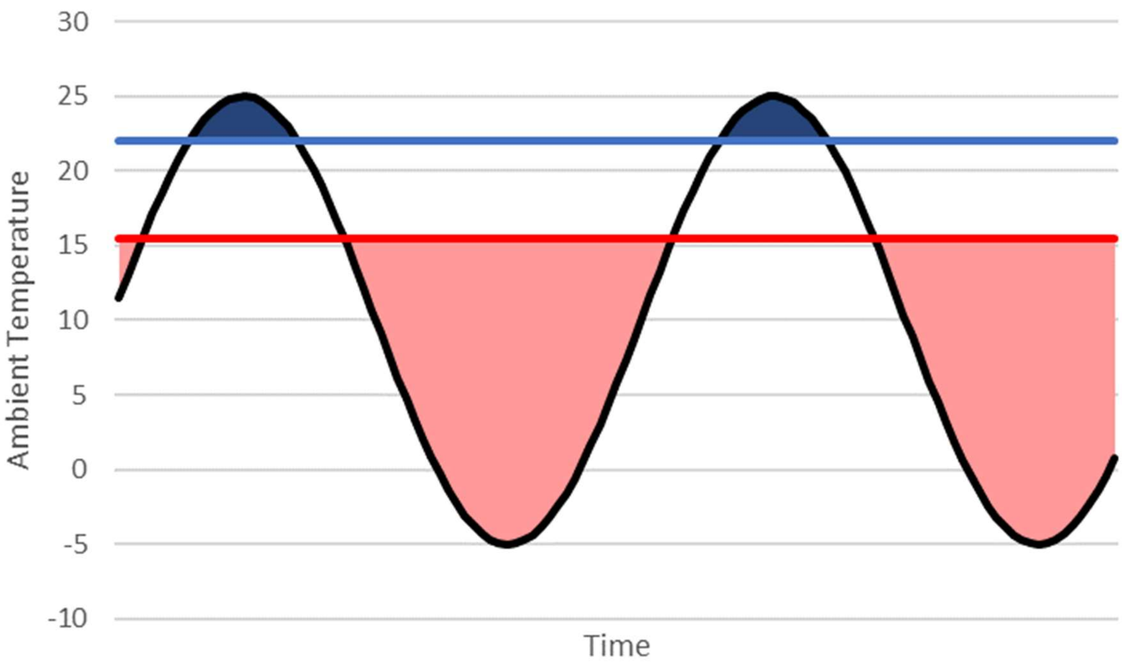

Figure 1. Heating degree and cooling degree days are given by the pink and blue areas respectively

Our model can also account for solar gains; some of the energy in the sunlight which falls on the building will be converted to heat - this varies with the colour and material of the building, for example dark buildings with large windows will experience higher solar gains than light buildings with small windows, and in general we have found it difficult to acquire these data from the HAs.

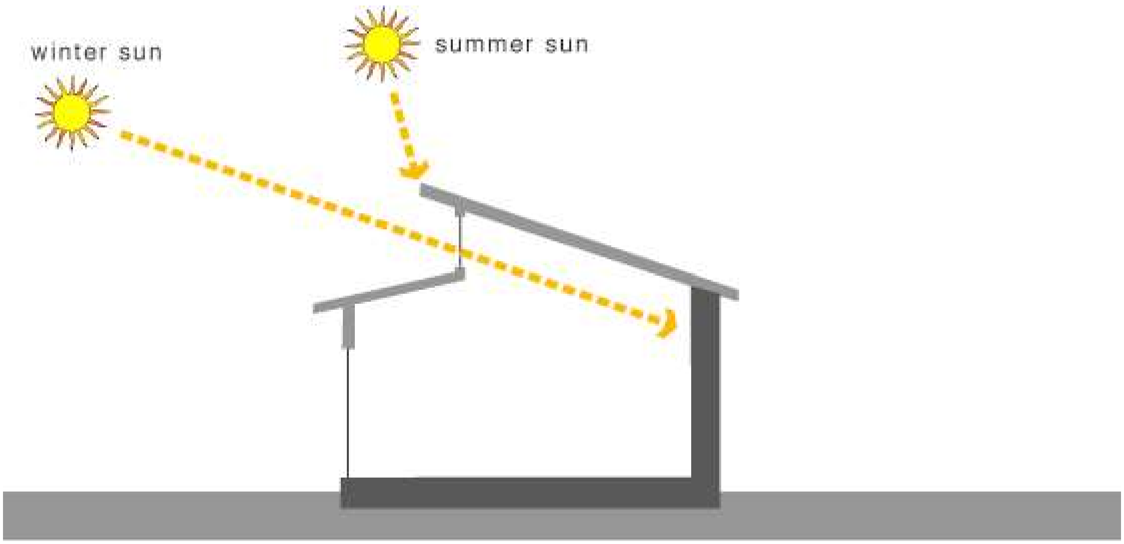

Figure 2. Solar gains are a function of building materials, orientation, geometry and solar position

In concert with the pipelines, we established that a minimum specification that HAs could report that would allow us to complete our calculations comprised:

- the dimensions of the building(s), including roof angle
- the orientation of the building(s)
- the fraction of the building(s) that is glazed (covered in windows)
- the materials of which the walls, floor, roof and windows are made
- the proposed improvements to the building.

In some cases, representative values for each MS can be used where the user cannot establish them, for example, roof angles are typically higher in northern (30-50°) and lower in southern (12-25°) Europe. The possibility of determining the geometry and glazed proportion automatically from photographs has also been investigated, though so far this has not been implemented.

This approach requires an understanding of building material and their U-values - a measure of how much heat flows through a square metre of the building per degree of temperature difference. By summing over the areas and weighting by their U-values we arrive at this expression for the total heat loss (or gain) per unit time for a given ΔT - the difference between the minimum (or maximum) acceptable user temperature.

$$\Theta_{building} = U_{walls}A_{walls} + U_{windows}A_{windows} + U_{floor}A_{floor} + U_{roof}A_{roof}$$
$$\Delta Q = \Theta_{building} \cdot \Delta T$$

So, for example if the exterior temperature is 10°C, $\Delta T = 15.5 - 10 - 5.5$°C, if the ambient temperature is 28°C, $\Delta T = 28 - 22 = 6$°C, and we see some cooling demand. For ambient temperature in the comfort range, ΔT: = 0.

The annual energy demand for space heating S (or cooling C is then given by)

$$S := \sum_{year} \Delta Q$$

Our model makes use of representative U-values taken from the CIBSE materials tables in the Domestic Heating Design guide 2020-21 to convert between the qualitative descriptions provided by the pipelines and the quantitative U-values for each component. For the pipelines this mapping was done manually, in the next tool iteration users will perform it automatically from a drop-down list.

	U-value (W/m² K)
Windows with wood or PVC-U frames	
Single	4.8
Double	2.8
Double, low-E glass	2.3
Double, low-E glass, argon filled	2.1
Triple	2.1
Triple, low-E glass	1.7
Triple, low-E glass, argon filled	1.6
Windows with metal frames	
Single	5.7
Double	3.4
Double, low-E glass	2.8
Double, low-E glass, argon filled	2.6
Triple	2.6
Triple, low-E glass	2.1
Triple, low-E glass, argon filled	2.0
Doors	
Solid wooden door	3.0
Wooden door with 25% single glazing	3.7
Wooden door with 50% single glazing	4.4
Wooden door with 25% double glazing	2.9
Wooden door with 50% double glazing	2.8

Figure 3. CIBSE Data Tables: Representative U-values for Windows[10]

Users who have a more technical understanding of their building's thermal performance, for example from EPC certification, can include that data and return a more bespoke estimate of their potential energy savings.

We can also calculate the associated carbon emissions and fuel cost - once users specify how heat is provided to their buildings, we can adjust for efficiency[11] and calculate:

- the cost of the heating fuel that is saved for their market
- the carbon emissions avoided through more efficient heating.

As our temperature data are temporally resolved we can calculate these values where they change over the year; for example, the price and carbon intensity of grid electricity will vary during the course of the day and year, as the generation mix changes. Where buildings are electrically heated (or cooled) we

[10] CIBSE - Domestic Heating Design Guide, 2020-21

[11] E.g. Modern gas boilers are typically around 85-90% efficient, with some heat lost to the exhaust.

multiply the hourly power price and emissions intensity with our savings to come up with a representative annual figure. Longer term cost and emissions savings will require projected prices for all fuels and may also need future grid CO_2 emissions intensity values where electrical heating and/or cooling are included in the projected savings.

4.1.1.3. Model Operation

Our model was developed in Python; the core functionality comprises 3 data classes, **BuildingGeometry**, **Location** and **Building** - the latter instantiating the former 2 metaclasses. The **BuildingGeometry** class takes as arguments the data provided by the HAs in their templates, and once instantiated uses these to calculate:

- The total areas of the walls, floor, window and roof
- the heat loss/gain per degree external temperature difference, $\Theta_{building}$ (as above) the main class method

The class also contains a validation method, which checks the data are in a plausible range avoiding unit confusion or spurious use cases.

The **Location** class takes as argument either a string, for example "Trieste" from which the latitude and longitude can be calculated using the positionstack API, or the latitude and longitude values themselves (this allows the model users to engage with the model without understanding these values). Once the location is specified, we can query the LARC API for the hourly dry bulb temperature and insolation at that location.

The **Building** dataclass then inherits the functionality from these 2 classes; the inputs define **BuildingGeometry** and a **Location** object, as well as the heating technology for the building. The get_timeseries_outputs class method then implements the calculations described above, querying the hourly heating and cooling demands, multiplying these by the time resolved fuel cost and emissions values[12], and returning the time resolved energy demand, fuel cost and associated emissions. These are then summed in the main class method **get_annual_outputs**.

The class also automates the SUPER-i savings analysis; for a given building the user can pass a list of proposed improvements, the calculate_investment_saving method then returns the energy, cost and emissions saving associated with the individual and combined improvements.

The class also includes a method to calculate the PV yield from the **Location**'s insolation data from a specified year or an indicate long term average; this allows an indicative assessment of the benefit of fitting PV to the roof - shading of the roof by trees and other structures, and the load bearing capacity of the roof are not considered.

4.1.1.4. Validation

The methodology described above produces an estimate of heating and cooling demands unadjusted for the occupancy patterns of the units in the building and the heating system control arrangements - heating may not be required in uninhabited units. Time-resolved data on occupancy were not generally available for the project pipelines but could be proxied by comparing the model estimates with real energy use

[12] In fact, as all participant schemes were gas or DH scheme heated, their unit cost and carbon intensity of heat did not vary of the course of the year, but where electrical heating such as heat pumps are used this would become relevant.

data. Only very basic heating, and no cooling, data were available from the pipelines, some in average total energy use per m², others referred to in EPC assessments. Using these data, we have validated our heating estimates against those produced by our model. In the case of energy bills, we have used the weather data from the specific time period the energy use data are taken from; for EPC data we have used a long term average. In some cases in Denmark, energy use data were available only on a aggregate per-m² basis; here we have assumed 65% of the energy used is for space heating.

The coefficient c, given by $\frac{Real\ Space\ Heating}{Modelled\ Space\ Heating}$ accounts for how much heating demand is not required due to occupancy patterns; in the Danish case, where the best energy data were available, this value is around 0.55. In order to time-resolve this parameter, we scale a typical occupancy pattern so the area under the curve gives this value, below.

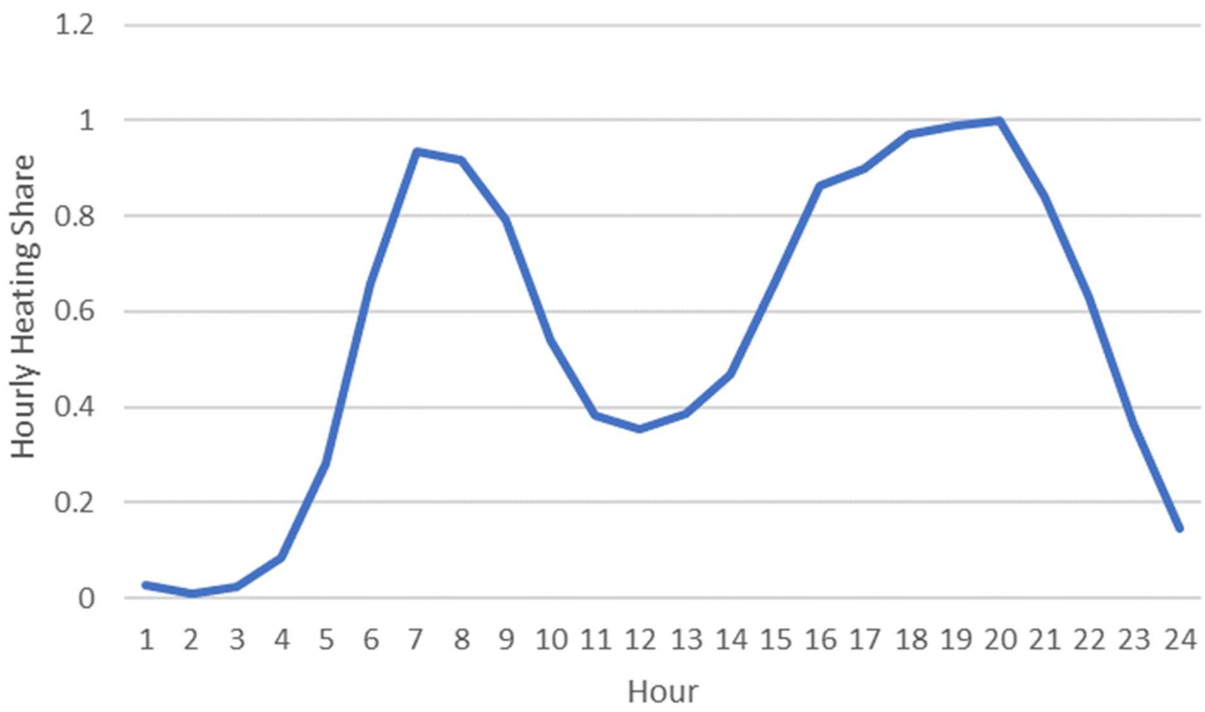

Figure 4: Model Occupancy Profile, based on Danish pipeline data.

Given the lack of available data, we use this value in the Italy and Slovenia pipelines buildings - better unit occupancy data would allow improvement of the model calibration.

4.1.1.5. Summary

We have developed a template and web form which captures the data needed to model annual heating and/or cooling demand for a building in a given location, and the savings that may be achieved through energy efficiency improvements. The included data are summarised below.

PARAMETER	Use in model	How Assessed
Hourly weather data time series	This allows us to calculate the difference between the external	Users' latitude and longitude are looked up from their city name,

	temperature and comfort range in the building's location. Other parameters are also relevant, e.g. insolation data allows us to calculate solar gains.	and their weather data are read from the LARC API.
Building Thermal Performance	Determines the heat loss (or gain) per degree of external temperature difference.	Users provide basic information on the dimensions, geometry, and material composition of their buildings. We map the latter onto a set of U-values using CIBSE data, and sum over the buildings walls, roof, floor and windows to find the total heat loss/gain value.
Fuel use, cost, and carbon emissions	Allows us to calculate market specific cost and CO_2 emissions associated with heating and cooling.	Users report their heating and cooling technologies. We adjust fuel use for efficiency using typical efficiency values, and then parse the (potentially time-variable) cost and carbon intensity of the fuel.

By running the model for the building as currently constituted, and with the set of proposed upgrades, we arrive at "before" and "after" annual heat and cooling values, and so can calculate the fuel, cost and CO_2 savings of a set of energy efficiency improvements. We can run the model for a subset of, or individual, improvements, allowing users to suggest a portfolio of upgrades, and then select only the most impactful. Given data on the cost of the improvements, users can also calculate secondary information, such as payback periods or return on investment.

4.1.2. Application to pilots

How the data provided by the pipelines were converted to model inputs is described below. In addition to these, we gathered time series weather data from the LARC API, and indicative fuel cost data are described in subsection 4.3.4 below.

4.1.2.1. Weather Data

The weather data used in our analysis are obtained from the National Aeronautics and Space Administration (NASA) Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) Project funded through the NASA Earth Science/Applied Science Program.

> These data include long-term climatologically averaged estimates of meteorological quantities and surface solar energy fluxes. Additionally, mean daily values of the base meteorological and solar data are provided in time series format. These satellite and model-based products have been shown to be sufficiently accurate to provide reliable solar and meteorological resource data over regions where surface measurements are sparse or non-existent. The products offer two unique features: the data is global and generally contiguous in time.[13]

[13] https://power.larc.nasa.gov/docs/methodology/

These features allow the model to be run for any location, and to validate real user energy space heating for a given time period against contemporaneous climatic data. Hourly temperature, dew point and insolation data are downloaded through an API, the request generator is built into our Python model. Human readable data can be downloaded through the viewer here https://power.larc.nasa.gov/data-access-viewer/.

4.1.2.2. Italy

The Italian pipeline comprises two building complexes in Trieste; a set of 8 blocks built in 1951 (Boito 5), and a set of 20 towers, grouped into 3 developments comprising a total of 251 units (Montasio 31). Due to its age Boito includes very few energy saving measures; it is built over a concrete and brick floor 16 cm deep (U values of around 1.4 W/m^2) and comprises a stone basement and four floors built of hollow brick and covered by a simple hipped tiled roof. The windows are single-glazed wood frames with high transmittance (U-values of around 3.6Wm-2). It is due to be comprehensively rebuilt, with the new building expected to use only half of the previous heating demand each year. The data template completed by the SUPER--i partners is shown below.

Building Name	Total floor area (m2)	# dwellings per building	EPC rating	storeys	Ground Floor area (m2)	Storey height (m)	Building height (m)	Building depth (m)	Building width (m)	Roof Area (m2)	N façade glazing fraction (%)	E façade glazing fraction (%)	S façade glazing fraction (%)	W façade glazing fraction (%)	N facing façade area (m2)	E facing façade area (m2)	S facing façade area (m2)	W facing façade area (m2)
MONTASIO 31	22,888	251	F	8	3,552	2.7	27	350	10	3,552	25%	11%	0	0	5,563	2,520	5171.0	2370.0
BOITO 5	552	16	G	4	150	2.8	15	18	9	150	9%	23%	0	0	111	242	110.4	181.8

Italian Pipeline: Building Geometry

Building Name	Description of Walls	Description of Windows	Description of Roof	Description of Floor	Wall U Value (W/mK)	Window U Value (W/mK)	Roof U Value (W/mK)	Floor U Value (W/mK)
MONTASIO 31	Reinforced concrete frame and infill in brick blocks plastered on the inside and tiled with terracotta tiles on the outside. The thickness of the perimeter wall delimiting the air-conditioned rooms from the outside is 45 cm	Double glazed, aluminium frames	pitched and the attic is not heated.	concrete and masonry	1.68	2.55	1.69	1.25
BOITO 5	Stone in basement, hollow bricks in upper walls	Wood frames	Hipped, tiled	brick and concrete, just 16 cm high	1.34	3.64	1.64	1.34

Italian Pipeline: Building Fabric Description and Associated U-values

Building Name	Heating	Insulation	Windows	Lighting	Generation	New Wall U Value (W/mK)	New Window U Value (W/mK)	New Roof U Value (W/mK)	New Floor U Value (W/mK)
MONTASIO 31	Replacement of centralised heat generators	External wall insulation. Horizontal opaque structures are insulated to delimit the heated volume from the external environment and from the non-heated environments such as cellar rooms, stairwell/atrium, technical rooms with the exception of those with particular classification of resistance to fire. The floors between heated and unheated rooms will be insulated until an average transmittance of approximately 0.45 W / m2K	Replacement of windows delimiting the heated volume. The new windows will be made of materials with high insulating power	The lamps will be low-consumption and the external lighting bodies with low light pollution	Exploitation of renewable energies (photovoltaic panels)	0.45	1.00	0.45	0.45
BOITO 5	Centralised heating and hot water production system using a natural gas condensing boiler; installation of consumption metering system for each housing unit; heating systems with heating elements for each housing unit	The building will be thermally insulated using 100 mm thick insulating panels applied externally to the walls (with a coat type system) and laid on the floor on the mezzanine, in the inter-floors and in the attic with panels of different thickness in relation to the insulation required.	External doors and windows of the housing units will be in aluminium, thermal break type with thermal imaging glass and will be equipped with aluminium shutters with wing or book opening	The lamps will be low-consumption and the external lighting bodies with low light pollution	Installation on the roof of solar panels with relative structures and flow and return circuits	0.45	1.00	0.45	0.45

Italian Pipeline: Improvements and Associated U-values

The buildings at Montasio comprise a reinforced concrete frame and a skin of brick blocks, plastered on the inside and tiled with terracotta tiles on the outside. The perimeter wall delimiting the air-conditioned rooms from the outside is 45 cm thick, using the CIBSE data we estimate a U-value of 1.68 W/m^2, though bridging effects may increase this. The towers are covered with a pitched roof, the space below which is used as an attic and not heated. The floors are made of concrete and brick, and the double-glazed windows are mounted in aluminium frames. The towers are to have their heating plant and windows upgraded, and to have insulation added to all horizontal surfaces (roofs, floors) between the heated parts of the complex and the exterior/unheated parts (attic, cellar etc). Modelling suggests this will improve the thermal performance by up to 40%. These improvements will be funded in part by a national funding scheme that sets minimum thermal performance standards by climatic region; as Trieste is in Zone E - the second coldest - the requirements are relatively high. Both buildings must reach the minimum values presented in Table 1, and to benefit from significant tax deductions must improve beyond the values shown in the third column.

Building element type	Maximum permitted U value (W/m²K)		
	2015	2021[14]	Tax Ded.[15]
Maximum thermal transmittance of vertical opaque structures	0.3	0.28	0.23
Maximum thermal transmittance U of horizontal or inclined opaque structures	0.26	0.24	0.2
Maximum thermal transmittance of horizontal flooring opaque structures	0.31	0.29	0.25
Maximum thermal transmittance of transparent and opaque technical closures and bins. including fixtures. outwards and towards non-air conditioned environments	1.9	1.4	1.3

Table 1 - Values of the characteristic parameters of the building elements in existing buildings subjected to energy redevelopment in Italian E climatic zones.

Further, one of the requirements to access the Superbonus is to present two energy performance certificates (pre-intervention or ante-operam APE and post-intervention or post-operam APE), to certify the improvement of the energy classification. which must be at least two letters.

4.1.2.3. Slovenia

The Slovenian pilot comprises a single 26-unit building in the city of Trbovlje, built in 2006. The proposed improvements involve adding insulation to the exterior walls and roof, which we expect to substantially improve the thermal performance of the building and save around 25% on annual energy bills.

Building Name	Total floor area (m2)	# dwellings per building	EPC rating	# storeys	Ground Floor area (m2)	Storey height (m)	Building height (m)	Building depth (m)	Building width (m)	Roof Area (m2)	N façade glazing fraction (%)	E façade glazing fraction (%)	S façade glazing fraction (%)	W façade glazing fraction (%)	N facing façade area (m2)	E facing façade area (m2)	S facing façade area (m2)	W facing façade area (m2)
Neža 26 a in b	1806	26	F	4	439	4.2	16.7	12.96	33.2	790	20	20	20	20	554.4	216.4	554.4	216.4

Slovenian Pipeline: Building geometry data

Building Name	Description of Walls	Description of Windows	Description of Roof	Description of Floor	Wall U Value (W/mK)	Window U Value (W/mK)	Roof U Value (W/mK)	Floor U Value (W/mK)
Neža 26 a in b	Brick. In the apartments the partitions are brick, thick 10 and 20 cm, and the walls between the flats and towards the corridor are made of brick blocks 38 cm thick or prefabricated structures from gypsum boards 20 cm thick.	PVC, double glazing, good fittings	The construction of the roof over the attic is sloping, the sloping roof is insulated with thermal insulation made of glass wool.	reinforced concrete floor	2.000	1.200	2.000	1.000

Slovenian Pipeline: Building Fabric Description and Associated U-values

[14] MISE. Supplemento ordinario n. 39 alla GAZZETTA UFFICIALE Serie generale - n. 162, Appendix B
[15] Decreto Efficienza Energetica - MEF, Allegato E, Requisiti degli interventi di isolamento termico

Building Name	Insulation	Windows	Lighting	New Wall U Value (W/mK)	New Window U Value (W/mK)	New Roof U Value (W/mK)	New Floor U Value (W/mK)
Neža 26 a in b	insulation on facade and roof	no improvement	no improvements	0.45	1.200	2.000	1.000

Slovenian Pipeline: Improvements and Associated U-values

Building parameters	Current State	Proposed Improvement
Walls	blocks without thermal protection, and has a U-value of 2.0 Wm^{-2}	incorporation of insulation on the exterior of at least 14 cm
Roof	Flat roof without insulation, similar U-value of around 2.0 Wm^{-2}	Glass wool to a thickness of at least 20 cm will be added

Renovation of the windows is not proposed, given their relatively good performance (due to the good fittings of the PVC frame and double glazing) our modelling suggests the return on investment would be low. No changes are proposed to the heating system, which will continue working with individual gas boilers to heat all the flats; but existing units will be replaced with more efficient models. The hot water supply will be switched from gas to smart electrical generation, using 80L thermal storage allowing generation to move to when electricity is cheap, rather than as it is needed. The main national policy driver of retrofit for energy efficiency is the government aim of reducing the share of buildings in the EPC category F and below; the pipeline building already meets this requirement, and there are no additional policies that bear on the performance requirements for the building improvement plan. As the works will be paid for from a fund paid for by a percentage of tenant rents, financing the retrofit places no performance demands to the renovation.

4.1.2.4. Denmark

The Danish pipeline comprises 3 social housing developments, Fruehoejgaard Social Housing Company, Housing Areas Børglumparken and Himmerland Boligforening Social Housing Company. Of the 15 complexes, including 1,831 units, included in the project, only the latter’s Afdeling Søndergade has been built since 1979, though only 20% of the units were built since 1993. Danish building energy performance standards have been higher than most European countries since the mid-70s, so these buildings are warmer than contemporary social housing in other nations. Also, all the developments are served by heat networks, which provide energy for space heating and hot water, and decarbonisation of heat has been achieved by switching these networks from fossil fuels to biomass, without the need to remove or install devices in the blocks or individual units. While well below Denmark’s current building standards, the buildings in the Danish pipeline are reasonably well insulated, summarised in the table below.

Building Parameter	**Value**
EPC Rating	All E or better, and only 4 worse than C
Windows	Double glazed PVC, around 10-15 years old
Walls	All buildings have cavity walls insulated with ~100mm mineral wool

The data template provided by the pipelines is provided below,

The proposed energy efficiency improvements therefore comprise no structural works or external insulation, instead they will replace the windows with more airtight triple glazing in all buildings, and:

- install a heat recovery system at Fruehoejgaard and Housing Areas Børglumparken
- improve the insulation on the heat network pipes at Himmerland Boligforening

Modelling suggests modest improvements (up to 5%) may be achieved through the improvement to the windows; the specifics of the heat network lagging and the heat recovery technology were not available.

4.1.3. Technical Key Performance Indicators (KPI's)

We have developed a simple model to predict space heating demand of a given building before and after retrofit, and worked with the project housing associations to iteratively define a data template they can complete to allow the modelling of their building, and the proposed improvements, see D3.3. This model calculates the time-resolved annual expected demand for space heating given the proportions and thermal performance of the walls, roof, windows, and floor of a building. By altering the insulating properties of the components to be upgraded, we can calculate this demand before and after retrofit. From these, we can calculate:

- an energy saving associated with the retrofit
- the fuel saving, calculated by adjusting the energy saving by the efficiency of the heating system
- the emissions saving, calculated by the emissions intensity associated with the fuel saving.

Defining name	Building Heat Loss per degree temperature difference
Category pillar	Model parameter
Definition	The heat lost to the environment per unit time per degree of temperature difference between the interior and exterior.
Formula	$U_{walls}A_{walls} + U_{windows}A_{windows} + U_{floor}A_{floor} + U_{roof}A_{roof}$ Where U_x is the average U-value of component x, $A_x$is the area of component x
Unit of measurement	kW/K
Data source	Calculated from the data provided by project pipelines
Actions/ Interventions	Used to calculated annual demand for space heat

Monitoring Interval	Detailed monitoring of space heating before retrofit were not available, in some cases it may be possible to obtain energy use data after retrofit

Defining name	Ambient Temperature time series
Category pillar	Model Parameter
Definition	The dry bulb temperature
Unit of measurement	°C, hourly resolution
Data source	LARC API, a reanalysis dataset, drawing on MERRA and
Actions/ Interventions	Used to calculate the annual space heating demand when multiplied by the building heat loss value above for each hour and summed over the year.
Monitoring Interval	Available at a 0.5° x 0.5° resolution, the accuracy of the data is discussed on the NASA website[16], broadly the error associated with the data is expected to be well within the model error. Recorded ambient temperature data were not available for any of the pipelines.

Defining name	**Energy Saving**
Category pillar	Retrofit improvement
Definition	The difference between the demand for space heating before and after retrofit. This is modelled on a time-series basis, though for all Super-I buildings we report the annual saving as none of the associated parameters are time-resolved.

[16] https://power.larc.nasa.gov/docs/methodology/

Formula	$Energysaving = S_{pre-retrofit} - S_{post-retrofit}$ where S is the modelled space heating
Unit of measurement	kWh
Data source	Building data are provided by the households, temperature data taken from the NASA LARC API.
Actions/ Interventions	Weather data Building Geometry Proposed interventions
Monitoring Interval	The model can be validated against pre- and post-retrofit bill data
Target	Varies by pipeline, but we expect savings of around 5% across the Danish portfolio, around 20% in the Slovenian building. Improvements in the building at Boito and difficult to compare, at Montasio we expect improvements of around 25%.
NEB	Technical

Defining name	Fuel Saving
Category pillar	Retrofit improvement
Definition	The difference between the fuel required for space heating before and after retrofit
Formula	$FuelSaving = \frac{EnergySaving}{HeatingSystemEfficiency}$ where $EnergySaving$ is defined above, and

	$HeatingSystemEfficiency = \frac{Useful\ Heat\ Out}{Fuel\ Enthalpy\ In}$
Unit of measurement	kWh
Data source	BEIS dataset on heating efficiency, though only the 85% value for gas boilers has been used in this project
Actions/ Interventions	Energy Saving (from above) Heating System Efficiency
Monitoring Interval	Data on real-world efficiency of the specific heating systems across the Super-i pipelines are not possible to access. However, the precision in boiler efficiencies are not expected to contribute significantly to model uncertainty.
Target	Percentage savings will be very similar to those in the Energy Saving above.
NEB	Technical, Financial

Defining name	Emissions Savings
Category pillar	Retrofit Improvement
Definition	The Emissions Saving is given by the annual GHG whose emission is avoided associated with the Fuel Saving, defined above. The Fuel Saving and the associated emissions can be time resolved, e.g. for electric heating powered by the national grid, though all the Super-I pipeline buildings are heated by gas boilers.
Formula	$EmissionsSaving = FuelSaving \cdot AssociatedEmissions$

Unit of measurement	Tonnes CO_2
Data source	Emissions intensity of gas taken from BEIS data. National grid time series emission data are available in some member states, in others only average values are published.
Actions/ Interventions	Fuel Saving from above Fuel emissions intensity
Monitoring Interval	Gas emissions intensity is not expected to vary much in the coming years, uptake of biomethane or hydrogen blending could make small differences across member states. Grid emissions are expected to come down across the EU, but do not affect any of the proposed improvements.
Target	Percentage savings will be very similar to those in the Energy Saving above.
NEB	Technical, Environmental

Defining name	Modelled PV Yield
Category pillar	Retrofit Improvement
Definition	The expected load factor for a PV panel, facing south on the building roof. No accounting for shading is applied.
Unit of measurement	% (load factor)
Data source	We use the renewables ninja API, https://www.renewables.ninja/. This uses the same datasets as the LARC APIs, giving data on the cloud adjusted insolation on an hourly basis.

Actions/ Interventions	Allows users to assess the potential benefit and payback period of installing
Monitoring Interval	Gas emissions intensity is not expected to vary much in the coming years, uptake of biomethane or hydrogen blending could make small differences across member states. Grid emissions are expected to come down across the EU, but do not affect any of the proposed improvements.
Target	Load factors of above 12% can indicate a viable project, depending on the market, though more detailed analysis will be required.
NEB	Technical, Environmental, Financial

5. Financial Analysis

5.1. Financial Key Performance Indicators (KPI's)

This section discusses the identified financial Key Performance Indicators (KPIs) that measures the impact of SUPER-i 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:

- Financial Profitability and cost reduction
- Funding sources
- Energy Poverty

5.1.1. Financial profitability and cost reduction

Defining name	Return on Investment (ROI)
Category pillar	Financial Profitability and cost reduction
Definition	This KPI evaluates the financial returns generated from investing in the proposed SUPER-i EE renovations to the social housing association.
Formula	$ROI = \frac{\sum_{t=1}^{T} \frac{total\ revenue_t}{(1+WACC)^t} - \sum_{t=1}^{T} \frac{total\ cost_t}{(1+WACC)^t}}{Investment\ cost}$
Unit of measurement	Percentage %
Data source	LSEG https://www.lseg.com/en/data-analytics SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● 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 • Total energy savings including CO2 emissions • Tax rate • Inflation rate • interest rate on debt • market value of buildings growth rate • WACC
Monitoring Interval	• Beginning of SUPER-i project • Halfway/ during the SUPER-i project • End of SUPER-i project
Target	Higher than the benchmark SP500 (8.14%)
NEB	Economic/Financial

Defining name	Net Present Value
Category pillar	Financial Profitability and cost reduction
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
Formula	$NPV = \sum_{t=0}^{T} \frac{in\ cashflow_t - out\ cashflow_t}{(1+WACC)^t}$
Unit of measurement	Monetary value in EUR
Data source	financial datasets (LSEG https://www.lseg.com/en/data-analytics)

	SUPER-i Survey
Actions/ Interventions	Improvements to: • Energy use • Fuel cost • GHG emission
Variable / Parameter	• 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 • Total energy savings including CO2 emissions • Tax rate • Inflation rate • interest rate on debt • market value of buildings growth rate • WACC
Monitoring Interval	• Beginning of SUPER-i project • Halfway/ during the SUPER-i project • End of SUPER-i project
Target	Positive NPV higher than that of SP500 (Changes on a yearly basis)
NEB	Economic

Defining name	Payback Period
Category pillar	Financial Profitability and cost reduction
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 takes into account several factors such as energy market price and project scope.
Formula	$$Payback\ period\ = \frac{initial\ investment\ cost}{annual\ net\ cash\ flows}$$
Unit of measurement	Number of years
Data source	LSEG https://www.lseg.com/en/data-analytics SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● 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 ● Total energy savings including CO2 emissions ● Tax rate ● Inflation rate ● interest rate on debt ● market value of buildings growth rate
Monitoring Interval	● Beginning of SUPER-i project ● Halfway/ during the SUPER-i project ● End of SUPER-i project
Target	Depending on the building and size of the renovations (4-10) years
NEB	Economic

Defining name	Operating cost reduction (OCR)
Category pillar	Financial Profitability and cost reduction
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.
Formula	$OCR = Annual\ O\&M_{before\ EE} - Expected\ annual\ O\&M_{after\ EE}$
Unit of measurement	Monetary value in EUR
Data source	LSEG https://www.lseg.com/en/data-analytics SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● Operating and maintenance costs of installed EE technologies ● Operating and maintenance cost of the building ● private owners ratio ● Inflation rate ● interest rate on debt
Monitoring Interval	● Beginning of SUPER-i project ● Halfway/ during the SUPER-i project ● End of SUPER-i project
Target	25% reduction
NEB	Economic

Defining name	Increase in property value (IPV)
Category pillar	Financial Profitability and cost reduction
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.
Formula	$IPV = \frac{Expected\ market\ value\ of\ building\ -\ Current\ market\ value\ of\ building}{Current\ market\ value\ of\ building} * 100\%$
Unit of measurement	%
Data source	SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● market value of the building ● property appraisals, market analyses to quantify the expected market value of the building after EE renovations.
Monitoring Interval	● Beginning of SUPER-i project ● Halfway/ during the SUPER-i project ● End of SUPER-i project
Target	at least 5% increase in property market value
NEB	Economic

5.1.2. Funding sources

Defining name	Cumulative investments made by European stakeholders in EE project in the social housing sector
Category pillar	Funding sources
Definition	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.
Formula	$$Cumulative\ investment = \sum_{t=1}^{T} Total\ investment_t$$
Unit of measurement	Monetary value in EUR
Data source	financial datasets LSEG https://www.lseg.com/en/data-analytics SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● Current annual investment in Energy efficiency projects in social housing ● Annual total investment in Energy efficiency projects in social housing for the past 10 years
Monitoring Interval	● Beginning of SUPER-i project ● Halfway/ during the SUPER-i project ● End of SUPER-i project
Target	10% increase per year
NEB	Economic

Defining name	Optimal leverage ratio
Category pillar	Funding sources
Definition	The optimal leverage ratio, as a Key Performance Indicator (KPI) for energy efficiency renovation projects in social housing buildings, refers to the ideal proportion of debt financing relative to equity financing that maximises the project's financial performance while ensuring long-term sustainability and risk management. In the context of social housing energy efficiency projects, the optimal leverage ratio serves as a metric to assess the balance between leveraging borrowed funds to finance renovations and minimising financial risk.
Formula	Using the WACC method we obtain Optimal Leverage Ratio as the leverage ratio that minimises the WACC, where the WACC is given by $$WACC = ((1 - LR) * R_E) + (LR * R_D * (1 - T_c))$$ Where $Leverage\ ratio(LR) = \frac{Debt}{Equity+Deb}$ R_E is the cost of equity, which is the minimum return from the project that the social housing company is willing to accept. R_D is the cost of debt which is proxied by the inflation adjusted interest rate (real interest rate). T_c is the corporate tax rate.
Unit of measurement	%
Data source	financial datasets LSEG https://www.lseg.com/en/data-analytics SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● Inflation rate ● Interest rate on debt ● Internal rate of return (Proxy for the cost of equity) ● Corporate tax rate

	• Investment cost
Monitoring Interval	• Beginning of SUPER-i project • Halfway/ during the SUPER-i project • End of SUPER-i project
Target	Higher than 70%
NEB	Economic

Defining name	*Number of available innovative funding sources*
Category pillar	Funding sources
Definition	This KPI measures the quantity of funding contracts specifically designed for energy-efficient renovation projects in social housing.
Unit of measurement	List/ Count
Data source	Publicly available information from government official websites SUPER-i Survey
Actions/ Interventions	Improvements to: • Energy use • Fuel cost • GHG emission
Variable / Parameter	• Current available funding sources to energy efficiency renovations in social housing • Planned funding sources • Innovative funding sources
Monitoring Interval	• Beginning of SUPER-i project • Halfway/ during the SUPER-i project • End of SUPER-i project

Target	Improve probability of acquiring external funding sources
NEB	Economic

Defining name	*Capital investment attraction (CIA)*
Category pillar	Funding sources
Definition	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.
Formula	$CIA = \frac{current\ year\ external\ capital\ raised\ for\ energy\ efficiency\ renovation}{Total\ external\ capital\ raised\ for\ energy\ efficiency\ projects\ for\ the\ past\ 10\ years}$
Unit of measurement	Percentage
Data source	SUPER-i Survey to partners
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● External capital raised for energy efficiency renovations
Monitoring Interval	● Beginning of SUPER-i project ● Halfway/ during the SUPER-i project ● End of SUPER-i project
Target	10% increase in attractiveness of Energy Efficiency renovations in social housing
NEB	Economic

5.1.3. Energy Poverty

Defining name	Energy cost savings (ECS)
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.
Formula	$ECS = Previous\ Energy\ costs - Energy\ costs\ after\ EE\ renovations$
Unit of measurement	Monetary value in EUR
Data source	financial datasets (LSEG https://www.lseg.com/en/data-analytics SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	● The CO2 emission savings ● Savings in electricity consumption ● Savings in heat consumption ● Market price of electricity ● market price of CO2 emission per tonne ● Heating demand ● North, east, west and south facade glazing fraction ● North, east, west and south facing facade area ● Wall U value ● Window U value ● Roof U value ● Floor U value ● ground floor area ● number of storeys ● storey height ● building height ● building width ● roof area

Monitoring Interval	• Beginning of SUPER-i project • Halfway/ during the SUPER-i project • End of SUPER-i project
Target	20% increase in energy savings
NEB	Economic

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
Formula	$Energy\ expenditure\ as\ a\ percentage\ of\ income\ = \frac{average\ energy\ expenditure}{average\ \ income} * 100\%$
Unit of measurement	%
Data source	SUPER-i Survey
Actions/ Interventions	Improvements to: • Energy use • Fuel cost • GHG emission
Variable / Parameter	Average energy expenditure per household if available or building Average income per household in the building.
Monitoring Interval	• Beginning of SUPER-i project • Halfway/ during the SUPER-i project • End of SUPER-i project
Target	20% decrease

NEB	Economic

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.
Formula	$\boldsymbol{Energy\ consumption\ per\ Sqm} = \frac{Total\ energy\ consumption}{Total\ renovated\ floor\ area}$
Unit of measurement	KWh/m2
Data source	SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	Total energy consumption: which is the Sum of energy consumed by households in social housing including heating, cooling, lighting, and other relevant energy consumption Total floor area of the building
Monitoring Interval	● Beginning of SUPER-i project ● Halfway/ during the SUPER-i project ● End of SUPER-i project
Target	15% decrease
NEB	Economic

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 in the SUPER-i pilot countries.
Formula	$\boldsymbol{Total\ arrears\ on\ Utility\ bills} = \frac{\boldsymbol{Total\ arrears\ on\ utility\ bills}}{\boldsymbol{Total\ Number\ of\ households\ in\ building}}$
Unit of measurement	Monetary value in EUR
Data source	SUPER-i Survey
Actions/ Interventions	Improvements to: ● Energy use ● Fuel cost ● GHG emission
Variable / Parameter	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 building. Total number of households in the building: The total count of residential units within the social housing building
Monitoring Interval	● Beginning of SUPER-i project ● Halfway/ during the SUPER-i project ● End of SUPER-i project
Target	20% decrease
NEB	Economic

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 SUPER-i pilot countries.
Formula	$\boldsymbol{disconnection\ rate = \frac{Number\ of\ households\ with\ energy\ disconnections}{Total\ number\ of\ households\ in\ the\ building} * 100\%}$
Unit of measurement	%
Data source	SUPER-i Survey
Actions/ Interventions	Improvements to: • Energy use • Fuel cost • GHG emission
Variable / Parameter	Number of households with energy disconnections Total number of households in the building
Monitoring Interval	• Beginning of SUPER-i project • Halfway/ during the SUPER-i project • End of SUPER-i project
Target	30% decrease
NEB	Economic

5.2. SUPER-i pilots Financial information

Following the financial data collection process with participation from the social housing associations in Italy, Denmark and Slovenia, we observe that social housing buildings in Italy and Slovenia require extensive energy efficiency refurbishments to improve the current energy consumption costs and the comfort level for the tenants due to the old age of the buildings and the state of installed energy technologies unlike the energy efficiency situation on Denmark. In this section we will outline the financial cost required to install the proposed EE renovations for each social housing building.

5.2.1. Italy

The Italian pilot consists of two social housing buildings (Montasio and Boito) in the region of Trieste managed by ATER Trieste. According to the performed initial analysis on the energy consumption of the buildings, Montasio requires extensive energy efficiency renovations while Boito requires a reconstruction of the whole building due to old age. In the case of Montasio, implementing the extensive energy efficiency renovations to the building will require an investment of 3,379,000 EUR. This investment cost was measured taking into account the corporate tax rate of 9.5% and inflation rate of 7%, however it does not include the interest rate on debt, which is the cost of getting a loan from a financial institution. Hence, in our analysis we consider the investment cost to be 3,547,950.00 EUR to include the cost of debt at 5% interest rate. To raise the required funds the social housing company, ATER, will cover 64% of the total investment cost while the other 36% will be covered by the current private owners who own part of the dwellings in the Montasio building. According to the currently collected monthly rent taking into account default in rents and vacant dwellings, ATER-Trieste collects 714,000 EUR annually and spends 428,135 EUR on operating and maintaining the building. Also, once the EE renovations are completed the rent is expected to rise to 742,560 EUR annually taking into account the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease significantly compared to maintaining the current EE technologies which will reduce the total costs of operating and maintaining the building to ATER-Trieste. Furthermore, we estimate a reduction of 13,337.00 EUR annually in energy consumption costs for residents in Montasio. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 10 years. In the case of Boito, due to the dire condition of the building's foundation, it was decided that the building will be demolished and then reconstructed using the latest EE technologies. The total investment costs for Boito are estimated to be 1,598,000 EUR taking into account the impact of corporate tax and inflation rate and the construction period to be 2 years. When the interest rate on debt is considered the investment cost increases to 1,677,900 EUR. The total investment cost will be covered entirely by ATER-Trieste as the building is fully owned by the social housing company. The expected annual rent to be collected after completing the renovations and the energy consumption savings to be 125,310 EUR per year, and the cost of maintaining and operating the new Boito building to be 30,326 EUR per year. Therefore, the expected payback period is expected to be 17 years. The reason behind the much higher payback period for Boito compared to Montasio is due to the higher costs per metre squared due to the demolition and construction costs. The table below shows a summary of the data collected from ATER-Trieste in regards to the EE renovation costs and building revenues for Montasio and Boito.

Building Name	Montasio 31		
ownership of the building	Total	Social housing	private ownership
Percentage of ownership	100%	64%	36%
Year	1976	1976	1976
Initial date of the refurbishment	2023	2023	2023
Lifetime	30	30	30
Payback period	15	15	15
Number of years	1	1	1
Building cost	€3,379,000	€2,162,560	€1,216,440
Total Investment Costs	€3,379,000	€2,162,560	€1,216,440
Maintenance costs	€111,920	€71,629	€40,291
Depreciation rate	3%	3%	3%
walls	2%	2%	2%
windows	2.86%	2.86%	2.86%
generators	5%	5%	5%
Operating costs	€307,711	€196,935	€110,776
Other costs	€11,295	€7,229	€4,066
Total Operating costs and other costs	€428,135	€274,006	€154,129
Interest expenses	5%	5%	5%
Other expenses	€84,336	€53,975	€30,361
Total Expenses	€84,336	€53,975	€30,361
Operating revenues	€444,000	€284,160	€159,840
Energy savings	€13,378	€8,562	€4,816
Tax rate	9.50%	9.50%	9.50%
Inflation rate	7%	7%	7%
Bank interest rate (lending)	5.00%	5.00%	5.00%
Other revenues	€206,000	€131,840	€74,160
Other income	€64,000	€40,960	€23,040
Increase in rent due to EE renovation	€742,560	€475,238	€267,322
Total Operating revenues and incomes	€727,378	€465,522	€261,856
Equity	100%	64%	36.00%
Growth rate	4%	4%	4%
Market value of building	€1,100,000	€704,000	€396,000
Private savings	100%	64%	36%
Rent increase	4%	4%	4%
default rate	3.20%	3.20%	3.20%
Number of residents	500	320	180
residents average income	€13,000	€13,000	€13,000

Table 2: Key financial information for Social housing building - Montasio 31

	Building Name	Boito Social housing
General information	Percentage of ownership	100%
	Year	1951
	Initial date of the refurbishment	2023
	Lifetime	30
	Payback period	35
	Number of years	2
Investments information	Building cost	€1,598,000
	Total Investment Costs	€1,598,000
Variable and fixed costs information	Maintenance costs	€20,390
	Depreciation rate	2%
	walls	2%
	windows	2%
	generators	2%
	Operating costs	€3,840
	Other costs	€720
	Total Operating costs and other costs	€24,950
	Interest expenses	5%
	Other expenses	€5,376
	Total Expenses	€5,376
Variable and fixed income information	Operating revenues	€27,500
	Energy savings	€80,520
	Tax rate	9.50%
	Inflation rate	7%
	Discount rate (WACC)	9%
	Central bank interest rate(lending)	2.15%
	Other revenues	€10,790
	Other income	€6,500
	Total Operating revenues and incomes	€125,310
Capital information	Equity	100%
	Growth rate	3%
	Market value of building	€650,000
Financing and funding sources information	National grants	100%
	Private savings	0%
Rent and residents related information	Rent increase	4%
	default rate	9%
	residents average income	€9,360

Table 3: Key financial information for social housing building - Boito

5.2.1.1. Financial Gap

The table below provides a detailed comparison of the investment needs and available funding for energy efficiency renovation projects in Italy. On one side, we see the specific areas where investment is required, including public buildings, district heating, waste, water management, and sustainable mobility, totalling EUR 60.5 billion. These areas cover a wide spectrum of infrastructure improvements necessary to enhance energy efficiency across various sectors. For instance, upgrading public buildings can reduce energy consumption, while investments in sustainable mobility can lead to more eco-friendly transportation systems. On the other side, we have a breakdown of the available funding, which includes contributions from both the EU and national levels. Notably, the EU demonstrates a significant commitment, with funds such as the Cohesion Fund and Next Generation EU amounting to EUR 33.6 billion. At the national level, various funds, and allocations, including the Italian Energy Efficiency Fund and the Italian National Recovery and Resilience Plan, contribute to a total of EUR 25.4 billion. However, despite the substantial funding, there remains a slight shortfall of EUR 0.97 billion, highlighting the need for strategic planning and collaboration to bridge any remaining gaps and ensure optimal resource utilisation.

	Summary of investment needs - Italy	
		Required investments
Energy efficency renovations and circular economoy	Energy efficiency in public buildings	15.3 billion
	Energy efficiency and renewable energy in districts	EUR 11.2 billion
	Sustainable mobility	EUR 34 billion
	Total investment needs	**EUR 60.5 billion**
	Summary of available funding - Italy	
	available fund	**Budget**
EU level	Cohesion fund	8.7 billion
	Next GenerationEU	24.9 billion
National level	Italian Energy Efficiency fund	175 million
	Invitalia	310 million
	Emilia-Romagna Eenrgy Fund	47 million
	Italian National Recovery and Resilience Plan	25.4 billion
	Total available funds	**EUR 59.53 Billion**

Table 4: Summary of currently available budget and investment needs for Italy

5.2.2. Slovenia

The Slovenian pilot consists of one social housing building, the Neza 26 in the region of Ljubljana managed by HFROS. According to the performed initial analysis on the energy consumption of the building, Neza 26 requires extensive energy efficiency renovations due to old age and current state of the energy efficiency installed measures. Implementing the extensive energy efficiency renovations to the building will require an investment of 200,000 EUR. This investment cost was measured considering the corporate tax rate of 9.5% and inflation rate of 7%, however it does not include the interest rate on debt, which is the cost of getting a loan from a financial institution. Hence, in our analysis we consider the investment cost to be 208,000 EUR to include the cost of debt at 5% interest rate. To raise the required funds the social housing company, HFROS, will cover 20% of the total investment cost using government grants and 80% using funding institutions. According to the currently collected monthly rent considering default in rents and vacant dwellings, HFROS collects 31,327.45 EUR annually and spends 21,200 EUR on operating and maintaining costs of the building. Also, once the EE renovations are completed the rent is expected to rise by 4.7% to 32,799.84 EUR annually taking into account the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease significantly compared to the cost of maintaining the current EE technologies which will reduce the total costs of operating and maintaining the building to HFROS. Furthermore, we estimate a reduction of 1940.45 EUR annually in energy consumption costs for residents in Neza 26. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 10 years.

	Building Name	Neža 26 a in b
General information	Ownership of the building	Social Housing
	Prercentage of ownership of property	100%
	Year	2005
	Initial date of the refurbishment	2023
	Lifetime	30
	Payback period	20
	Number of years	2
Investments information	Building cost	€190,000
	Start-up and other costs	€10,000
	Total Investment Costs	€200,000
Variable and fixed costs information	Maintenance costs	€6,800
	Depreciation rate	2%
	Operating costs	€14,400
	Total Operating costs and other costs	€21,200
	Other expenses	€2,400
	Total Expenses	€23,600
Variable and fixed income information	Operating revenues	€21,600
	Energy savings	€1,940
	Tax rate	9.50%
	Inflation rate	7%
	Discount rate (WACC)	8.99%
	Central bank interest rate(lending)	1.90%
	Other revenues	€7,787
	Total Operating revenues and incomes	€31,327
	Growth rate	13%
	Market value of building	€1,757,319
Financing and funding sources	Debt	80%
	National grants	20%
Rent and residents related information	Rent increase	0.50%
	default rate	8%
	Number of residents	72

Table 5: Key financial information for social housing building - Neza 26 a-b

5.2.3. Denmark

The Danish pilot consists of 6 social housing buildings, Borgumparken, Afdeling, Vaevergaarden, Stoorgarden, Hammerthor, and Frisenburgparken managed by BL. According to the performed initial analysis on the energy consumption of the buildings, the social housing buildings do not require extensive energy efficiency renovations as the current state of the energy efficiency installed measures have been recently refurbished. In the case of **Borlgumparken**, implementing the planned energy efficiency renovations will require an investment of 5,930,023 DKK. To raise the required funds the social housing company, BL, will cover 28% of the total investment cost using private savings and the rest 72% using funding institutions. According to the currently collected monthly rent considering default in rents and vacant dwellings, BL collects 5,719,502.00 DKK annually and spends 5,565,126.00 DKK on operating and maintaining costs of the building. Also, once the EE renovations are completed the rent is expected to rise by 5% increasing the collected annual rent to 6,005,477.10 DKK annually taking into account the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease but not as significantly as in the case of Italy and Slovenia. Furthermore, we estimate a reduction of 154,376 DKK annually in energy consumption costs for residents in Borlgumparken. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 38 years. The table below summarises the data collected for Borgumparken.

	Building Name	Borlgumparken	
	ownership of the properties	DKK	EUR
	percentage of ownership of proper	100%	100%
	Year	1986	1986
	Initial date of the refurbishment	2023	2023
	Lifetime	30	30
	Payback period	32	32
General information	Number of years	1	1
	Total Investment Costs	€5,930,023	€770,903
	Maintenance costs	€1,452,000	€188,760
	Depreciation rate	3%	3%
	walls	3%	3%
	windows	3.33%	3.33%
	generators	4%	4%
	Operating costs	€2,013,725	€261,784
	Other costs	€2,099,401	€272,922
Variable and fixed costs	Total Operating costs and other co	€5,565,126	€723,466
information	Interest expenses	5.10%	5.10%
	Operating revenues	€5,546,514	€721,047
	Energy savings	€154,376	€20,069
	Tax rate	22%	22%
	Inflation rate	6%	6%
	Discount rate (WACC)	7%	7%
	Central bank interest rate(lending)	2.43%	2.43%
	Other revenues	9353	€1,215.89
	Interest income	9259	€1,203.67
Variable and fixed income	Other income	0	0
information	Total Operating revenues and inco	€5,719,502	€743,535
	Equity	100%	
	Growth rate	4%	4%
Capital information	Debt	€84,524,010	€10,988,121
	Loans from financial institutions	72%	€555,050
	Private savings	28%	€215,853
	Rent increase	5%	5%
Rent and residents related	default rate	1.20%	1.20%
information	Vacant	2%	2%

Table 6: Key financial information for social housing building - Borlgumparken

In the case of **Vaevergaarden**, implementing the planned energy efficiency renovations will require an investment of 2,246,678.00 DKK. To raise the required funds the social housing company, BL, will cover 39% of the total investment cost using private savings and the rest 61% using funding institutions.

According to the currently collected monthly rent considering default in rents and vacant dwellings, BL collects 2,066,529.00 DKK annually and spends 1,946,167.00 DKK on operating and maintaining costs of the building. Also, once the EE renovations are completed the rent is expected to rise by 5% increasing the collected annual rent to 2,290,217.45 DKK annually considering the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease but not as significantly as in the case of Italy and Slovenia. Furthermore, we estimate a reduction of 120,362 DKK annually in energy consumption costs for residents in Vaevergaarden. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 12 years. The table below summarises the data collected for Vaevergaarden.

	Building Name	Vaevergaarden	
	ownership of the properties	DKK	EUR
	Percentage of ownership	100%	100%
	Year	1985	1985
	Initial date of the refurbishment	2023	2023
	Lifetime	30	30
	Payback period	41	41
General information	Number of years	1	1
	Total Investment Costs	€2,246,678	€292,068
	Maintenance costs	€326,000	€42,380
	Depreciation rate	3%	3%
	walls	3%	3%
	windows	3.33%	3.33%
	generators	4%	4%
	Operating costs	€296,012	€38,482
	Other costs	€1,324,155	€172,140
Variable and fixed costs information	Total Operating costs and other co	€1,946,167	€253,002
	Interest expenses	5.10%	5.10%
	Operating revenues	€1,925,304	€250,290
	Energy savings	€120,362	€15,647
	Tax rate	22%	22%
	Inflation rate	6%	6%
	Discount rate (WACC)	7%	7%
	Central bank interest rate(lending)	2.43%	2.43%
	Other revenues	€16,971	€2,206
	Interest income	€3,892	€506
Variable and fixed income information	Other income	0	0
	Total Operating revenues and inco	€2,066,529	€268,649
	Equity	100%	100%
	Growth rate	4%	4%
Capital information	Debt	€22,750,362	€2,957,547
Financing and funding sources information	Loans from financial institutions	61%	€178,162
	Private savings	39%	€113,907
	Rent increase	5%	5%
Rent and residents related information	default rate	1.20%	1.20%
	Vacant	2%	2%

Table 7: Key financial information for social housing building - Vaevergarden

In the case of **Afdeling Sondergade**, implementing the planned energy efficiency renovations will require an investment of 2,848,475.00 DKK. To raise the required funds the social housing company, BL, will cover 74% of the total investment cost using private savings and the rest 26% using funding institutions. According to the currently collected monthly rent considering default in rents and vacant dwellings, BL collects 1,650,077.00 DKK annually and spends 999,346.00 DKK on operating and maintaining costs of the building. Also, once the EE renovations are completed the rent is expected to rise by 5% increasing the collected annual rent to 1,732,580.85 DKK annually taking into account the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease but not as significantly as in the case of Italy and Slovenia. Furthermore, we estimate a reduction of 185,629 DKK annually in energy consumption costs for residents in Afdeling. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 14 years. The table below summarises the data collected for Afedling Sondergade.

	Building Name	Afdeling	
	ownership of the properties	DKK	EUR
	Percentage of ownership	100%	-%
	Year	1917	1917
	Initial date of the refurbishment	2024	2024
	Lifetime	30	30
	Payback period	24	24
General information	Number of years	1	1
	Total Investment Costs	€2,848,475	€370,302
	Maintenance costs	€316,000	€41,080
	Depreciation rate	3%	3%
	walls	3%	3%
	windows	3.33%	3.33%
	generators	4%	4%
	Operating costs	€183,673	€23,877
	Other costs	€499,673	€64,957
Variable and fixed costs information	Total Operating costs and other co	€999,346	€129,915
	Interest expenses	5.10%	5.10%
	Operating revenues	€1,419,109	€184,484
	Energy savings	€185,629	€24,132
	Tax rate	22%	22%
	Inflation rate	6%	6%
	Discount rate (WACC)	7%	7%
	Central bank interest rate(lending)	2.43%	2.43%
	Other revenues	€40,785	€5,302
	Interest income	€4,554	€592
Variable and fixed income information	Other income	0.00	€0.00
	Total Operating revenues and inco	€1,650,077	€214,510
	Equity	100%	100%
Capital information	Growth rate	4%	4%
	Debt	€13,463,754	€1,750,288
Funding Source	Loans from financial institutions	72%	€266,617
	Private savings	28%	€103,684
	Rent increase	5%	5%
Rent and residents related information	default rate	1.20%	1.20%
	Vacant	2%	2%

Table 8: Key financial information for social housing building - Afdeling

In the case of **Storgaarden**, implementing the planned energy efficiency renovations will require an investment of 4,874,888.00 DKK. To raise the required funds the social housing company, BL, will cover 74% of the total investment cost using private savings and the rest 26% using funding institutions. According to the currently collected monthly rent considering default in rents and vacant dwellings, BL collects 2,374,667.00 DKK annually and spends 1,554,494.00 DKK on operating and maintaining costs of the building. Also, once the EE renovations are completed the rent is expected to rise by 5% increasing the collected annual rent to 2,493,400.35 DKK annually considering the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease but not as significantly as in the case of Italy and Slovenia. Furthermore, we estimate a reduction of 218,955 DKK annually in energy consumption costs for residents in Afdeling. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 9 years. The table below summarises the data collected for Storgaarden.

	Building Name	Storgaarden	
General information	Currency	DKK	EUR
	Percentage of ownership	100%	100%
	Year	1993	1993
	Initial date of the refurbishment	2023	2023
	Lifetime	30	30
	Payback period	22	22
	Number of years	1	1
Variable and fixed costs information	Total Investment Costs	€4,874,888	€633,735
	Maintenance costs	€461,000	€59,930
	Depreciation rate	3%	3%
	walls	3%	3%
	windows	3.33%	3.33%
	generators	4%	4%
	Operating costs	€316,247	€41,112
	Other costs	€777,247	€101,042
	Total Operating costs and other co	€1,554,494	€202,084
	Interest expenses	5.10%	5.10%
Variable and fixed income information	Operating revenues	€2,366,532	€307,649
	Energy savings	€218,955	€28,464
	Tax rate	22%	22%
	Inflation rate	6%	6%
	Discount rate (WACC)	7%	7%
	Central bank interest rate(lending)	2.43%	2.43%
	Other revenues	€4,000	€520
	Interest income	€4,135	€538
	Other income	€0	€0
	Total Operating revenues and inco	€2,374,667	€308,707
Capital information	Equity	100%	100%
	Growth rate	4%	4%
	Debt	€36,450,542	€4,738,570
Financing and funding sources information	Loans from financial institutions	26%	€164,771
	Private savings	74%	€468,964
Rent and residents related information	Rent increase	5%	5%
	default rate	1.20%	1.20%
	Vacant	2%	2%

Table 9: Key financial information for social housing building - Storgaarden

In the case of **Hammerthor,** implementing the planned energy efficiency renovations will require an investment of 313,840.00 DKK. To raise the required funds the social housing company, BL, will cover 100% of the total investment cost using funding institutions. According to the currently collected monthly rent considering default in rents and vacant dwellings, BL collects 2,292,434.00 DKK annually and spends 1,128,517.00 DKK on operating and maintaining costs of the building. Also, once the EE renovations are completed the rent is expected to rise by 5% increasing the collected annual rent to 2,407,055.70 DKK annually considering the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease but not as significantly as in the case of Italy and Slovenia. Furthermore, we estimate a reduction of 65,957 DKK annually in energy consumption costs for residents in Hammerthor. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 1 year. The table below summarises the data collected for Hammerthor.

	Building Name	Hammerthor	
General information	ownership of the properties	DKK	EUR
	Percentage of ownership	100%	100%
	Year	2003	2003
	Initial date of the refurbishment	2023	2023
	Lifetime	30	30
	Payback period	24	24
	Number of years	1	1
Variable and fixed costs information	Total Investment Costs	€313,840	€40,799
	Maintenance costs	€225,274	€29,286
	Depreciation rate	3%	3%
	walls	3%	3%
	windows	3.33%	3.33%
	generators	4%	4%
	Operating costs	€494,711	€64,312
	Other costs	€408,532	€53,109
	Total Operating costs and other cos	€1,128,517	€146,707
	Interest expenses	5.10%	5.10%
Variable and fixed income information	Operating revenues	€2,289,492	€297,634
	Energy savings	€65,957	€8,574
	Tax rate	22%	22%
	Inflation rate	6%	6%
	Discount rate (WACC)	7%	7%
	Central bank interest rate(lending)	2.43%	2.43%
	Other revenues	0.00	€0.00
	Interest income	2,942.00	€382.46
	Other income	0.00	€0.00
	Total Operating revenues and incon	€2,358,391	€306,591
Capital information	Equity	100%	100%
	Growth rate	4%	4%
Funding sources	Loans from financial institutions	100%	100%
	Private savings	0%	0%
Rent and residents related information	Rent increase	5%	5%
	default rate	1.20%	1.20%
	Vacant	2%	2%

Table 10: Key financial information for social housing building - Hammerthor

In the case of **Frisenborgparken**, implementing the planned energy efficiency renovations will require an investment of 2,125,638.00 DKK. To raise the required funds the social housing company, BL, will cover 72% of the total investment cost using funding institutions and the rest 28% from private savings. According to the currently collected monthly rent considering default in rents and vacant dwellings, BL collects 1,006,329.00 DKK annually and spends 1,061,740 DKK on operating and maintaining costs of the building. Also, once the EE renovations are completed the rent is expected to rise by 5% increasing the collected annual rent to 1,056,645.45 DKK annually taking into account the impact of the discount factor, and the costs for operating and maintaining the EE renovations will decrease but not as significantly as in the case of Italy and Slovenia. Furthermore, we estimate a reduction of 30,695 DKK annually in energy consumption costs for residents in Frisenborgparken. Based on these collected data and considering the impact of time on the value of money and inflation rate we estimate the payback period of recovering the investment costs for implementing the proposed EE renovations to be 43 years. The table below summarises the data collected for Frisenborgparken.

	Building Name	Frisenborgparken	
General information	ownership of the properties	DKK	EUR
	Percentage of ownership	100%	100%
	Year	1989	1989
	Initial date of the refurbishment	2023	2023
	Lifetime	30	30
	Payback period	69	69
	Number of years	1	1
Variable and fixed costs information	Total Investment Costs	€2,125,638	€276,333
	Maintenance costs	€176,350	€22,926
	Depreciation rate	3%	3%
	walls	3%	3%
	windows	3.33%	3.33%
	generators	4%	4%
	Operating costs	€354,520	€46,088
	Other costs	€530,870	€69,013
	Total Operating costs and other cos	€1,061,740	€138,026
	Interest expenses	5.10%	5.10%
Variable and fixed income information	Operating revenues	€1,003,716	€130,483
	Energy savings	€30,695	€3,990
	Tax rate	22%	22%
	Inflation rate	6%	6%
	Discount rate (WACC)	7%	7%
	Central bank interest rate(lending)	2.43%	2.43%
	Other revenues	0.00	0
	Interest income	€2,613	€340
	Other income	€118,891	€9,145
	Total Operating revenues and incon	€1,037,024	€134,813
Capital information	Equity	100%	100%
	Growth rate	4%	4%
	Debt	€17,005,661	€2,210,736
	Loans from financial institutions	28%	€77,373
	Private savings	72%	€198,960
Rent and residents related information	Rent increase	5%	5%
	default rate	1.20%	1.20%
	Vacant	2%	2%

Table 11: Key financial information for social housing building - Frisenbourgparken

5.2.3.1. Financial Gap

The table below offers a brief description of Denmark's investment needs and the sources of funding available for energy efficiency projects. The breakdown of these investment requirements highlights three principal domains: energy efficiency renovations in affordable public housing, the integration of energy efficiency alongside renewable energy in district settings, and energy efficiency renovations in other sectors to meet the NECP objectives set by the EU amounting to a total of EUR 21.77 billion. This detailed categorization underscores Denmark's commitment to advancing energy efficiency and sustainability objectives, aligning with both national goals and those articulated in the National Energy and Climate Plans (NECP). Regarding financial support, a blend of contributions from the European Union (EU) and domestic sources is evident. At the EU level, funds from initiatives such as Next Generation EU and the EU Regional Development Fund total EUR 2.238 billion, reflecting substantial backing from European institutions for Denmark's energy efficiency endeavours. Meanwhile, domestically, Denmark has mobilised significant resources through various avenues. Contributions from entities like the National Building Fund, Denmark Government Grants, and Denmark Green Future Fund collectively amount to EUR 19.3 billion, showcasing the nation's robust commitment to investing in energy efficiency and sustainability on the domestic front. Nevertheless, despite the substantial pool of available funds, a shortfall of EUR 2.47 billion remains in comparison to the total investment requirements. This disparity underscores the importance of strategic planning and resource allocation to ensure optimal utilisation of available funds. Moreover, it emphasises the ongoing necessity for collaborative engagement between EU and national-level stakeholders to address any remaining gaps and maximise the impact of investments. In conclusion, the tables offer a comprehensive overview of Denmark's endeavours to advance energy efficiency and sustainability. They underscore the significant investment requirements and proactive measures undertaken at both EU and national levels to tackle these challenges. Going forward, effective coordination and prudent allocation of resources will be essential to unlock the full potential of energy efficiency initiatives and realise Denmark's environmental and climate objectives.

	Summary of investment needs - Denmark	
		Required investments
Energy efficency renovations and circular economoy	Energy efficiency in public buildings	EUR 2.68 billion
	Energy efficiency and renewable energy in districts	EUR 4.0 billion
	Other EE projects to meet NECP objectives	EUR 13.27 billion
	Total investment needs	**EUR 21.77 billion**
	Summary of available funding - Denmark	
	available fund	**Budget**
EU level	Next GenerationEU	EUR 1.43 billion
	EU Regional and development fund	EUR 808 million
National level	National building fund	EUR 5.5 billion
	Denmark government grants	EUR 10.5 billion
	Denmark Green future fund	EUR 3.3 billion
	Total available funds	**EUR 19.3 Billion**

Table 12: Summary of currently available budget and investment needs for Denmark

5.3. Energy Price Data

In order to perform the proposed evaluation methodology to investigate the financial impact of implementing the SUPER-i proposed EE renovations, we simulate natural gas price for the coming 25 years considering three scenarios (Worst case scenario (high natural gas price), neutral scenario (stable natural gas price) and best-case scenario (low natural gas price)). The adopted simulation methodology in the SUPER-i project is based on the Monte Carlo simulation approach using the GARCH-MIDAS model of Engle et al. (2013). This model allows us to model high frequency datasets (daily) using macro and micro economic variables that are observed at a lower frequency (Monthly, Quarterly, semi-annually, etc). The SUPER-i Simulation method is applied as follow:

Step 1: We obtain daily natural gas prices for the last 25 years (1/1/1999-31/01/2024).
Step 2: We obtain monthly inflation rate, Economic uncertainty index, and Global production of natural gas index for the same period (01/1999 - 01-2024).
Step 3: We model the natural gas price using the GARCH-MIDAS model, and the macroeconomic indicators as independent variables in the GARCH-MIDAS model.
Step 4: Using the obtained GARCH-MIDAS model that fits the natural gas prices for the period (1999-2024) we perform an out of sample analysis to obtain the estimated future natural gas price for the period (2024-2048).
Step 5: we take the average of simulated future natural gas prices for the period (2024-2048).
Step 6: we repeat steps 3-5 three times:

- **Worst case Scenario**: we consider that the inflation rate, economic policy uncertainty are increasing rapidly by inducing a high multiplier for the periods where the global economy was in crisis such as (the Enron crisis, the middle east conflicts, the Financial crisis, COVID-19, and the recent energy crisis in the EU).
- **Neutral case Scenario:** we consider that the inflation rate and economic policy uncertainty are stable by inducing an equal multiplier for the economic distress periods and economic boom periods.
- **Best case Scenario:** we consider that the inflation rate and economic policy uncertainty are stable and decreasing on average for the next 25 years by inducing a higher multiplier for the periods where the global economy was booming or experiencing an increasing growth rate.

  The graph below shows the annual average of simulated natural gas price for the period (2024-2047), and the average for the overall period. From the graph below, we observe that considering the natural gas future price (32.0583 EUR/MWh) for the next 25 years in the neutral case is very comparable with the natural gas forward price (Natural Gas EU Dutch TTF (EUR/MWh)) for year 2045 (31.818 EUR/MWh)

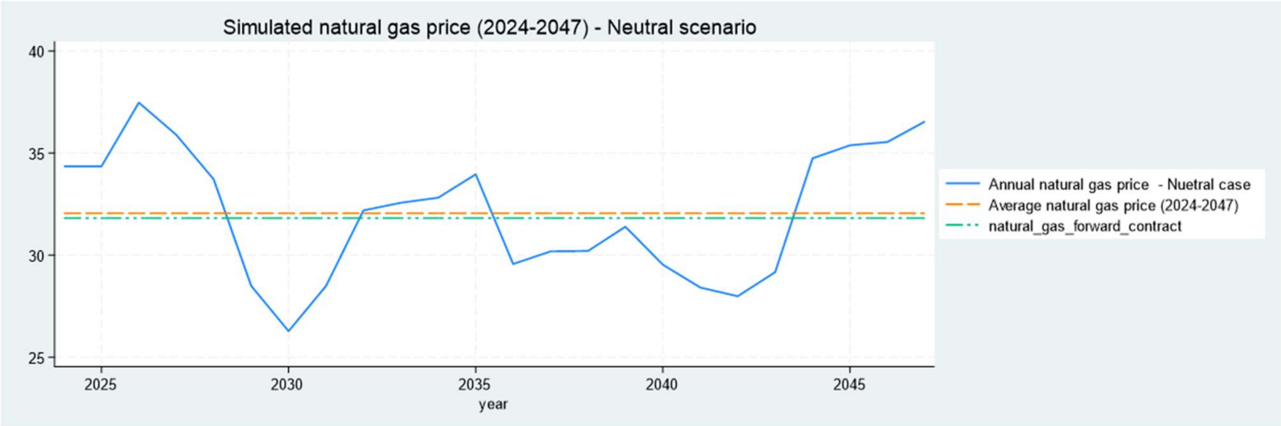

Figure 5: Simulated annual natural gas price for the period (2024-2047) - Neutral Scenario

The graph below shows the simulated natural gas price under the worst-case scenario.

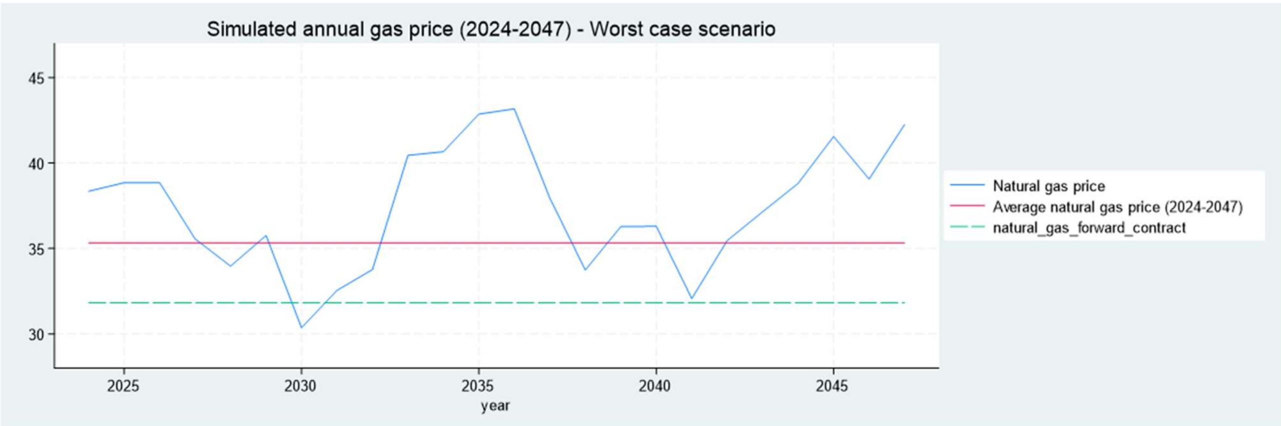

Figure 6: Simulated annual natural gas price for the period (2024-2047) - Worst case Scenario.

The graph below presents the simulated natural gas price under the best-case scenario.

Figure 7: Simulated annual natural gas price for the period (2024-2047) - Best case Scenario

5.4. Energy poverty

In Italy, the percentage of individuals facing challenges in adequately heating their homes in winter and cooling them in summer in Italy fluctuates between 17% and 44% over the period 2011-2020. While there has been a decline from 36.1% in 2011 to 17% in 2021, this reduction is insufficient compared to the lower overall percentage of such individuals in the European Union. This underscores the imperative for energy efficiency enhancements in existing buildings in Italy. The percentage of people experiencing arrears on utility bills in Italy has decreased from 11.9% in 2013 to 4.5% in 2019. However, the percentage of individuals at risk of poverty and social exclusion, although on a declining trend, remains relatively high, ranging from 24.6% to 28.5%. Concerning the material and social deprivation rate among social housing tenants in Italy, it surpasses that of other SUPER-I countries. Additionally, the percentage of low-income social housing tenants living in substandard conditions, such as dwellings with leaking roofs or damp walls, decreased from 30.1% in 2013 to 16.4% in 2019, only to rise again to 24.5%, potentially linked to the economic impact of COVID-19. Lastly, social housing residents in Italy grapple with overcrowding issues, with an overcrowding rate among owners with mortgages and tenants with subsidised rent remaining consistently high at 30%, surpassing that of the European Union.

In Denmark, the percentage of the population facing challenges in adequately heating their homes in winter or cooling them in summer falls between 6.6% and 10.9%. This range is the most favourable when compared to other countries and the European Union as a whole. Additionally, Denmark boasts the lowest rates of arrears on utility bills, nearly half of that observed in the European Union. Moreover, individuals residing in social housing in Denmark exhibit a lower likelihood of experiencing poverty or social exclusion. According to EUROSTAT, both property owners with outstanding mortgages or housing loans and tenants paying subsidised rent or residing rent-free in Denmark face lower rates of material and social deprivation compared to their counterparts in EU countries. For low-income social housing tenants in Denmark living in substandard conditions, such as dwellings with leaking roofs or damp walls, the percentage ranges between 14.9% and 16.8%, a relatively low figure compared to other SUPER-i pilot countries. Denmark's housing cost overburden rate falls between 3.9% and 7.5%, ranking the second lowest after Italy. Furthermore, the overcrowding rate in Denmark ranges from 3.5% to 4.9%, standing as the lowest among all the compared countries.

In Slovenia, the percentage of individuals unable to adequately heat their homes in winter or cool them in summer in Slovenia falls between 8.2% and 12.4%. Like Italy, Slovenia has witnessed a notable decrease in this percentage, dropping from 17.3% in 2011 to 12.9% in 2020. Despite a significant reduction in arrears on utility bills during this period, Slovenia experiences a higher percentage of such arrears compared to the European Union as a whole. On a positive note, the share of social housing tenants at risk of poverty or social exclusion in Slovenia is the lowest among the pilot countries, even below the European Union average. Furthermore, the percentage of low-income individuals residing in substandard conditions, such as dwellings with leaking roofs or damp walls, has decreased from 34.7% in 2011 to 20.8% in 2020. Unlike Italy and Denmark, Slovenia's low-income population was not adversely affected by sudden increases in inflation rates or the impact of COVID-19 on the housing sector. Additionally, the housing cost overburden rate for owners with mortgages and tenants paying subsidised rent in Slovenia has decreased from 10.5% in 2011 to 4.4% in 2020. However, like Italy, social housing residents in Slovenia face challenges related to overcrowding, with rates ranging from 12.4% to 8.3% (owners with mortgages) and 20.4% to 16.4% (tenants with subsidised rent) from 2011 to 2020. These rates are comparatively higher than those in other SUPER-i countries for social housing residents.

5.5. Available funding sources to social housing EE renovation projects

5.5.1. EU level

Cohesion Fund[17]: The Cohesion Fund of the European Union is designed to diminish economic and social disparities among EU member countries and encourage sustainable development. This fund lends support to environmentally beneficial energy projects, such as those aimed at reducing greenhouse gas emissions, increasing the utilisation of renewable energy, or enhancing energy efficiency. A portion of the Cohesion Fund is dedicated to implementing the energy union strategy in collaboration with the Energy and Managing Authorities Network (EMA).

Connecting Europe Facility:[18] The Connecting Europe Facility (CEF) serves as the EU's financial instrument for enhancing energy, transportation, and digital infrastructure. Renewed for the period 2021-2027 with a budget of €42.3 billion, CEF supports investments in EU infrastructure networks for energy (€8.7 billion), transport (€30.6 billion), and digital (€3 billion). The program, representing a 47% increase compared to 2014-2020, facilitates the application of funding for projects of common interest (PCIs) through a biennial call for proposals.

European Investment Bank and the European Fund for Strategic Investments: The European Investment Bank (EIB) plays a pivotal role in financing energy projects by offering companies loans and other financial instruments. In collaboration with the European Commission, the EIB launched the European Investment Advisory Hub, an entity providing advice and expertise on administration and project development across the EU. The European Fund for Strategic Investments (EFSI), a joint initiative with the European Investment Fund and the Commission, aims to mobilise private investment in strategically vital EU projects, particularly in energy efficiency, renewable energy, power grids, and interconnectors.

InvestEU[19]: The InvestEU Programme consolidates the European Fund for Strategic Investments and 13 other EU financial instruments to support sustainable investment, innovation, and job creation in Europe. With the aim of triggering over €372 billion in additional investment from 2021-2027, the program brings together various financial tools.

Just Transition Mechanism[20]: The Just Transition Mechanism serves as a financial tool offering targeted support to vulnerable regions heavily dependent on coal during the transition to a greener economy. Over the period 2021-2027, it is expected to mobilise at least €150 billion, distributed across three pillars: the Just Transition Fund (€40 billion in grants), a dedicated scheme under InvestEU to attract private investments, and a public sector loan facility with the EIB Group to leverage additional investments.

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17 https://ec.europa.eu/regional_policy/2021-2027_en

18 https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/connecting-europe-facility_en

19 https://investeu.europa.eu/index_en

20 https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/programme-performance-statements/just-transition-mechanism-performance_en

LIFE: Clean Energy Transition:[21] A subprogram of the LIFE Programme, the Clean Energy Transition initiative allocates close to €1 billion (2021-2027) to support sustainable energy policies aligned with the European Green Deal objectives. Managed by CINEA, the sub-program focuses on coordinating and supporting actions across Europe to transition towards an energy-efficient, renewable energy-based, and resilient economy.

Modernisation Fund:[22] The Modernisation Fund addresses the investment needs of ten lower-income EU countries, supporting projects in renewable energy, energy efficiency, energy storage, modernization of energy networks, and just transition in carbon-dependent regions. The fund, with potential revenues of around €14 billion (2021-2030), involves the European Investment Bank (EIB) in auctioning EU allowances, assessing proposed investments, and managing resources.

Recovery and Resilience Facility:[23] As the primary instrument of NextGenerationEU, the Recovery and Resilience Facility (RRF) supports Europe in emerging stronger from the COVID-19 pandemic. Structured around six pillars, the RRF targets green transition, digital transformation, economic cohesion, productivity, competitiveness, social and territorial cohesion, and health, economic, social, and institutional resilience.

The Innovation Fund:[24] Managed by the European Climate, Infrastructure, and Environment Executive Agency (CINEA), the Innovation Fund aims to incentivize investment in cutting-edge low-carbon and net-zero technologies. With an estimated revenue of €40 billion (2020-2030) from the EU Emissions Trading System, it supports projects in energy-intensive industries, carbon capture storage and utilisation, renewable energy, and energy storage.

[21] https://cinea.ec.europa.eu/programmes/life/clean-energy-transition_en

[22] https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/modernisation-fund_en

[23] https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility_en

[24] https://cinea.ec.europa.eu/programmes/innovation-fund_en

Summary table fo funding solutions availablefor EE renovation projects			
Name	**objective**	**Budget**	**Period**
Cohesion fund	Support to environmentally beneficial energy projects, such as those aimed at reducing greenhouse gas emissions, increasing the utilisation of renewable energy, or enhancing energy efficiency	**373 billion EUR**	**2020-2030**
Connecting Europe Facility	serves as the EU's financial instrument for enhancing energy, transportation, and digital infrastructure	**42.3 billion EUR**	**2021-2027**
EIB & the European Fund for Startegic Investments	The European Fund for Strategic Investments (EFSI), a joint initiative with the European Investment Fund and the Commission, aims to mobilise private investment in strategically vital EU projects, particularly in energy efficiency, renewable energy, power grids, and interconnectors.	**550 billion EUR**	**2015-**
InvestEU	Support sustainable investment, innovation, and job creation in Europe.	**372 billion EUR**	**2021-2027**
Just Transition Mechanism	Financial tool offering targeted support to vulnerable regions heavily dependent on coal during the transition to a greener economy.	**150 billion EUR**	**2021-2027**
Modernesation Fund	Addresses the investment needs of ten lower-income EU countries, supporting projects in renewable energy, energy efficiency, energy storage, modernization of energy networks, and just transition in carbon-dependent regions.	**14 billion EUR**	**2021-2030**
Recovery and Reseliance Facility	Structured around six pillars, the RRF targets green transition, digital transformation, economic cohesion, productivity, competitiveness, social and territorial cohesion, and health, economic, social, and institutional resilience.	**249 billion EUR**	**2021-2027**
The Innovation Fund	to incentivize investment in cutting-edge low-carbon and net-zero technologies	**40 billion EUR**	**2020-2030**
Total		**1790.3 billion EUR**	

Table 13: Summary of the main European funding sources for the EE renovation projects.

5.5.2. SUPER-i pilot country

In this section, we list the available funding sources to meet the investment demands for the implementation of energy efficiency renovations accessible to social housing associations for each of the SUPER-i pilot countries.

5.5.2.1. Denmark

In the case of Denmark, several funding sources are available such as:

The National Building Fund (NBF)[25]: The NBF operates as an autonomous entity with its dedicated board. This fund comprises substantial resources, constituting approximately 15% to 20% of the housing stock in Denmark, contributing to its financial pool. Its investment activities are subject to legal regulations. During the financial crisis, the NBF played a crucial role in stimulating the Danish economy by facilitating increased renovation activities. This approach funnelled additional resources into the construction

[25] https://single-market-economy.ec.europa.eu/system/files/2021-03/ecso_pfs_dk_nbf_2019_0.pdf

industry, leading to the creation of more jobs and, consequently, fostering economic growth. As the original construction loans are paid off, housing departments or organisations continue their payments initially to the state and subsequently to The National Building Fund. The fund is structured into distinct components, namely the Revolving Renovation Fund (RRF), the housing organisation's own disposition fund, and a fund designated for new construction. The RRF within the NBF serves a specific and well-defined purpose, yet tenants also have the option to directly initiate renovations for their homes.

Energy Saving Obligations (ESO):[26] Denmark has implemented Energy Saving Obligations that require energy companies to achieve energy savings targets. Funding and incentives may be available for energy efficiency measures, including those in social housing.

Energispareordningen (Energy Saving Scheme):[27] The Energy Saving Scheme is a subsidy program that provides financial support for energy-saving initiatives, including those related to social housing. The scheme is administered by the Danish Energy Agency.

Danish Energy Agency (DEA) Grants:[28] The Danish Energy Agency offers various grants and support programs to promote energy efficiency and renewable energy projects, including those targeting social housing.

Energistyrelsen (The Danish Energy Agency) Programs:[29] The Danish Energy Agency may administer specific programs or initiatives aimed at promoting energy efficiency in buildings, including social housing. Check their website or contact them directly for information on available programs.

Local Municipality Programs:[30] Some municipalities in Denmark may have their own programs and grants to encourage energy efficiency measures in social housing. Contact the local municipality housing department for information on available funding.

EU Funding Programs[31]**:** Depending on the specific nature of the project, there may be opportunities to access funding from European Union programs dedicated to energy efficiency or social housing. Explore EU funding programs that align with the goals of your renovation project.

Green Finance Initiatives[32]**:** Denmark has been active in promoting green finance and sustainable investment. Explore financing options from banks and financial institutions that prioritise green and energy-efficient projects.

Energy Service Companies (ESCOs): ESCOs in Denmark may offer energy performance contracts or financing solutions for social housing energy efficiency projects. These companies often provide turnkey solutions and may share the cost savings with the building owner.

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26 https://www.iea.org/policies/1115-danish-energy-efficiency-obligation

27 https://sparenergi.dk/

28 https://ens.dk/sites/ens.dk/files/Tilskud/application_guide_2022.pdf

29 https://ens.dk/en

30 https://energy.ec.europa.eu/system/files/2019-08/sei_forums_copenhagen_nr2_proceedings_en_final_0.pdf

31 https://climate.ec.europa.eu/eu-action/eu-funding-climate-action_en

32 https://www.greenfinanceplatform.org/country/denmark

Private Foundations and NGOs: Some private foundations and non-governmental organisations (NGOs) in Denmark may support energy efficiency initiatives. Explore partnerships and funding opportunities with relevant organisations.

5.5.2.2. Italy

Italy has various funding sources and support mechanisms for social housing energy efficiency (EE) renovation projects. Here are some potential funding sources for social housing EE renovation projects in Italy:

National Energy Efficiency Fund (FEE):[33] Italy has a National Energy Efficiency Fund (FEE) that supports energy efficiency initiatives, including those in the housing sector. The FEE may provide grants, incentives, and financing for social housing EE renovations. For example, in Sicily, with the support of the Region and ENEA, the Municipality of Marsala (managed by the social housing company located in the city of Trapani) has implemented an energy efficiency programme for 80 social housing dwellings using Public-Private Partnerships. This EE programme has the goal to upgrade the heating and hot water systems while improving the building insulation and installing solar PVs. The project has been developed in line with the Minimum Requirements Decree: it is expected to generate energy savings of around 80% compared to the existing situation, allowing the building to achieve nZEB classification. The planned interventions are eligible for the Conto Termico incentive scheme.

Conto Termico:[34] Conto Termico is an Italian government incentive program that provides financial support for energy efficiency and renewable energy projects. It includes incentives for measures such as building renovations, heating system upgrades, and insulation improvements in social housing.

Superbonus:[35] is a new financial measure which supports structural energy efficiency refurbishment of buildings via a tax deduction at a rate of 110%. The EE measures include thermal insulation of facades and/or roofs (such as external cladding) and replacing heating systems, in combination with the installation of photovoltaic systems or micro-cogeneration systems. Beneficiaries of the Superbonus can also carry out additional energy efficiency measures on their building (such as replacing windows and doors or installing a home automation system). The Superbonus allows the beneficiary to transfer the tax credit to a third party so that energy retrofitting can be implemented also when the owner cannot afford the initial investment.

National Housing Plan (Piano Nazionale Casa):[36] Italy's National Housing Plan may include provisions and funding for social housing renovations, including energy efficiency measures. This plan may be administered at the national or regional level.

Green New Deal - Italy's Recovery and Resilience Plan[37]**:** Italy's Recovery and Resilience Plan, part of the Green New Deal, allocates funds to support sustainable development and green initiatives. Some of these funds may be directed towards energy efficiency projects in social housing.

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[33] https://oneplace.fbk.eu/financing-energy-efficiency/financing-energy-efficiency/comparative-analysis-and-best-practices-2/new-page/italy/national-funding-in-italy/

[34] https://www.gse.it/servizi-per-te/efficienza-energetica/conto-termico

[35] https://www.casaandcountry.com/article/italian-super-bonus

[36] https://www.arl-international.com/knowledge/country-profiles/italy#general_information

[37] https://commission.europa.eu/business-economy-euro/economic-recovery/recovery-and-resilience-facility/country-pages/italys-recovery-and-resilience-plan_en

ESCOs (Energy Service Companies): Energy Service Companies in Italy may offer energy performance contracts and financing solutions for energy efficiency projects. ESCOs often implement measures and are compensated based on the achieved energy savings.

Local and Regional Funding Programs[38]: Some local municipalities and regional authorities in Italy may have their own funding programs to promote energy efficiency in social housing. It's advisable to check with local housing departments for available grants and support.

Incentivi alla Ristrutturazione degli Edifici Residenziali Pubblici:[39] Italy may offer specific incentives and grants for the renovation of public residential buildings, which can include energy efficiency measures in social housing.

Private Financing and Investment:[40] Private banks, financial institutions, and investors may offer financing options for social housing energy efficiency projects in Italy. Explore opportunities for collaboration and financing with private entities interested in sustainable initiatives.

5.5.2.3. Slovenia

Eco Fund (Eko Sklad)[41]: The Eco Fund (Eko Sklad) is a government-funded financial institution that supports various environmental and energy efficiency projects, including those related to social housing. The Eco Fund, established in 1993, plays a pivotal role in promoting environmental protection through financial incentives, including soft loans and grants, for various environmental investment projects. Initially focused on soft loans for environmental investments, it shifted towards maintaining the real value of its assets and introduced grants in 2008. These grants are primarily funded by energy end-users' fees and the climate change fund (CO2 allowances). The fund operates through yearly plans, issuing public calls for applications. The increasing number of applications reflects its impact on tax revenues, reducing the grey economy, creating green jobs, and fostering sustainable development. Eco Fund has expanded its role to include the organisation of a free energy advisory network and addressing energy poverty by covering costs for selected households. Facing new challenges, it aims to align financial incentives with national strategies, emphasising deep energy renovations, addressing energy poverty, stimulating refurbishments in the building stock, and developing innovative financial instruments.

Public Calls and Programs from the Ministry of Infrastructure:[42] The Ministry of Infrastructure in Slovenia may initiate public calls and programs to support energy efficiency projects, including those in social housing. These initiatives could include grants, subsidies, or financing options.

ESCOs (Energy Service Companies): Energy Service Companies in Slovenia may offer energy performance contracts and financing solutions for social housing energy efficiency projects. ESCOs often specialise in implementing measures and guaranteeing energy savings.

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38 https://leap4sme.eu/wp-content/uploads/2022/11/SME-Energy-efficiency-policies-in-Italy-Energy-Evaluation.pdf

39 https://toffoligiochi.com/contributi-per-edilizia-residenziale-pubblica/

40 https://core.ac.uk/download/pdf/76530641.pdf

41 https://www.ekosklad.si/english#:~:text=Eco%20Fund%2C%20Slovenian%20Environmental%20Public,for%20different%20environmental%20investment%20projects.

42 https://balkangreenenergynews.com/slovenia-to-launch-public-calls-worth-eur-30-million-for-renewable-energy-projects/

Local Municipality Programs:[43] Local municipalities in Slovenia may have their own funding programs to promote energy efficiency in social housing. These programs could offer grants, incentives, or other financial support.

Green Finance Initiatives[44]**:** including loans and investments dedicated to sustainable projects, may be available from banks and financial institutions in Slovenia. These options can support social housing EE renovations.

National Energy Efficiency Action Plans[45]**:** Slovenia's National Energy Efficiency Action Plans may outline specific measures and funding mechanisms to improve energy efficiency in buildings, including social housing.

Incentives for Renewable Energy and Energy Efficiency[46]: Slovenia may provide incentives and grants specifically for renewable energy and energy efficiency projects. Social housing providers could benefit from such incentives to fund renovations.

	Country		
	Denmark	Italy	Slovenia
Country Specific Funding sources	The National Building Fund (NBF)	National Energy Efficiency Fund	Eco Fund (Eko Sklad)
	Energy Savings Obligations	Conto Termico	Public Calls and Programs from the Ministry of Infrastructure
	Energispareordningen (Energy Saving Scheme)	Superbonus	ESCOs (Energy Service Companies)
	Danish Energy Agency (DEA) Grants	National Housing Plan (Piano Nazionale Casa	Local Municipality Programs
	Energistyrelsen (The Danish Energy Agency) Programs	Green New Deal - Italy's Recovery and Resilience Plan	Green Finance Initiatives
	Local Municipality Programs	ESCOs (Energy Service Companies)	National Energy Efficiency Action Plan
	Green Finance Initiatives	Local and Regional Funding Programs	Incentives for Renewable Energy and Energy Efficiency
	Energy Service Companies (ESCOs)	Incentivi alla Ristrutturazione degli Edifici Residenziali Pubblici	
	Private Foundations and NGOs	Private Financing and Investment	

Table 14: Summary of currently available funding sources at national level for the SUPER-i pilot countries

5.6. Innovative financing solutions to EE renovation projects

5.6.1. Public Private Partnership contracts

Public-Private Partnerships (PPPs) involve long-term agreements aligning government service delivery objectives with private profit objectives, as defined by the OECD in 2008. In a time of limited financial resources, PPPs become crucial for accessing finance and reducing capital expenditure in energy infrastructure projects. The European Commission distinguishes between contractual and institutionalised PPPs. Over the past two decades, PPPs and project finance have thrived in European countries like the UK, Spain, France, Germany, Italy, and Portugal. The private and public sectors can

[43] https://www.gov.si/en/policies/state-and-society/local-self-government-and-regional-development/regional-development/

[44] https://www.gov.si/assets/ministrstva/MF/Zakladnistvo/Dolg-RS/Slovenian-Sovereign-Sustainability-Bond-Framework.pdf

[45] https://energy.ec.europa.eu/system/files/2020-06/si_final_necp_main_en_0.pdf

[46] https://core.ac.uk/download/pdf/159431628.pdf#page=34

benefit mutually through PPPs. The private sector gains guarantee to face project risks, while the public sector receives capital investment and management expertise. Despite the potential, PPP transactions have slowed due to unfavourable conditions in capital markets. Benefits of PPPs include ensuring necessary investments, effective public resource management, timely service provision, long-term remuneration for the private sector, utilisation of private sector expertise, and off-balance sheet classification for assets. However, drawbacks include potential cost increases, negative impacts on fiscal indicators, longer and costlier procurement procedures, and inflexibility due to the complexity and long-term nature of PPP agreements. In terms of finance structures for PPPs, a Special Purpose Vehicle (SPV) is often used as the private party, raising finance through a combination of equity and debt. Equity investors, typically project developers, construction companies, and private equity funds, take higher risks and seek higher returns.

PPP financing often involves non-recourse project finance, where lenders are paid from project revenues without demanding compensation from equity investors. This allows equity investors to bear project losses first. Non-recourse project finance structures often involve a large proportion of debt, ranging from 70 to 95 percent of total finance. While project finance is beneficial for large projects, it comes at a cost, with higher interest rates than government borrowing. Alternatives to non-recourse project finance include corporate guarantees, full-recourse corporate finance, and limited recourse project finance. Governments may participate in the finance structure by providing finance as a lender to the project company or guaranteeing project debt. Lenders often seek additional credit support, and alternatives like step-in rights or government participation can help lower the cost of finance for PPPs.

5.6.1.1. Direct credit line:

DCL, introduced by public entities such as government bodies, non-profit organisations, and banking foundations, serve as funding sources for Energy Efficiency (EE) projects through collaboration with private financial institutions. Typically, these private financial institutions include banks or investment funds, contributing additional financing, known as co-financing, for EE initiatives. This financing mechanism strategically utilises funds from government sources, international financial institutions (IFIs), or donor agencies to incentivize increased lending by Local Financial Institutions (LFIs) dedicated to EE projects. The objective is to overcome the challenge of insufficient or non-existent lending to EE projects, primarily stemming from LFIs' limited knowledge and understanding of the unique characteristics and benefits associated with such projects.

Through this mechanism, the public partner provides funds to LFIs at generally low-interest rates, creating an incentive for these private-sector entities to further lend funds for EE projects. Since the on-lending by LFIs typically occurs at higher interest rates (often aligned with market rates, as observed in World Bank credit lines), LFIs can realise a profit on these loan transactions. The collaborative agreement between the public and private partners usually stipulates that LFIs co-finance the loans, effectively leveraging and augmenting the overall financing available for EE projects. This collaborative approach, as exemplified by initiatives like the World Bank in 2008, addresses the critical issue of expanding financial support for EE projects by encouraging private financial institutions to actively participate in advancing sustainable and energy-efficient endeavours.

5.6.1.2. Guaranteed savings contract:

Under the guaranteed savings contract, the Social housing association is responsible for covering 100% of the investment costs necessary for implementing the EE renovation project while the ESCO company is responsible for the implementation of the EE renovation and the project design. Furthermore, the ESCO company is also responsible for the costs associated with the installed EE technologies and takes on the full financial and technical risks of the project. Under this contract, the Social housing company is guaranteed a fixed predetermined energy savings which is equal to the cost of debt obtained to finance the EE project. If the energy savings from the installed EE renovations are higher than the guaranteed energy savings, then the social housing company receives the fixed minimum guaranteed energy savings plus 20% of the difference between the energy savings and the minimum guaranteed savings (extra energy savings), while the ESCO company receives 80% of the extra energy savings after covering the guaranteed savings to the social housing company. However, when the energy saving generated by the EE renovations is lower than the guaranteed energy savings by the ESCO to the social housing company, the social housing company receives all the generated energy savings and the ESCO will cover the difference between the generated energy savings and the guaranteed energy savings, which explains why social housing company under this contract does not bear any risk.

5.6.1.3. Shared savings contract

Under the shared savings contract, the ESCO is responsible for covering 100% of the investment costs necessary for implementing the EE renovation project as well as the implementation of the EE renovation and the project design, and the social housing company will be providing the equity (building). The ESCO company is also responsible for the costs associated with the installed EE technologies and takes on the full financial and technical risks of the project. Under this contract, the ESCO is guaranteed a fixed predetermined energy savings. If the energy savings from the installed EE renovations are higher than the guaranteed energy savings, then the social housing company receives the 35% of the extra energy savings, while the ESCO receives 65% of the extra energy savings plus the guaranteed energy savings. However, when the energy saving generated by the EE renovations is lower than the guaranteed energy savings, the ESCO receives all the generated energy savings and considers the difference between the guaranteed savings and the generated energy savings as a financial loss, while the social housing company does not receive any energy savings.

Under these two PPP contracts, the energy efficiency improvements are implemented through a loan or facilitated by an ESCO. For loans, the energy efficiency improvements are selected by the building owner, often from an approved list of measures. This means that, without the support and expert opinion an ESCO can provide, the measures chosen are not always the most effective use of finance for energy efficiency. The ESCOs are experts in energy efficiency measures and are incentivised to maximise energy efficiency savings for minimum cost, sometimes through a savings guarantee. There are however barriers to the ESCO model, including low public awareness of their benefits, that can prevent them from having a wide impact. This means that ESCOs can struggle to generate profits unless a large number of contracts are won. This issue is avoided for larger ESCO business models. Super ESCOs can offer more stable business models, particularly in markets without an established ESCO industry. These larger ESCO business models are particularly appropriate for building owners with a large building stock (e.g. social housing). Energy efficiency improvements can be made to an entire building stock as cost-effectively as possible, without the risk of the ESCO collapsing as super ESCOs are supported by governments and have financial certainty from their larger contracts.

5.6.1.4. Energy supply contract

Energy supply contracts (ESCs) are the ESCO business model most like traditional energy suppliers. Social housing companies choose to install energy efficiency measures and pay for them through their energy or utilities bill. Under this contract, the social housing company and the ESCO company co finance the EE renovation project costs and no party is guaranteed a minimum energy savings. The financial risk in this contract is shared between the ESCO and the Social housing company. Furthermore, the energy savings generated by the EE renovations are divided between the social housing company and the ESCO company based on the percentage of the investment costs covered by each party, usually between 50%-90% for ESCO company and 10%-50% for the Social housing company. Note that for this contract, the debt typically stays with the metre, meaning that if the Social housing company sells the building, the new building owner takes on the contract.

6. LCA/SLCA

The assessments consider environmental and social factors, aligning with the principles of sustainable development. This ensures that investments contribute positively to the economic, social, and environmental well-being of the partner countries.

The methodologies of Life Cycle Assessment (LCA) and Social Life Cycle Assessment (SLCA) serve as valuable tools for social housing owners and stakeholders to understand the environmental and social implications associated with refurbishment and renovation strategies for social housing. The European Standard EN 15804:2012+A2:2019 sets the benchmark for conducting Life Cycle Assessment (LCA) of construction products. This standard outlines the fundamental guidelines for assessing the environmental impact of construction products, while Environmental Product Declarations (EPDs) provide information on a product's environmental performance derived from LCA methodology.

Figure below delineates the stages and boundaries specific to LCA for buildings undergoing refurbishment.[47]

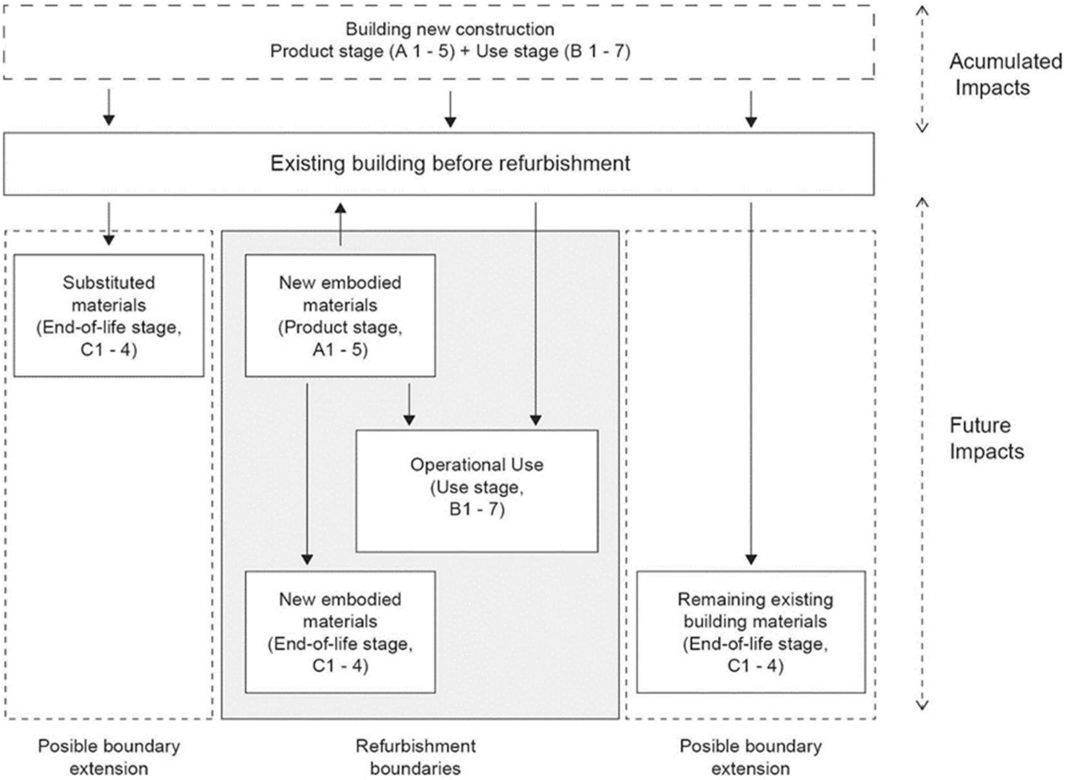

Figure 8: Stages and boundaries of the LCA methodology

The LCA study follows four main phases:

- **Goal and Scope Definition:** This phase involves defining the purpose of the study and the system boundaries.

[47] CIRCE foundation and contributors. D4.3. - LCA-LCC study for technical results and demo cases. BuildHeat project GA N. 680658, November 2018.

- **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 level. The European methodology for the assessment of the environmental performance of buildings – Level(s)[48] is based on EN 15978[49] and therefore also on EPD information. Regarding the scope of the SUPER-i project, 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, 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.

In accordance with the proposed recommendations, a combination of environmental indicators have been meticulously considered, due to the ease of access to the information needed for their evaluation

[48]Introducing Level(s). (n.d.). Environment. https://environment.ec.europa.eu/topics/circular-economy/levels/introducing-levels_en

[49]UNE-EN 15978:2012 Sostenibilidad en la construcción. Evaluació. . . (n.d.). https://www.une.org/encuentra-tu-norma/busca-tu-norma/norma?c=N0049397&gad_source=1&gclid=Cj0KCQiA5-uuBhDzARIsAAa21T9js_zMl9u7c6fW2V3HAotWXAl2iUErK9eG675dtr7wYNmrQhncMJgaAs6CEALw_wcB

and their ease of adaptability to different EU countries, ensuring the replicability and scalability of the investment models. 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.

The evaluation of the social performance of buildings involves assessing how well a building meets the needs and expectations of the people who use or are affected by it. This evaluation goes beyond the traditional measures of energy efficiency and considers aspects related to well-being, comfort, and overall satisfaction of the occupants. To take into account social aspects (SLCA) during the renovation of buildings, a set of Social KPI's has been developed that may be used during the detailed design phase to encourage solutions that increase occupants' well-being and comfort during the use phase of the building. It will also be possible to measure the degree of satisfaction of building users during its use and maintenance.

Standard EN 15643:2021[50] establishes the general framework for buildings' sustainability assessment. Specifically, UNE-EN 16309+A1:201512[51], which focuses on social performance at building level, has been investigated along with CIRCE´s projects SUPERSMART[52] and RINNO[53] and taken as a reference point to develop the social performance indicators.

Numerous methodologies and other EU-funded HORIZON Europe[54] projects have undergone evaluation to pinpoint appropriate indicators for assessing the use stage impact in social residential buildings. In accordance with the proposed recommendations, we have meticulously considered a combination of environmental and social indicators that can be easily adapted to different countries, ensuring the replicability and scalability of the investment models. This is particularly important for projects that can be expanded or adapted to similar contexts within the SUPER-I partner countries. This approach not only addresses energy poverty within the social housing sector but also aligns with the European initiative to decarbonize cities[55].

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[50] BS EN 15643:2021 Sustainability of construction works. Framework for assessment of buildings and civil engineering works. (n.d.). https://www.en-standard.eu/bs-en-15643-2021-sustainability-of-construction-works-framework-for-assessment-of-buildings-and-civil-engineering-works/

[51] UNE EN 16309+A1:2015 Sustainability of construction works - Assessment of social performance of buildings - Calculation methodology. (n.d.). https://www.en-standard.eu/une-en-16309-a1-2015-sustainability-of-construction-works-assessment-of-social-performance-of-buildings-calculation-methodology/

[52] MOTIVATION & IMPACT - Supersmart Project. (2023, January 31). Supersmart Project. https://supersmart-project.eu/

[53] Circe - RINNO | Secure, clean and efficient energy. (2022, May 26). RINNO | Secure, Clean and Efficient Energy. https://rinno-h2020.eu/about/partners/circe/

[54] Horizon Europe. (2024, February 13). Research and Innovation. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

[55] Climate-neutral and smart cities. (2023, December 20). Research and Innovation. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en

6.1. Environmental KPIs (LCA)

Figure 9: Environmental KPIs categories defined for the SUPER-I project.

While initiatives to address energy poverty in social housing can have serious environmental consequences, they can be managed and reduced with careful planning and design. To guarantee that such interventions support sustainable development, it is imperative that these effects be taken into account during the planning and execution stages. The term "environmental impact" refers to the effects of an action on the environment in several directions. The elements of that activity that have the potential to interact with the environment are known as environmental aspects or vectors.

This document's point will analyse the interventions in terms of how they affect the following categories: waste management, land use, energy, atmosphere, water, materials, and indoor quality. The table below illustrates the Environmental Key Performance Indicators (KPIs) repository incorporated in the SUPER-i project evaluation. These KPIs are based on the criteria proposed by BuildUpon framework (relevance, availability, measurability and reliability) and has been adopted by several HORIZON projects due to its applicability to any type of project and take into consideration the categories stated before.

ENVIRONMENTAL KPI´S
ENERGY
E1. CO2 EMISSIONS REDUCTION

Defining name	Action name
Category Pillar	ENERGY
Definition	Reduction of annual direct CO_2 emissions after energy rehabilitation (only emissions during the use phase). CO_2 stands as a major contributor to global warming, emitted into the atmosphere through the combustion of fossil fuels for heating and cooling purposes as well as in the production of hot water and electricity for building use. Building accounts for 36% of CO_2 emissions in the EU.
Reference	https://climate.ec.europa.eu/eu-action/climate-strategies-targets/progress-made-cutting-emissions_en
Formula	● Main Metric: *Reduction in CO2 emissions (Ton CO2 eq. / year) = ∑ (Emissions (Ton CO2 eq. / year) before rehabilitation - Emissions (Ton CO2 eq. / year) after rehabilitation)* Calculates the reduction in CO_2 emissions by summing up the differences between emissions before and after rehabilitation for each individual project. ● Complementary Metric: *% Reduction of CO2 Emissions= ((Initial Emissions−Final Emissions)/Initial Emissions) × 100* This formula represents the percentage reduction achieved by comparing the difference between initial (before rehabilitation) and final (after rehabilitation) CO_2 emissions to the initial emissions. The result provides a measure of the relative decrease in CO_2 emissions due to the rehabilitation efforts.
Unit of measurement	● Main metric: *Ton CO2 eq/year* ● Complementary Metric: *% CO2 emissions/reduction*
Data Source	Calculation is based on the summation of data from each individual project. It requires the Energy Performance Certificates (EPC), both before and after the implementation of specific projects.

	When utilising real data, it is essential to conduct real-time monitoring of final energy consumption for at least 12 months before and after rehabilitation. CO_2 emissions can be derived from actual energy consumption by applying conversion factors, with data obtained through monitoring or energy bills. Energy supply companies can supply the requisite data for this purpose. This approach ensures a comprehensive assessment of CO_2 emissions based on observed energy usage patterns. The Covenant of Mayors Guidelines for Climate and Energy Reporting also include tables of default emission factors for different types of energy (fossil and renewable) and for electricity by country and year.
Actions / Interventions	Insulation and HVAC systems improvement.
Variable / Parameter	Reduction of annual direct CO_2 emissions after energy rehabilitation (only emissions during the use phase).
Monitoring Interval	Calculate the emissions before and after the rehabilitation works. The calculation is conducted over an agreed-upon period, typically one year.
Target	Reducing the KPI by a certain percentage compared to a baseline period.
Relationship with other KPIs	E2 E3 E4 A1

E2. REDUCTION OF FINAL ENERGY CONSUMPTION

Defining name	**Action name**
Category Pillar	ENERGY

Definition	Reduction in final energy consumption after energy rehabilitation for the purposes covered by the Energy Performance Certificate (EPC). Final energy consumption (also known as supplied energy) reflects the energy consumed by the end-user and is dependent on the building's energy needs, the efficiency of its systems, and its usage. Measuring and evaluating final energy consumption encourages the adoption of an energy rehabilitation approach that prioritises the building envelope.
Reference	Energy Performance of Buildings Directive. (n.d.). Energy. https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en
Formula	● Main Metric: *Reduction in final energy consumption (kWh/year) = ∑ ((Energy consumption before rehabilitation (kWh/year)) − (Energy consumption after rehabilitation (kWh/year)))* Complementary Metric: *% Reduction of kWh/year=((Initial energy consumption before rehabilitation (kWh/year)−Final energy consumption after rehabilitation (kWh/year))/ Initial energy consumption before rehabilitation (kWh/year))×100*
Unit of measurement	● Main Metric: *kWh/year* ● Complementary Metric: *% Reduction of kWh/year*
Data Source	Calculation is based on the summation of data from each individual project. It requires the Energy Performance Certificates (EPC), both before and after the implementation of specific projects.
Actions / Interventions	Insulation & HVAC systems improvement.
Variable / Parameter	Calculate the difference in final energy consumption in kWh/year before and after rehabilitation works. All types of energy used for heating, ventilation, and air conditioning should be considered.

Monitoring Interval	The calculation is conducted over an agreed-upon period, typically one year.
Target	Reduce the energy consumption after energy rehabilitation for the purposes covered by the Energy Performance Certificate (EPC).
Relationship with other KPIs	E3 E4 A1

E3. RENEWABLE ENERGY PRODUCTION

Defining name	**Action name**
Category Pillar	ENERGY
Definition	Increase in on-site generated and utilised renewable energy because of energy rehabilitation. The provision of additional renewable energy, both for electricity and heating, will replace fossil fuels and their associated CO2 emissions with clean renewable energy. It also reduces energy dependence and provides security and diversification to the energy supply. To achieve this, it is essential, first, to decrease energy demand and then enhance the performance of installations to minimise final energy consumption.
Reference	
Formula	• Main Metric: *Increment of renewable energy production in situ (kWh/year) = ∑ ((kWh/year renewable energy production after rehabilitation) – (kWh/year renewable energy production before rehabilitation))* • Complementary Metric: *% Increment of renewable energy production =(Increment of renewable energy production(kWh/year)/ Total renewable energy production in situ (kWh/year))×100*
Unit of measurement	• Main Metric: *kWh/year* • Complementary Metric: *% Increment of renewable energy production*

Data Source	Calculation is based on the summation of data from each individual project. It requires the Energy Performance Certificates (EPC), both before and after the implementation of specific projects during a minimum period of 12 months.
Actions / Interventions	Implementation of renewable energy systems: PV Solar Panels, and Geothermal.
Monitoring Interval	The calculation is conducted over an agreed-upon period, typically one year.
Target	Reduce the energy demand after energy rehabilitation and enhance the performance of installations to minimise final energy consumption.
Relationship with other KPIs	E2 E4 A1

E4. IMPROVEMENT OF NET HEATING AND COOLING DEMAND

Defining name	**Action name**
Category Pillar	ENERGY
Definition	Reduction in the total energy demand required by the building to maintain predefined thermal conditions (temperature, humidity, etc.) in all conditioned spaces.
Reference	https://www.eea.europa.eu/publications/decarbonisation-heating-and-cooling

Formula	● Main Metric: Reduction in energy demand in kWh/m2 per year: The weighted average (WA) of energy demand reductions is calculated based on the surface area and can be obtained using the following formula: *WA (reduction in demand)= ∑((prior demand(kWh/m2 year)-posterior demand(kWh/m2 year))*surface area(m2))/ ∑ living area(m2)* ● Complementary Metric: *Percentage of energy demand reduction(%)=(Energy demand reduction (kWh/m2 year)/WA (previous demand (kWh/m2 year)))*100*
Unit of measurement	● Main Metric: *kWh/m2 per year* ● Complementary Metric: *% Percentage of energy demand reduction*
Data Source	Calculation is based on the summation of data from each individual project. The heating and cooling energy demand is theoretically determined and is mandatory information found in Annex II of the Energy Performance Certificate (EPC), measured in kWh/m2 per year. The EPC is a compulsory document within the technical project, and cities may request this information before and after rehabilitation when applying for a permit. As it is a weighted average based on surface area, it is necessary to collect the surface area of each individual intervention. Therefore, the necessary data to be collected from the EPC for each intervention would be: • Energy demand before and after rehabilitation intervention in kWh/m2 per year. • Surface area according to the EPC in square metres (a data point collected for other indicators).
Actions / Interventions	Envelope´s insulation and HVAC systems improvement.

Variable / Parameter	The assessment of a building's performance is significantly influenced by its energy demand for heating and cooling. This measure reflects both the effectiveness of architectural interventions and the building's ability to perform well independently (with good efficiency even without active systems), ultimately contributing to a reduction in energy dependence. In sustainable rehabilitation, the established protocol places a priority on implementing passive measures initially to decrease energy demand, ensuring optimal functionality of the building envelope. Subsequent efforts focus on system optimization, aiming for a minimal level of final energy consumption that can be easily met through renewable energy sources.
Monitoring Interval	The calculation is typically conducted over an agreed-upon period, usually 1 year.
Target	A reduction of the total energy demand required by the building should be achieved to prove the efficiency of the solutions implemented on the renovation.
Relationship with other KPIs	E2, E4

WATER

W1. WATER USE

Defining name	**Action name**
Category Pillar	WATER
Definition	Water consumption is a metric used to measure and evaluate the amount of water used for different purposes. It provides insights into the environmental impact of water usage and helps to set targets for reducing water use and improving overall water efficiency. In this case the assessment will be based on the quantity of water used by the heating/cooling systems before and after the renovation.
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	● Main Metric: The formula provides a percentage that indicates the relative increase or decrease in water use after the renovation. A positive percentage suggests an increase, while a negative percentage indicates a decrease in water use. It helps to evaluate the effectiveness of the renovation in terms of water efficiency. *% Change in Water Use=((Water Consumption After Renovation (m3) – Water Consumption before Renovation (m3))/Water Consumption Before Renovation(m3))*100*
Unit of measurement	● Main metric: % Change in Water Use
Data Source	The data can be gathered from different sources: 1. Water Bills: obtain water bills or consumption data from the utility company for the building before and after the renovation. These bills typically provide information on water usage over a specific billing period. 2. Real-Time Monitoring Systems: if real-time monitoring systems are in place, extract data from these systems for both pre-renovation and post-renovation periods. Real-time monitoring can provide detailed insights into water consumption patterns.
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	Monitoring and understanding water use in heating and cooling systems contribute to assessing their efficiency, environmental impact, and overall sustainability
Monitoring Interval	To calculate the Percentage Change in Water Use before and after renovation, you'll need data from both periods.
Target	A reduction of the water used after the rehabilitation will be required after rehabilitation to prove the efficiency of the renovation measures applied.
Relationship with other KPIs	W2

W2. RECYCLING WATER

Defining name	**Action name**
Category Pillar	WATER

Definition	Recycling water after building renovation involves implementing strategies to reuse or repurpose water within the building.
Reference	https://kb.breeam.com/wp-content/plugins/breeamkb-pdf/pdf/?c=975
Strategies Proposed	- *Rainwater Harvesting*: Install rainwater harvesting systems to collect and store rainwater for non-potable uses. This harvested rainwater can be utilised for irrigation, flushing toilets, or other non-drinking water applications. - *Greywater Systems:* Implementing greywater systems to capture and treat water from sources such as showers, sinks, and washing machines. Treated greywater can be reused for toilet flushing or landscape irrigation. - *Water-Efficient Appliances and Fixtures:* Install water-efficient appliances and fixtures during renovation to reduce overall water consumption. This will conserve the water but also contributes to the sustainability of the building. - *Irrigation Systems:* If applicable, incorporate recycled water into landscape irrigation systems. This is a common application for both rainwater harvesting and treated greywater.
Data Source	The data collection will be done through a survey after building renovation where different recycling water strategies can be selected through a yes/no option button.
Actions / Interventions	Implementation of any of the recycling water strategies proposed.
Variable / Parameter	Water Recycling will be considered as a qualitative Key Performance Indicator (KPI) where data collection involves a yes or no response to various proposed strategies, this should be based on the successful implementation and adherence to water recycling practices. This approach is likely chosen because of varying water standards in different regions of the same country.
Target	Recycling water after renovation is a sustainable practice that aligns with water conservation efforts. By incorporating these strategies,

	you can contribute to reducing overall water demand and promoting a more environmentally friendly building operation.
Relationship with other KPIs	W1
ATMOSPHERIC	
A1. GLOBAL WARMING POTENTIAL (GWP100)	
Defining name	**Action name**
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.
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	CO_2 Savings
Target	Reduce the CO_2 emissions of the building as per EU and national regulations.
Relationship with other KPIs	E1
WASTE MANAGEMENT	
WM1. CONSTRUCTION WASTE MANAGEMENT	
Defining name	**Action name**
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	Main Metric: 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.
Target	Reduction in the generation of Construction Waste.
Relationship with other KPIs	WM2

WM2. WASTE REDUCTION RATE

Defining name	Action name
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 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	Reduction of waste generation.

WM3. EFFICIENCY IN WASTE DISPOSAL PROCESSES

Defining name	**Action name**
Category Pillar	WASTE MANAGEMENT
Definition	This indicator assesses how efficient the disposal process is in the buildings. 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. BCR: Percentage of waste materials that are used for Biomass, Composting or Reusing. *Please note that this formula obtains the results 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 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	Waste Disposal Efficiency
Target	Improvement of waste disposal strategies.

Relationship with other KPIs	WM1, WM2
INDOOR QUALITY (SOCIAL)	
IQ1. INDOOR AIR QUALITY	
Defining name	**Action name**
Category Pillar	INDOOR QUALITY
Definition	The built environment with proper indoor air quality in conditioned spaces.
Reference	BS EN 16798-1:2019 - Energy performance of buildings. Ventilation for buildings. ISO 10551:2019 and ISO 28802:2012 - Ergonomics of the physical environment. LEVELs - Indoor Air Quality
Formula	● Main Metric: Rehabilitated Built , Environment with Adequate Indoor Air Quality (IAQ) *Number of dwellings with adequate IAQ = ∑ (Number of rehabilitated dwellings with adequate IAQ)* ● Complementary Metric: Percentage of the rehabilitated built environment with Adequate Indoor Air Quality (IAQ) *Percentage(%)=(Number of dwellings rehabilitated with Adequate IAQ/ Total number of rehabilitated dwellings)×100*
Unit of measurement	● Main Metric: *Number of dwellings* ● Complementary Metric: *% Percentage of improvement*

Data Source	Any of the next options or a combination of them can be used for data gathering. In all cases, it is necessary to be transparent with the methodology used and the assumptions adopted. ● Ventilation systems compliant with national standards or the standard EN 16798-1. Count the number of rehabilitated dwellings and the surface area in square meter of non-residential buildings that comply with the predefined ventilation rates in the national Building code (CTE/RITE) for good indoor air quality. If there is no national building code requirement to guarantee a minimum level of air quality the standard EN 16798-1 should be taken into consideration. ● Survey to users and residents. A survey methodology could be employed to collect information about residents' viewpoints. This survey should be conducted both before and after the rehabilitation, once the building is in the occupancy phase. ISO 10551 and ISO 28802 are the main references for household comfort and wellbeing in this context. ● On-site monitoring through sampling. Co2 is a good indicator of IAQ, as it can provide an idea of the ventilation level in spaces used by people. On-site monitoring measures the CO2 level in units of parts per million (ppm). To consider a space to have adequate IAQ, CO2 measurements should not exceed the defined range (IEQ in Table 1 or national requirement) for more than 5% of the occupancy time. <table><tr><th>CATEGORY</th><th>Concentrations of CO2 above the exterior levels during full occupancy (assuming outdoor levels as around 400ppm)</th></tr><tr><td>IEQ I</td><td>≤ 500 ppm</td></tr><tr><td>IEQ II</td><td>> 550ppm & ≤ 800 ppm</td></tr><tr><td>IEQ III</td><td>> 800 ppm & ≤ 1350 ppm</td></tr><tr><td>IEQ IV</td><td>> 1350 ppm</td></tr></table>
Actions / Interventions	Installation of monitoring systems to help inhabitants to know where the dwelling needs to be ventilated to improve air quality or installations of smart ventilation devices for an automation of the ventilation.
Variable / Parameter	Key pollutants affecting indoor air quality are CO2, carbon monoxide, particles, and volatile organic compounds (VOCs). The main sources of indoor air pollution are within buildings.

Monitoring Interval	Calculate the rehabilitated built environment with proper indoor air quality after energy rehabilitation The calculation is typically conducted over an agreed-upon period, usually 1 year.
Target	Europeans spend about 90% of their time indoors, and indoor air pollution is a significant health and environmental concern due to its adverse effects. Controlling and eliminating pollutants through effective ventilation is crucial for maintaining a healthy indoor environment.

IQ2. WINTER THERMAL COMFORT

Defining name	**Action name**
Category Pillar	INDOOR QUALITY
Definition	The rehabilitated built environment with adequate Winter Thermal Comfort (WTC) in all conditioned spaces.
Reference	LEVELs - Protection of occupier health and thermal comfort
Formula	● Main Metric: Rehabilitated Built Environment with Adequate Winter Thermal Comfort (WTC) *Number of dwellings with adequate WTC = ∑ (Number of rehabilitated dwellings with adequate (WTC))* ● Complementary Metric: Percentage of the rehabilitated built environment with Adequate Winter Thermal Comfort (WTC) *Percentage(%)=(Number of dwellings rehabilitated with Adequate WTC/ Total number of rehabilitated dwellings)×100*
Unit of measurement	● Main Metric: Number of dwellings ● Complementary Metric: % Percentage of improvement.

Data Source	Any of the next options or a combination of them can be used for data gathering. In all cases, it is necessary to be transparent with the methodology used and the assumptions adopted. ● Heating systems compliant with national standards or the standard EN 16798-1:2019. Count the number of rehabilitated dwellings and the surface area in square meter of non-residential buildings that comply with the predefined interior Winter Thermal Comfort in the national Building code. There is no standard that establishes acceptable hours outside of comfort temperatures, although sometimes reference is made to 5% of the annual occupancy hours (*Regnier, Cindy. Guide to Setting Thermal Comfort Criteria and Minimising Energy Use in Delivering Thermal Comfort. United States: N. p., 2012. Web. doi:10.2172/1169480*). ● Survey to residents. In this scenario, the evaluation of winter thermal comfort relies on post-occupancy surveys measuring the level of dissatisfaction with thermal conditions. These surveys are conducted 12 months after the completion of the rehabilitation work, once the buildings are in use. ISO 10551 and ISO 28802 are the main references for household comfort and wellbeing in this context. ● On-site monitoring through sampling. Monitoring hourly thermal conditions in a building allows for the assessment of winter thermal comfort throughout and entire heating season. The national building code's minimum requirements for winter thermal comfort should be use as a reference for conducting the evaluation. In countries where there are no clear requirements for the warranty of winter thermal comfort, the standard EN 16798-1:2019 should be taken into consideration.
Actions / Interventions	Improve Heating systems to comply with national standards or the standard EN 16798-1:2019.
Variable / Parameter	It is defined by environmental parameters such as temperature, relative humidity, and air velocity, as well as personal factors like

	clothing, activity level, gender, and age, which influence a person's metabolic rate.
Monitoring Interval	Calculate the number of rehabilitated dwellings with adequate Winter Thermal Comfort (WTC). The calculation is typically conducted over an agreed-upon period, usually 1 year.
Target	Thermal comfort can improve the health and well-being of individuals. It is defined by environmental parameters such as temperature, relative humidity, and air velocity, as well as personal factors like clothing, activity level, gender, and age, which influence a person's metabolic rate. According to the standard EN ISO 7730, "thermal comfort is the condition of mind that expresses satisfaction with the thermal environment".
Relationship with other KPIs	IQ1, IQ3

IQ3. SUMMER THERMAL COMFORT

Defining name	**Action name**
Category Pillar	INDOOR QUALITY
Definition	The rehabilitated built environment with a limited risk of overheating due to energy rehabilitation.
Reference	[LEVELs - Protection of occupier health and thermal comfort]
Formula	• Main Metric: Rehabilitated Built Environment with improved Summer Thermal Comfort (STC) *Number of dwellings with adequate STC = ∑ (Number of rehabilitated dwellings with adequate (STC))* • Complementary Metric:

	Percentage of the rehabilitated built environment with improved Summer Thermal Comfort (STC) *Percentage(%)=(Number of dwellings rehabilitated with Adequate STC/ Total number of rehabilitated dwellings)×100*
Unit of measurement	● Main Metric: Number of dwellings ● Complementary Metric: % Percentage of improvement
Data Source	Any of the next options or a combination of them can be used for data gathering. In all cases, it is necessary to be transparent with the methodology used and the assumptions adopted. ● National Building Code Standard/CIBSE TM52. This option involves assessing the theoretical risk of overheating during the design phase. The count includes dwellings and non-residential spaces (m²) in rehabilitated buildings that meet or are below the theoretical overheating criterion set in the national building code. In the absence of a clear definition in the national building code, the CIBSE TM52 reference (TM59 for dwellings) can be utilised. ● Survey to residents. In this case, surveys for residents are used to determine the level of dissatisfaction with summer thermal comfort after energy rehabilitation. These surveys are conducted 12 months after the completion of the rehabilitation work, once the buildings are in use. ISO 10551 and ISO 28802 are the main references for household comfort and wellbeing in this context. ● On-site monitoring through sampling. Monitoring hourly thermal conditions in a building allows for the assessment of risk of overheating. The national building code's minimum requirements for overheating should be use as a reference for conducting the evaluation. In the absence of a clear definition in the national building code, the CIBSE TM52 reference (TM59 for dwellings) can be utilised.

Actions / Interventions	Improve Cooling systems to comply with national standards or the standard EN 16798-1:2019.
Variable / Parameter	The thermal performance of buildings in summer is evaluated based on a reference temperature that should not be surpassed for a specific number of hours during the annual occupancy period.
Monitoring Interval	Calculate the number of rehabilitated dwellings and with adequate summer Thermal Comfort. The calculation is typically conducted over an agreed-upon period, usually 1 year.
Target	Excessive heat, influenced by factors like climate change, urbanisation, tall buildings, and winter energy efficiency measures, poses a risk to residents' health and wellbeing, particularly affecting sleep. To protect people, it is essential to ensure that energy rehabilitation efforts do not amplify the risk of overheating. The thermal performance of buildings in summer is evaluated based on a reference temperature that should not be surpassed for a specific number of hours during the annual occupancy period.
Relationship with other KPIs	IQ1, IQ2
CONSTRUCTION MATERIALS	
CM1. MATERIALS RECYCLE/REUSE	
Defining name	**Action name**
Category Pillar	CONSTRUCTION MATERIALS
Definition	Use of recyclable and recycled materials.
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 m3.
Data Source	Certificates provided.
Actions / Interventions	All measures can use these KPIs to assess responsible sourcing.
Variable / Parameter	Reduction in the use of Ozone Depleting Substances.
Monitoring Interval	Whole Life Cycle of the Building including renovations.
Target	Excessive heat, influenced by factors like climate change, urbanisation, tall buildings, and winter energy efficiency measures, poses a risk to residents' health and wellbeing, particularly affecting sleep. To protect people, it is essential to ensure that energy rehabilitation efforts do not amplify the risk of overheating. The thermal performance of buildings in summer is evaluated based on a reference temperature that should not be surpassed for a specific number of hours during the annual occupancy period.
Relationship with other KPIs	Construction materials.

CM2. MATERIALS LIFECYCLE ANALYSIS

Defining name	**Action name**
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	● Choose materials with low carbon impact such as biogenic or recycled. ● 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	Reduce the CO2 emissions through the utilisation of materials with low embodied carbon.
Relationship with other KPIs	A1, E1

To facilitate the coordination of the data gathering process and promote a shared understanding of the information to be monitored among various stakeholders, we have included the selected Key Performance Indicator (KPI). These serve as a reference point, providing a standardised framework for tracking and evaluating key metrics essential to the project's success. Their use ensures consistency in data collection and reporting, fostering effective collaboration and informed decision-making across all stakeholders involved in the initiative.

6.2. Social KPIs (SLCA)

From a social perspective, the Social Key Performance Indicators (KPIs) (SLCA) offer a comprehensive analysis of the consequences of renovation works across various categories, with a primary focus on tenants. These categories include Accessibility, Health & Comfort, Energy Poverty, and Safety & Security. The relevance of these indicators is particularly pronounced during the use phase of the building.

Figure x: Social KPIs Categories.

Moreover, some of these indicators remain pertinent even at the detailed design stage of the renovation. In this advanced phase, where the final specifications of products and measures are under consideration, these indicators gain significant value. Although they may not be directly factored into the scenario selection, they play a crucial role in encouraging and promoting the design team to contemplate additional factors when finalising the specifications for the renovation.

As part of this assessment, it is crucial to integrate considerations of the affordability of household energy. This includes examining the financial feasibility for occupants to meet their energy needs within their means, ensuring equitable access to energy services. By incorporating affordability considerations, the evaluation aims to address potential economic challenges that households may face in accessing and utilising energy resources during the use and maintenance phases of the building. This holistic approach aligns with sustainability goals and contributes to a more comprehensive understanding of the social impact of building renovations.

A scoring system has been implemented for each category and social aspect; it has been based on previous methodology developed by CIRCE in other EU projects like RINNO, RESPONSE and INCUBE and it has been adapted to the specific needs of the SUPER-i project. The questions and answers of the questionnaire with their corresponding scores are also included. These indicators should be analysed before and after the renovation to evaluate the data through comparison and be able to check the improvement of the renovation implemented, and it will be taken in consideration data provided by the pilots and its inhabitants.

The indicators are outlined below:

ACCESSIBILITY		
A1. APPROACH TO THE BUILDING		
Defining name	**Action name**	
Category Pillar	ACCESSIBILITY	
Social Aspects	Approach to the building	
Definition	Accessibility facilities for parking and access to the building.	
Reference	UNE-EN 16309+A1:2015	
Indicators	1. Accessibility facilities for parking and access to the building. 2. Pick up points for individuals with special needs. 3. Curb ramps between the road and the entrance to the building. 4. Accessibility measures to allow access and movement inside the building for individuals with special needs.	
Unit of measurement	YES	100.00%

	NO	0.00%
Data Source	Survey to residents or pilots.	
Actions / Interventions	Implementation of accessible parking spaces, pick up points for individuals with special needs, curb ramps, accessibility measures in common areas.	
Monitoring Interval	Before and after renovation.	
Target	Inclusion through improvement of the accessibility facilities for the tenants.	
Relationship with other KPIs	A1	

A2. ACCESS TO BUILDING SERVICES

Defining name	Action name	
Category Pillar	ACCESSIBILITY	
Social Aspects	Access to building services.	
Definition	Arrangement and ease of operation of switches and control systems (for heating, lighting).	
Reference	UNE-EN 16309+A1:2015	
Indicators	1. Arrangement and ease of operation of switches and control systems (for heating, lighting).	
Unit of measurement	Control and monitoring devices are located at a height between 80 and 120 cm.	33.33%

	Power or signal sockets are located between 40 and 120cm.	33.33%
	The distance to corner meetings is at least 35 cm.	33.33%
Data Source	Survey to residents or pilots.	
Actions / Interventions	Place operation switches and control systems following accessibility measures.	
Monitoring Interval	Before and after renovation.	
Target	Social inclusion, accessibility.	
Relationship with other KPIs	A1, A2	

HEALTH & COMFORT

HC1. THERMAL CHARACTERISTICS (BUILDING)

Defining name	**Action name**
Category Pillar	HEALTH & COMFORT
Social Aspect	Thermal Characteristics
Definition	Satisfaction degree with thermal environment: operating temperature, humidity, air velocity and distribution.
Reference	LEVELs - Protection of occupier health and thermal comfort

Indicators	1. Satisfaction degree with thermal environment: operating temperature, humidity, air velocity and distribution.	
Unit of measurement	Winter <18->26ºC_H<40%, Summer tª<21->28_H>60%	0.00%
	Winter tª 18-26ºC_H40-50%, Summer tª21-28_H45-60%	25.00%
	Winter tª 19-25ºC_H40-50%, Summer tª22-27_H45-60%	50.00%
	Winter tª 20-24ºC_H40-50%, Summer tª23-26_H45-60%	75.00%
	Winter tª 21-23ºC_H40-50%, Summer tª23,5-25,5_H45-60%	100.00%
Data Source	Monitoring systems or by default survey to residents.	
Actions / Interventions	Improvement of building thermal characteristics through insulation.	
Monitoring Interval	Before and after renovation.	
Target	Improvement of health & comfort of residents.	
Relationship with other KPIs	HC2, HC3, HC4	
HC2. THERMAL CHARACTERISTICS (USER & CONTROL SYSTEM)		
Defining name	**Action name**	

Category Pillar	HEALTH & COMFORT	
Social Aspect	Thermal Characteristics	
Definition	Possibility to measure and control the temperature, humidity and air distribution in the building and/or in individual rooms.	
Reference	LEVELs - Protection of occupier health and thermal comfort	
Indicators	1. Possibility to measure and control the temperature in the building and/or in individual rooms. 2. Ability to control operating temperature at building level and/or in individual spaces. 3. Ability to control humidity at building level and/or in individual spaces. 4. Ability to control air distribution at building level and/or in individual spaces.	
Unit of measurement	No.	0.00%
	Yes, in less than 25% of the spaces.	25.00%
	Yes, ≥ 25% and <50% of the spaces are possible.	50.00%
	Yes, ≥50% and <75% of the spaces are possible.	75.00%
	Yes, in 75% or more of the spaces.	100.00%
Data Source	Survey to residents.	
Actions / Interventions	Installation of control devices for HVAC systems.	

Monitoring Interval	Before and after renovation.	
Target	Residents' accessibility to control temperature, humidity, and air flow.	
Relationship with other KPIs	HC1, HC3, HC4	

HC3. INDOOR AIR QUALITY (BUILDING)		
Defining name	**Action name**	
Category Pillar	HEALTH & COMFORT	
Social Aspect	Indoor Air Quality	
Definition	Control of construction products and materials that may be potential sources of volatile organic compounds. For example (paints and varnishes, floor coverings, adhesives and sealing agents, particle boards, etc.).	
Reference	LEVELs - Protection of occupier health and thermal comfort	
Indicators	1. Declare substance emissions in building materials used.	
Unit of measurement	YES	100.00%
	NO	0.00%
Data Source	Survey to pilots	
Actions / Interventions	Use of environmentally friendly materials.	
Monitoring Interval	Before and after renovation.	
Target	Reduction of construction materials with high levels of volatile compounds.	

Relationship with other KPIs	HC1, HC2, HC4	
HC4. INDOOR AIR QUALITY (USER & CONTROL SYSTEM)		
Defining name	**Action name**	
Category Pillar	HEALTH & COMFORT	
Social Aspect	Indoor Air Quality	
Definition	Existence of ventilation control in the building. Users' ability to control ventilation automatically and/or manually. Existence of CO2 concentration and humidity measurements and monitoring in individual spaces.	
Reference	LEVELs - Protection of occupier health and thermal comfort	
Indicators	1. Is there any ventilation control that can be used by users automatically or manually? 2. Are there any monitoring devices to check the CO2 concentration in individual spaces? 3. Are there any monitoring devices to check humidity in individual spaces?	
Unit of measurement	No.	0.00%
	Yes, in less than 25% of the spaces.	25.00%
	Yes, ≥ 25% and <50% of the spaces are possible.	50.00%
	Yes, ≥50% and <75% of the spaces are possible.	75.00%
	Yes, in 75% or more of the spaces.	100.00%

Data Source	Survey to residents	
Actions / Interventions	Installation of monitoring systems and control devices for HVAC systems	
Monitoring Interval	Before and after renovation.	
Target	Allow users to control the HVAC systems and monitor key variables for their comfort.	
Relationship with other KPIs	HC1, HC2, HC3	
HC5. ACOUSTIC CHARACTERISTICS		
Defining name	**Action name**	
Category Pillar	HEALTH & COMFORT	
Social Aspect	Acoustic Characteristics	
Definition	Noise levels of service equipment, such as sanitary and ventilation systems, as well as other environmental noise sources.	
Reference	LEVELs - Acoustics and protection against noise	
Indicators	Have noise levels from service equipment, such as sanitary and ventilation systems, as well as other sources of environmental noise been considered in the facilities design	
Unit of measurement	NO	0.00%
	YES	100.00%
Data Source	Survey to residents	

Actions / Interventions	Installation of service equipment with a low noise impact
Monitoring Interval	Before and after renovation.
Target	Reduction of environmental noises

HC6. VISUAL COMFORT (BUILDING)

Defining name	**Action name**	
Category Pillar	HEALTH & COMFORT	
Social Aspect	Visual Comfort	
Definition	Daylight contribution: Daylight factor (%).	
Reference	LEVELs - Lighting and Visual Comfort	
Indicators	Most spaces have an average DF (Daylight factor) of:	
Unit of measurement	Unknown	0.00%
	<2%	33.33%
	2% to 5%	66.66%
	>5%	100%
Data Source	Survey to pilots if they performed any daylight study before and renovation.	
Actions / Interventions	Integrating daylight strategies can reduce a building's reliance on artificial lighting, benefiting the resident’s health & comfort and reducing energy bills.	

Monitoring Interval	Before and after renovation.	
Target	Improve Daylight factor according to LEVELs framework to benefit residents health and comfort and reduce energy bills.	
Relationship with other KPIs	HC7	

HC7. VISUAL COMFORT (USER & CONTROL SYSTEM)		
Defining name	**Action name**	
Category Pillar	HEALTH & COMFORT	
Social Aspect	Visual Comfort	
Definition	Users' ability to control the amount of daylighting in individual spaces.	
Reference	LEVELs - Lighting and Visual Comfort	
Indicators	Are there systems (blinds, shutters, blinds, etc.) to control the amount of daylighting? Users' ability to control the amount of daylighting in individual spaces.	
Unit of measurement	No.	0.00%
	Yes, in less than 25% of the spaces.	25.00%
	Yes, ≥ 25% and <50% of the spaces are possible.	50.00%
	Yes, ≥50% and <75% of the spaces are possible.	75.00%
	Yes, in 75% or more of the spaces.	100.00%

Data Source	Survey to residents
Actions / Interventions	Installation of daylighting control systems
Monitoring Interval	Before and after renovation.
Target	Users ability to control the amount of daylighting in individual spaces.
Relationship with other KPIs	HC6

SAFETY & SECURITY

SS1. RESILIENCE TO CLIMATE CHANGE

Defining name	**Action name**	
Category Pillar	SAFETY & SECURITY	
Social Aspect	Resilience to Climate Change	
Definition	Under resilience for climate change KPI, wind resistance & strength to solar radiation have been taken into consideration.	
Reference	[LEVELs - Increased risk of extreme weather events]	
Indicators	1. Have measures been taken to prevent the detachment of facade elements? 2. Are there solar control measures (shading elements,blinds, types of window glazing, etc.) to control the amount of solar radiation? 3. Possibility of using air-conditioning or ventilation systems.	
Unit of measurement	NO	0.00%

	YES	100.00%
Data Source	Survey to pilots	
Actions / Interventions	Implementation of security measurements for avoidance of facade elements detachment, solar control measures and HVAC systems.	
Monitoring Interval	Before and after renovation.	
Target	Assessing potential risks and vulnerabilities to extreme weather events in the region and building plot.	
Relationship with other KPIs	SS2, SS3	

SS2. RESILIENCE TO ACCIDENT BEHAVIOUR	
Defining name	**Action name**
Category Pillar	SAFETY & SECURITY
Social Aspect	Resilience to Accident Behaviour
Definition	Under resilience to accident behaviour KPI, seismic resistance and burning behaviour have been taken into consideration.
Reference	LEVELs - Increased risk of extreme weather events European Fire Standards and National Legislations

Indicators	1. Are elements with higher fire resistance classes used or other measures included in the design to improve the load-bearing capacity, integrity and/or insulation of the building elements? 2. Are elements with higher fire resistance classes used or other measures included in the design to improve the load-bearing capacity, integrity and/or insulation of the building elements?	
Unit of measurement	No, in most of the buildings, only the limit required by the regulations is met.	0.00%
	Yes, in more than 50% of the building components, the limit required by the regulations is exceeded.	100.00%
Data Source	Survey to pilots	
Actions / Interventions	Assessing materials comply with fire resistance regulations and assessing vulnerabilities to extreme weather events in the region and building plot.	
Monitoring Interval	Before and after renovation.	
Target	Make the building more resilient and resistant to extreme weather events and fire resistance.	
Relationship with other KPIs	SS1, SS3	

SS3. PEOPLE AND PROPERTY SECURITY

Defining name	**Action name**
Category Pillar	SAFETY & SECURITY
Social Aspect	People and Property Security

Definition	Impact resistance of building envelopes to protect against vandalism and other security measures in the building have been taken into consideration under this KPI.	
Indicators	Does the building envelope exceed the impact resistance to protect against vandalism? Is there a security lock system? Does the building have motion sensitive lighting in the common areas? Are there any alarm surveillance systems?	
Unit of measurement	NO	0.00%
	YES	100.00%
Data Source	SCLA RINNO Project	
Actions / Interventions	Installation of security measures to protect residents, assuring their safety within the property at building level.	
Monitoring Interval	Before and after renovation.	
Target	Assessment of security measures to be implemented at building level to assure residents safety.	

ENERGY POVERTY

EP1. ENERGY POVERTY EXPENDITURE AS PERCENTAGE OF INCOME

Defining name	**Action name**
Category Pillar	ENERGY POVERTY

Social Aspect	People Poverty
Definition	Energy poverty arises from the combination of low-income households, high energy consumption and low energy efficient houses. It can be addressed by improving key elements that contribute to the thermal quality of buildings. Reducing energy poverty is crucial for fostering social equity, improving public health, enhancing economic productivity, promoting environmental sustainability, and supporting global sustainable goals. It contributes to resilient communities, urban development, and energy and security while aligning with government policies for social stability and overall community well-being.
Reference	This KPI has been evaluated within the financial analysis above (Financial KPIs - Energy Expenditure as a percentage of income)
Unit of measurement	% Of Energy Expenditure as a Percentage of Income
Actions / Interventions	Improvement of Energy Efficient measures through adding insulation to walls, floors, roof and replacement of windows.
Monitoring Interval	Before and after renovation.
Target	Reducing energy poverty in risk areas through EE building rehabilitation.
Relationship with other KPIs	Financial: Energy Expenditure as a percentage of income
EP2. JOB CREATION	
Defining name	**Action name**
Category Pillar	ENERGY POVERTY
Social Aspect	Job Creation

Definition	Job creation serves as a direct route to fulfil energy poverty, through improving their economic circumstances. A research study conducted by the International Labour Organization (ILO) found that countries with higher employment levels tend to have lower poverty rates. Moreover, job creation has social implications such as improving individuals' overall quality of life.	
Reference	International Labour Organization (ILO) - Working Towards Sustainable Development - Opportunities for decent work and social inclusion in a green economy.	
Indicators	1. Will the refurbishment create any new jobs? 2. Are there any of these jobs expected to last even after the refurbishment?	
Unit of measurement	NO	0.00%
	YES	100.00%
Data Source	Survey to pilots	
Actions / Interventions	Assessment of job creation through Energy Efficient building renovations.	
Monitoring Interval	Before and after renovation.	
Target	Creation of new job opportunities within the building sector.	

6.3. Environmental Impact Assessment of the solutions proposed per pilot

The interventions on the pilots for the building envelope and systems, along with the addition of energy-efficient equipment and renewable energy sources, may have a variety of effects on different environmental aspects:

- **Atmosphere:** By increasing the building's energy efficiency, the suggested improvements hope to lower greenhouse gas emissions. By substituting energy sources based on fossil fuels, the installation of renewable energy sources would further cut emissions.

- **Water:** The building may consume less water as a result of the heating system improvement and the installation of heat-reclaiming ventilation systems. However, when exposed to moisture, insulation materials can absorb water, which could negatively impact the surrounding buildings as well as their ability to provide thermal insulation.
- **Waste:** Renovating buildings using circular principles can help cut down on waste. For instance, modernising and increasing the energy efficiency of existing EU buildings is largely attributed to the renovation wave. Nevertheless, waste could be produced during renovating, particularly if outdated items are taken out and not recycled.
- **Construction Materials:** New building materials will be used during the renovation procedure. The environmental effect can be reduced if these resources are procured responsibly and used effectively. By lowering the need for heating and cooling, insulation in the building envelope can also lower the need for materials that produce energy.
- **Social:** Renovations to a building may affect how space is used or result in the temporary relocation of its tenants, among other social effects. But these upgrades can also result in better living conditions and a decrease in energy poverty. Resilient communities and energy independence can be enhanced by the installation of renewable energy sources, such as rooftop photovoltaic panels.

An extensive, high-level evaluation of the environmental effects connected to the suggested interventions is given in this table. The evaluation is based on the results that are commonly found in Life Cycle Assessments (LCAs) for similar treatments. Later in the publication, a more thorough analysis of the pilots before and after renovations was established, offering more specific details on the implementations carried out.

INTERVENTION DESCRIPTION	ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACT	COUNTRY		
			ITALY	DENMARK	SLOVENIA
Window Fittings	Atmosphere	Potential for greenhouse gas emissions	Moderate	Moderate	High
	Water	Potential for water pollution due to manufacturing	Low	Low	Low
	Land	Potential land degradation due to raw material extraction	Low	Low	Low
	Waste	Potential for waste generation due to production and disposal	Moderate	Moderate	Moderate
	Construction Materials	Potential for environmental impact due to use of various materials	Moderate	Moderate	Moderate

	Energy	Potential of increment of energy use through production and installation phase	Moderate	Moderate	Moderate
	Social	Potential of activity disruption of residents due to installation	Low	Low	Low
External/Internal Coating	Atmosphere	Potential for greenhouse gas emissions	Moderate	Moderate	Moderate
	Water	Potential for water pollution due to manufacturing	Low	Low	Low
	Land	Potential land degradation due to raw material extraction	Low	Low	Low
	Waste	Potential for waste generation due to production and disposal	Moderate	Moderate	Moderate
	Construction Materials	Potential for environmental impact due to use of various materials	Moderate	Moderate	Moderate
	Energy	Potential of increment of energy use through production and installation phase	Low	Low	Low
	Social	Potential of activity disruption of residents due to installation	Moderate	Moderate	Moderate
HVAC Renovations	Atmosphere	Potential for greenhouse gas emissions	High	High	High
	Water	Potential for water pollution due to manufacturing	Low	Low	Low
	Land	Potential land degradation due to raw material extraction	Low	Low	Low

	Waste	Potential for waste generation due to production and disposal	Moderate	Moderate	Moderate
	Construction Materials	Potential for environmental impact due to use of various materials	High	High	High
	Energy	Potential of increment of energy use through production and installation phase	High	High	High
	Social	Potential of activity disruption of residents due to installation	Moderate	Moderate	Moderate
Renewable Sources - Solar Panels	Atmosphere	Potential for greenhouse gas emissions	High	High	High
	Water	Potential for water pollution due to manufacturing	Moderate	Moderate	Moderate
	Land	Potential land degradation due to raw material extraction	Moderate	Moderate	Moderate
	Waste	Potential for waste generation due to production and disposal	High	High	High
	Construction Materials	Potential for environmental impact due to use of various materials	High	High	High
	Energy	Potential of increment of energy use through production and installation phase	Moderate	Moderate	Moderate
	Social	Potential of activity disruption of residents due to installation	Moderate	Moderate	Moderate

6.4. Evaluation of LCA & SLCA for Pilot site before and after renovation

Given the limited availability of data from the pilots regarding the quantity of materials used for the renovation, conducting a comprehensive Life Cycle Assessment (LCA) for each building will not be feasible. Consequently, the analysis will pivot towards assessing the improvement of materials, HVAC systems, and renewable energy utilisation by comparing the building's baseline with its state post-renovation.

In order to evaluate both the initial and implemented solutions effectively, a comparative analysis will be carried out for each pilot case scenario. This analysis is crucial for evaluating the Environmental Impact and Social Impact of the solutions. To streamline this evaluation process, we will utilise the Eco-Portal (https://www.eco-platform.org/epd-data.html), a platform that houses Environmental Product Declarations (EPDs) for various building and construction components. The Eco-Platform acts as a unifying body for EPD Programme operators throughout Europe, providing a comprehensive resource for assessing environmental and social impacts in the construction industry.

6.3.1 DENMARK

The Danish pilot scheme comprises 17 buildings across 3 social housing schemes located in north and central Denmark. These are low density (1-3 story) buildings, each divided into between 40 and 200 individual units. Most of the Danish housing stock evaluated for this project has been developed between 1980 and 2000 and have undergone gradual renovations during the previous 40 years.

The country's recent efforts to comply with more stringent thermal efficiency regulations, implemented since the mid 1970´s, at both EU and national levels, are demonstrated by the EPC values. This means that some improvements that enhance insulation and retrofitting windows will significantly increase the energy efficiency of the building, leading to an estimated saving of 20-30% on energy bills. This not only improves comfort for vulnerable families but also underscores the social dimension of these enhancements. The table below shows the energy performance certificate on the baseline of the buildings conforming the 3 Pipelines and their CO2 emissions based on the EPC .

<table>
<tr><th>Development Name</th><th>Building Name</th><th>Year</th><th>EPC Rate</th><th>Global Warming (kg CO2 eq)</th></tr>
<tr><td colspan="2">Housing Areas Børglumparken</td><td>1986-89</td><td>D</td><td>5.99</td></tr>
<tr><td rowspan="6">Fruehoejgaard Social Housing Company</td><td>Afdeling Søndergade</td><td>1904-1917</td><td>D/E</td><td>5.63</td></tr>
<tr><td>Vaevergaarden</td><td>1985</td><td>C</td><td>5.91</td></tr>
<tr><td>Storgaarden</td><td>1993-2003</td><td>C</td><td>7.39</td></tr>
<tr><td>Afdeling 9</td><td>1993-2003</td><td>B/C/D</td><td>2.85</td></tr>
<tr><td>Hammerthor</td><td>2003</td><td>B</td><td>3.5</td></tr>
<tr><td>Frisenborgparken</td><td>1989</td><td>C</td><td>1.85</td></tr>
</table>

Himmerland Boligforening Social Housing Company	Afdeling 20 Hvalpsundvej, Aalborg	1981	C	5.1
	Afdeling 21, Næssundvej, Aalborg	1983	E	4.96
	Afdeling 23, Vildsundvej, Aalborg	1986	D	5.27
	Afdeling 24, Oddesundvej, Aalborg	1981	C	6.32
	Afdeling 40, Fredrik Bajersvej, Aalborg	1979	C	4.84
	Afdeling 35, Runddyssen, Svenstrup	1981	C	4.81
	Afdeling 36, Runddyssen, Svenstrup	1982	C	5.02
	Afdeling 37, Hellekisten, Svenstrup	1985	B	5.42

After previous analysis on D3.3 on the impact of different construction solutions and energy systems based on Energy Efficiency, LCA and SLCA analysis, the following solutions have been implemented:

Pipeline 1: Housing Areas Børglumparken

WINDOWS: Replacement of the double glass window -> Low energy 3-layer glass window. Two options have been assessed from EPD registration S-P-01969. All products consist of a glass cassette that is mounted in a frame/profile which may consist of wood or wood/aluminium. The windows have a U-factor of 1.1 W/m2K. The glass cassettes are triple insulated 3-glass. All products are produced in the factory in Edsbyn, and the wood used in the frame is manufactured in Söderhamn. All the wood used is 100% pine.

Materials	Wood/Aluminium Fixed Window Triple Glass	Wood fixed Window Triple Glass
Glass cassette (kg)	26.82	26.82
Wood (kg)	7.90	7.90
Steel (kg)	0.00	0.00
Aluminium (kg)	0.94	1.58
EPDM (kg	0.26	0.26
Water based paint (kg)	0.27	0.27
Sealants (kg)	0.03	0.03
Glue (kg)	0.05	0.05
Plastic (kg)	0.11	0.11
Global warming potential (GWP)(kg $CO_{2\ eq}$)	62.1	66.7
Environmental Impact (per m2 window)		
Indicator	**Production Phase A1-A3**	

Abiotic depletion potential for fossil resources (ADPF)(MJ)	353.4	412.0
Abiotic depletion potential for non-fossil resources (ADPE)(kg Sb $_{eq}$)	0.001	0.001
Acidification potential of soil and water (AP)(kg $SO_{2\ eq}$)	0.39	0.42
Depletion potential of the stratospheric ozone layer (ODP)(kg CFC 1_{eq})	3.9E-6	4.4E-6
Eutrophication potential (EP)(kg PO_4 3-_{eq})	0.08	0.09
Formation potential of tropospheric ozone (POCP)(kg $C_2H_{4\ eq}$)	0.06	0.06
Hazardous Waste disposed (kg/ m2)	0.13	0.13
Non-Hazardous Waste disposed (kg/ m2)	1.41	1.41

Wood windows represent an important reduction in GHG emissions with a long lifespan and an important reduction in waste generation due to their sustainable materials but they require frequent maintenance (with the consequently increase of the potential formation of photochemical oxidation by 2.3 times more than plastic). In this sense, the combination of timber/wood with aluminium reduces the whole impact and includes the strength of aluminium, and it is easy to maintain, with a long lifespan.

Aluminium material has the lowest environmental impact but including the production phase the impact increases due to the high amount of energy used, the GHG emissions can be lowered when including a high rate of recycled material, otherwise this type of window could be the worst environmentally friendly, the positive aspect is its resistance to the weather conditions.

In terms of double or triple-glazed there will be the need to study in more detail their environmental impact including all the phases of the building (from A to C), in this case the impact of the production could opaque the benefits of the energy savings obtained with higher glazed windows .

HEATING: Implementation of heat recovery system, decentralised.
Decentralised heat recovery systems is a technology designed to capture residual heat generated from various industrial processes, an example are the HVAC systems. It works by transferring heat from one location to another, typically from areas where heat is produced but not utilised effectively to areas where it can be beneficially used. . Some key considerations are:

- Energy Efficiency: They will potentially improve the overall energy efficiency. By reusing residual heat from various sources and using it for other purposes, these reduce the need for additional energy generation, thereby lowering the CO2 emissions and reducing the environmental footprint.
- Resource Use: Depending on the type of recovery systems and the materials used for its construction, there may be implications on the number of materials used, which will mean a high environmental impact associated with the production phase. This could offset some of the environmental benefits gained from improved energy efficiency.
  More data will be necessary to analyse the impact of the system during production phase (A1-A3) and perform a full LCA analysis during all phases of the buildings.
- Emissions: The impact of this solution is low on CO2 emissions as explained before because it reuses the residual heat and just adding some insulation to it has a low environmental impact compared with replacing the system, where the production, use, maintenance and end of life impacts should be considered.
- Water usage: some heat recovery systems may require water for cooling. Which could have some impact on areas with water scarcity, although not in this scenery, where the impact is minimum.
- Waste generation: Minimum impact on waste generation is observed in this type of system. The waste generated will come from the maintenance phase, Proper management of this waste will be enough to minimise environmental impacts.

Pipeline 2: Fruehoejgaard Social Housing Company
WINDOWS: Replacement of the double glass window -> Low energy 3-layer glass window. This is the same solution used on Pipeline 1.
HEATING: Implementation of heat recovery system, decentralised. This is the same solution used on Pipeline 1.

Pipeline 3: Himmerland Boligforening Social Housing Company
WINDOWS: Replacement of the double glass window -> Low energy 3-layer glass window. This is the same solution used for Pipelines 1 and 2.

INSULATION: District heating grids in the housing areas must improve insulation. District heating is considered a sustainable, cost-effective decarbonized solution. It consists of a network of pipes for heating and cooling. Key considerations:

- Energy Efficiency: They will potentially improve the overall energy efficiency. They could connect renewables, residual heat, thermal storage, power grid, and thermal grid, using 50% less energy consumption than other solutions. Although it can experience heat losses during transmission and distribution in older or poorly insulated networks. This fact will be improved with the solution proposed by adding insulation.
  Moreover, its flexibility and resilience allow changes in the energy sources used and can be easily adapted in energy demands or supply. It has a positive impact on energy poverty (SLCA) mitigating the impacts of energy supply disruptions or price fluctuations.
- Resource Use: The maintenance of district heating infrastructure proposed for the Danish pilot by adding insulation to the pipes require materials and resources, which can have environmental impacts such as habitat disruption (SLCA), resource depletion, and pollution associated with manufacturing processes. This impact is low compared with the installation of a new system and will bring a better performance of the system, adding value to energy efficiency and improve the comfort of the residents.
- Emissions: It is considered a great solution to work towards the decarbonisation of heating and cooling, achieving high efficiency, renewable energy and complying with EU directives towards decarbonisation.
- Water usage: some district heating systems may require water for cooling. This could have some impact on areas with water scarcity, although not in this scenery, where the impact is minimum.
- Waste generation: Minimum impact on waste generation is observed in this type of system. The waste generated will come from the maintenance phase, Proper management of this waste will be enough to minimise environmental impacts.

In conclusion a ranking table for the solutions implemented by the Danish pilot is included to evaluate the LCA and SLCA analysis. This data has been gathered through surveys to pilots.

DENMARK			
Interventions	**LCA**	**SLCA**	**LCA/SLCA Analysis**
Windows	5	8	Replacement of windows with high performance triple glazing materials and design should be evaluated when choosing the windows (LCA). Positive impact from the point of view of the residents as they will improve the comfort and ventilation and temperature control with minimal disruption (SLCA)
Energy Supply	7	6	Heat provided by a heat network, increasing low-carbon heat options, such as heat pumps, would improve the emissions associated with heating, but would need to be decided at the municipal level. Low environmental impacting technologies to be considered (LCA). Temperature control improvement by the residents (SLCA), significant energy savings that will impact positively in residents' economy (SLCA).

6.3.2 ITALY

The main buildings that are part of the SUPER-i Italian pilot are called Boito and Montasio. The Italian pilot comprises two social housing developments in the Adriatic port of Trieste; Boito – built in 1951 which will be entirely rebuilt – and Montasio, built in 1976, which will be extensively renovated.

6.3.2.1 BOITO

The former is a complex of 8 buildings, each holding 4 small apartments (31 to 36 m2) in each of 4 floors, making a total of 128 units. It included no heating or electrical systems at the time of its construction, though some units have retrofitted gas heaters. The renovations will entirely remake the buildings to include larger, more energy efficient buildings that meet current standards, and will restore nearly green spaces. The decision to completely revamp Boito's buildings due to their poor state and non-compliance with energy efficiency regulations represents a significant step towards improving environmental sustainability and meeting regulatory standards. By undergoing thorough analysis and subsequent redevelopment, these buildings will not only meet energy efficiency regulations but also provide housing options for low-income individuals, addressing a growing demand for affordable housing.

From a Social Life Cycle Assessment (SLCA) perspective, the benefits of this redevelopment project are evident. The new developments will not only improve the living conditions of tenants but also contribute to social well-being by providing safe and energy-efficient housing options for those with limited resources. However, from a traditional Life Cycle Assessment (LCA) standpoint, it's important to acknowledge the environmental impact associated with demolishing the existing buildings and constructing new ones. The demolition process and construction activities can result in significant emissions of greenhouse gases and other pollutants. Despite this immediate impact, the long-term benefits of improved energy efficiency and reduced operational emissions from the new buildings are expected to outweigh these initial costs. To fully assess the environmental impact of the redevelopment project, more data collection and analysis are necessary. A data-driven approach will provide insights into the specific emissions and resource consumption associated with demolition, construction, and long-term operation of the new buildings. This information can inform decision-making processes and help identify opportunities to minimise environmental impact throughout the project lifecycle. Overall, while there may be short-term environmental challenges associated with the redevelopment of Boito's buildings, the long-term benefits in terms of energy efficiency, social well-being, and environmental sustainability are likely to be substantial. Continued monitoring and evaluation will be essential to ensure that the project achieves its sustainability goals effectively.

The table below shows the proposed solutions for the new development.

Boito 5 - Proposed energy efficiency solutions	
Year	○ 1951
Heating	○ Centralised heating and hot water production system using a natural gas condensing boiler; ○ Installation of consumption metering system for each housing unit; ○ Heating systems with heating elements for each housing unit;
Insulation	○ The building will be thermally insulated using 100 mm thick insulating panels applied externally to the walls (with a coat type system) and laid on the floor on the mezzanine;

	○ The inter-floors and in the attic panels of different thickness in relation to the insulation is required. It will probably be decided to respect the limits in force for the energy efficiency of existing buildings;
Windows/Doors	○ External doors and windows of the housing units will be in aluminium, thermal break type with thermal glass and equipped with aluminium shutters with wing or book opening.
Lighting	○ The lamps will be low-consumption and the external lighting bodies with low light pollution.
Energy generation	○ New methane gas heat generators dedicated to the heating of housing units and to heat water production;

6.3.2.2. MONTASIO

Montasio comprises 20 towers joined into 3 complexes, holding a total of 251 units. Tower exteriors are made of reinforced concrete, internal walls and roofs are made of concrete and brick. Hot water for space heating is generated by 3 large gas boilers that produce 3.5 MWh in the basement in one of the complexes, domestic hot water is produced by ~1.2kW boilers in the individual apartments. At Montasio, the current heating infrastructure is to be replaced with high performance condensing gas boilers, and heat exchangers that reclaim waste heat will be installed. Additional insulation will be added that will reduce the U-values of external walls, and walls between heated and unheated parts of the building (basements, stairwells etc) to below 0.45W/m2K. The windows will also be replaced, reducing their U-value to below 1.3.W/m2K. The climate of Trieste is relatively mild; freezing temperatures are rare in winter, and summer highs over 30°C are uncommon. Significant space heating demand is required though, with average temperatures below 15°C for around half the year. The table below shows the energy performance certificate on the baseline of the buildings conforming the Italian pilots and their CO2 emissions based on the EPC.

Building Name	Year	EPC Rate	Global Warming (kg CO2 eq)
Montasio 31	1976	F	2.89
Boito 5	1951	G	4.45

Environmental and Social Impact Analysis of the solutions implemented in Montasio:

HEATING: Replacement of centralised heat generators with new natural gas condensing boilers with heat exchangers. The replacement of centralised heat generators with new natural gas condensing boilers with heat exchangers compared to existing centralised heat generators requires consideration of various factors, including energy efficiency, emissions, costs, and operational characteristics. To that end, a comparative analysis of the two systems is provided.

Energy Efficiency: New natural gas condensing boilers are known for their high energy efficiency, typically achieving efficiencies of over 90%. They recover heat that would otherwise be lost in conventional boilers, thereby maximising energy utilisation. The efficiency of existing centralised heat generators may vary depending on factors such as the age and condition of the equipment. Older boilers or heat generators may have lower efficiency compared to modern condensing boilers. This solution will impact positively in resident's economy (SCLA) and comfort. The efficiency of the system will impact positively in the volume of energy used, reducing it considerably thereby reducing the environmental impact (LCA).

Emissions: Condensing boilers burning natural gas generally produce lower emissions of greenhouse gases and pollutants compared to older boilers. This is due to their higher efficiency and cleaner combustion technology. In contrast, older centralised heat generators may emit higher levels of pollutants such as nitrogen oxides (NOx) and carbon monoxide (CO) compared to modern condensing boilers. Upgrading to newer equipment can help reduce emissions and improve air quality, contributing to a lower environmental impact (LCA) and having a positive impact on residents' health (SLCA).

Resource use: The installation of new natural gas condensing boilers is frequently associated with the use of materials such as steel, copper, and insulation. While these materials are readily available, their extraction and processing can have ecological impacts such as habitat destruction and energy consumption. More data will be needed to analyse the production phase (LCA-A1-A3). If these components are not obtained sustainably or disposed of in an environmentally friendly manner, they may contribute to resource depletion. Therefore, it is essential to weigh the environmental implications of these actions and take measures to minimise their negative effects where practicable (LCA).

Operational characteristics: Condensing boilers with heat exchangers are typically more compact and easier to install than older centralised heat generators. They also offer better control over heating output and can modulate their operation to match varying demand, improving overall system efficiency, and allowing residents to have control of the temperature, with a positive impact in the comfort (SLCA). In contrast, older centralised heat generators may be less flexible in responding to changes in heating demand and may require more manual intervention for operation and maintenance.

Water use: New Natural Gas Condensing Boilers have a relatively low environmental impact (LCA) on water usage due to their efficient operation and minimal water consumption. However, local water availability and quality concerns must be considered, particularly in regions experiencing water scarcity or pollution issues.

Waste generation: Replacing centralised heat generators with new natural gas condensing boilers with heat exchangers presents many benefits. However, the installation of new boilers may generate waste materials that require proper disposal or recycling. Older centralised heat generators may also generate waste materials and require proper disposal or recycling to prevent environmental harm. Proper waste management practices are crucial to reduce the environmental impact of heating systems (LCA).

INSULATION: It will probably be decided to respect the limits in force for the energy efficiency of existing buildings. The environmental impact of leading wall insulation materials was assessed through a literature analysis. EPS, stone wool, and glass have similar environmental impacts, which are lower than XPS, PUR, and other non-renewable materials. Cellulose and renewable-based materials have the lowest environmental impact. According to Stefan Füchsl et al[56] cellulose and hemp are the most environmentally friendly materials, followed by EPS, glass wool, stone wool, XPS, PUR, and cork. However, the impact of

[56] Stefan Füchsl, Felix Rheude, Hubert Röder, Life cycle assessment (LCA) of thermal insulation materials: A critical review, Cleaner Materials, Volume 5, 2022, 100119, ISSN 2772-3976, https://doi.org/10.1016/j.clema.2022.100119.

added materials, such as binders and additives, should not be ignored. Renewable resource materials combined with appropriate additives and binders could potentially reduce environmental impact.

WINDOWS: Replacement of windows delimiting the heated volume. The new windows will be made of materials with high insulating power. Replacing aluminium windows with high-insulating alternatives offers numerous benefits, including improved energy efficiency (LCA/SLCA) by reducing the heat transfer between the interior and exterior of the windows; enhanced comfort (SLCA) by maintaining more consistent indoor temperatures; reduced maintenance(LCA/SLCA) by minimising condensation build up that happens with the aluminium frames and can lead to moisture related issues, as well longer lifespan; noise reduction(SLCA) by providing better sound insulation, creating a quieter and more pleasant indoor environment; design flexibility, and environmental sustainability (LCA) by reducing energy consumption for heating and cooling, high-insulating windows contribute to environmental sustainability and help mitigate climate change. Additionally, materials such as uPVC and fibreglass are recyclable, further reducing their environmental impact.

LIGHTING: The lamps will be low-consumption and the external lighting bodies with low light pollution. Using low-consumption lamps and external lighting fixtures with low light pollution can have numerous environmental benefits, including energy savings (SLCA), resource conservation, reduced light pollution, and preservation of wildlife and ecosystems. By directing light downward and using shielding to prevent light from spilling into the sky or neighbouring properties, these fixtures can minimise glare and skyglow, improving visibility of stars and reducing energy waste. Adopting these practices can also contribute to regulatory compliance with environmental regulations and sustainable development.

ENERGY GENERATION: Exploitation of renewable energies (photovoltaic panels). While photovoltaic panels are beneficial for the environment by producing clean electricity, their entire lifecycle, including production, use, and end-of-life management, involves environmental trade-offs (LCA) that require careful consideration and mitigation through sustainable practices and policies. In addition to their environmental benefits, photovoltaic panels can provide energy benefits for residents of buildings (SLCA).

In conclusion a ranking table for the solutions implemented by the Italian pilot is included to evaluate the LCA and SLCA analysis. This data has been gathered through surveys to pilots.

ITALY - MONTASIO 31			
Interventions	**LCA**	**SLCA**	**LCA/SLCA Analysis**
Windows	8	8	Replacement of the aluminium windows for high performance ones will improve energy efficiency (LCA), enhance comfort (SLCA), reduce maintenance (LCA/SLCA), provide better sound insulation (SLCA), contribute to environmental sustainability and help mitigate climate change (LCA).

Walls	6		Adding insulation to the external walls will improve the energy savings (LCA) which result in resource conservation (LCA) and extend the building lifespan(LCA). Although it will generate an impact on the production phase and end-of-life phase that should be taken into consideration (LCA). On the social part an improvement of indoor air quality which leads to improved health and well-being and comfort of the residents has been observed (SLCA).
Energy Supply	7	7	Development proposes to supply heat using gas boilers, low carbon HP would reduce the emissions significantly. Low environmental impacting technologies to be considered (LCA). Temperature control improvement by the residents (SLCA), significant energy savings that will impact positively in residents' economy (SLCA).
Renewable Energy	6	6	Photovoltaic panels have been added to the roof. An environmental impact reduction is observed in comparison with the use of fossil fuels (LCA). Although it needs to be considered the impact of the production and end of life of this product(LCA). They will provide energy benefits to residents (SLCA)

6.3.3 SLOVENIA

The main buildings that are part of the SUPER-i Slovenian pilot are in Trbovlje. The Slovenian pilot comprises a single four-floor building comprising 26 apartments, located in Trbovlje, and was built in 2005. Given the recency of its construction, most of the components were built to high standards, and it is not considered cost-effective to replace the windows; instead proposed renovations involve refurbishment of the heating system, and the addition of insulation to the roofs and external walls. The improvements proposed to the building include injecting insulation into the exterior walls; these are 20 and 10 cm brick cavity walls. This is expected to reduce the heat lost through the walls by a factor of 4. The other components of the building fabric are already built to a high standard, and it is not economical to upgrade them at this stage. Environmental and air quality benefits are likely to be achievable through the installation of heat pumps, but these are not included in the proposal. We have also considered the addition of rooftop PV; the solar resource in the country is good and the grid is ~30% renewable, so significant emissions savings could be achieved, but the specifics of this building as a site for solar generation are not available. The table below shows the energy performance certificate on the baseline of the buildings conforming to the Slovenian pilot and their CO2 emissions based on the EPC and the solution implemented.

Building Name	Year	EPC Rate	Global Warming (kg CO2 eq)	Insulation
Neža 26 a in b	2005	F	10.3	Insulation on exterior walls and roof

Environmental and Social Impact Analysis of the Slovenian pilot:

Previously, several improvements were analysed (D3.3) and some were rejected after evaluating their Life Cycle Assessment (LCA), Social Life Cycle Assessment (SLCA), and economic feasibility. A detailed examination of the implemented solutions is now presented below, and a summary of the findings is provided in the subsequent table.

INSULATION: Adding insulation to walls and roof. In general, injected insulation can be a useful and practical approach for enhancing a building's energy efficiency (LCA/SLCA) and comfort (SLCA). In this case it will potentially benefit the compliance with EU regulation towards EPC with values D-E. Nonetheless, it is crucial to consider the potential disadvantages and restrictions of this insulation method. It is also essential to select the appropriate materials and installation techniques based on the unique features and requirements of the building. More detailed data needs to be collected to provide a more detailed assessment.
From an environmental perspective, injected insulation can help reduce greenhouse gas emissions (LCA) by minimizing heat transfer through walls and roofs, which leads to lower energy consumption and saving on energy bills (SLCA) for heating and cooling. By reducing energy consumption, injected insulation can help decrease reliance on fossil fuels and, in turn, reduce carbon dioxide emissions. Moreover, injected insulation can be made from recycled materials or natural fibres, making it an eco-friendly insulation option that can reduce waste and promote sustainable practices. It can enhance the comfort of indoor spaces (SLCA) by maintaining consistent temperatures throughout the year, eliminating drafts, cold spots, and overheating, improving health and well-being for building occupants, particularly those who are vulnerable to temperature-related health issues. Furthermore, injected insulation can reduce noise transmission between indoor and outdoor spaces, improving acoustics and reducing disturbances from external sources such as traffic or neighbours, enhancing a better quality of life for building occupants. Moreover, injected insulation is a non-invasive option that can be installed without extensive construction work or disruption to the building's occupants (SLCA), reducing the environmental impact (LCA) of the installation process.

SLOVENIA - Neža 26 a in b			
Interventions	**LCA**	**SLCA**	**LCA/SLCA Analysis**
Windows	N/A	N/A	*Note: Buildings are already built to a high standard. Social and environmental considerations should be considered (LCA and SLCA) when refurbishing. Not much LCA and SLCA impact is expected.*
Walls	7	6	Savings of around 35% when significant additional lagging is added. Natural materials should be considered (LCA), it is likely to be disruptive, and may require significant works to the building envelope given the existing insulation but on the other hand comfort will be increased, natural based paints without additives should be considered as they will increase the comfort and health conditions (LCA and SLCA)

Energy Supply	7	7	Development proposes to supply heat using gas boilers, low carbon HP would reduce the emissions significantly. Low environmental impacting technologies to be considered (LCA). Temperature control improvement by the residents (SLCA), significant energy savings that will impact positively in residents' economy (SLCA).
Renewable Energy	6	4	A small development and the inclusion of rooftop PV and electrical storage may be costly or disruptive. Slovenia's grid is only around one third renewable. Environmental impact reduction in comparison with fossil fuels. (LCA). Change of resident habits will be needed, residents may reject this measure (SLCA)

7. Monitoring of all phases of the actual renovation projects & post-renovation monitoring

7.1. Technical Monitoring

7.1.1. Model Validation

The simple building model developed above has been validated against very basic energy demand data, with the scaling coefficient converted into an hourly diversified occupancy profile. Assuming no changes in occupancy patterns before and after retrofit, we will be able to compare real energy demand use data after retrofit to the modelled improvements in thermal performance; any disagreement should not then be explained by occupancy patterns, so might allow us to identify where performance of the installed improvements is failing to meet, or exceeding, modelled performance. Other data from EPC and other certification processes as part of the retrofit may also inform the second step model validation, and also the update of the

7.1.2. Monitoring KPIs

The technical KPIs outlined above are, in general, difficult to assess in isolation - though they will of course contribute to the overall energy saving.
Where solar panels are installed, our estimates of the load factor for PV could be compared against the real generation data, this would allow us to validate our estimates. We note that no pipelines have committed to installation.
The accuracy of projected fuel cost savings will depend on the gas price projections, we previously used an indicative long term value of around €0.04/kWh, during 2022/3 this has risen driven by various geopolitical and economic factors, there are signs in early 2024 that these costs may be returning to the pre-pandemic levels, though we propose to include a range of cost scenarios.

7.1.3. Resident Experience

The work associated with the proposed retrofits will necessarily affect the residents during the process; the impact on residents of the retrofit will be captured using a project questionnaire, covering (at minimum) the questions below.

1. Were you aware of the process through which the proposed upgrades were decided?
2. Were you able to contribute to this process?
3. What recommendations, if any, did you make?
4. What is your understanding of the benefits of the proposed works?
5. Before the works started, what was your view on them?
6. What steps did your housing association take to make you aware of the impacts of the proposed works?
7. What possible impacts were identified?
8. What time frame were you told the works would take?
9. What impacts of the retrofit works have you seen?

10. Are the actual impacts of the retrofit works different from those suggested to you before they started?
11. What time frame did the work take?
12. Now the works have been completed, what is your view of them?

7.2. Financial monitoring

7.2.1. Monitoring KPIs

The monitoring process for the SUPER-i project involves regular annual tracking and analysis of the identified Key Performance Indicators (KPIs) designed to evaluate the EE project financial performance, funding sources, and impact on energy poverty at key intervals: beginning of the SUPER-i project, midway, and end of the SUPER-i project. Financial KPIs such as Return on Investment (ROI), Net Present Value (NPV), Payback Period, Operating Cost Reduction (OCR), and Increase in Property Value (IPV) offer insights into the project's profitability, cost-effectiveness, and potential market value enhancement. Meanwhile, funding related KPIs like Cumulative Investments by European Stakeholders, Optimal Leverage Ratio, Number of Available Innovative Funding Sources, and Capital Investment Attraction gauge the project's financial health, funding diversity, and attractiveness to external investors. Additionally, KPIs addressing energy poverty, including Energy Cost Savings (ECS), Energy Expenditure as a Percentage of Income, Energy Consumption per Sqm, Arrears on Utility Bills, and Energy Disconnection Rate, shed light on the project's socio-economic impact, focusing on reducing energy-related expenses and improving affordability for residents.

At the beginning of the project, baseline data for each KPI is collected to establish a reference point for measurement and comparison. This involves gathering financial data from sources such as LSEG financial datasets and the SUPER-i Survey, as well as relevant information on energy consumption, funding sources, and indicators of energy poverty. During the midway point of the project, progress towards project goals and targets is assessed by comparing current data against initial benchmarks. This includes evaluating financial performance metrics like ROI, NPV, and OCR to determine if the project is on track to meet its objectives. Additionally, funding related KPIs such as Cumulative Investments and Capital Investment Attraction are monitored to ensure sufficient financial support and identify any funding gaps or opportunities. At the end of the project, a comprehensive evaluation is conducted to measure the overall impact and success of the SUPER-i initiative. This involves analysing final KPI data to assess financial profitability, funding effectiveness, and improvements in energy poverty indicators. Stakeholders review the outcomes against predetermined targets and objectives to determine the project's overall effectiveness and identify lessons learned for future endeavours.

Throughout the monitoring process, stakeholders collaborate to collect data from various sources, including financial datasets, surveys, and external reports. Data analysis techniques such as trend analysis, variance analysis, and benchmarking are applied to interpret the results and derive actionable insights. Regular communication and reporting ensure transparency and accountability, allowing stakeholders to make informed decisions and adjustments as needed to optimise project performance and outcomes.

7.2.2. Ranking of PPPs

The monitoring process of ranking Public-Private Partnerships (PPPs) based on risk-adjusted extra return analysis involves meticulous steps to ensure accurate evaluation and timely updates.

At the beginning of the SUPER-i project, a thorough data collection and statistical analysis are conducted, gathering baseline data on energy market bid prices, natural gas prices, inflation rates, and interest rates on debt. This comprehensive dataset serves as the basis for the initial financial analysis of the SUPER-i proposed EE renovations specific to each pilot. Through the developed risk adjusted extra return model, an initial evaluation of PPP contracts' financial performance and associated risks is performed, initial findings are presented in the SUPER-i website (https://super-i-supershine.eu/). Scenario modelling, employing a comprehensive Monte Carlo simulation method, considers potential fluctuations in energy market conditions, enabling social housing managers to prepare for various scenarios. Midway through the project, continuous monitoring and updates allow for ongoing assessment of the PPP contracts, with updates to risk adjusted extra returns analysis and scenario modelling considering the changes in energy market prices and key macroeconomic indicators. Finally, at the end of the SUPER-i project, a comprehensive financial analysis will be conducted. Stakeholder feedback will be provided to capture valuable insights for future projects and a final monitoring report will be prepared to summarise achievements, lessons learned, and recommendations for replication to other SUPER-i pilots. This systematic monitoring approach ensures that PPP contracts remain responsive to changing market conditions, maximising their effectiveness and sustainability.

7.3. Environmental monitoring

7.3.1. Monitoring KPIs

7.3.1.1. Social Key Performance Indicators (KPIs) Objective:

The primary aim of the Social KPIs is to monitor and track the environmental impact of Energy Efficiency renovations at the building level. Additionally, it seeks to establish stronger connections between local and national initiatives. These KPIs are intended to foster greater citizen engagement, inform policy making processes, and drive investment towards sustainable practices. Moreover, they are designed to assist stakeholders in developing effective strategies, identifying best practices, facilitating replication, and serving as a starting point for proposing Social Housing Energy Efficiency renovation projects.

7.3.1.2. Data Collection and Monitoring Approach:

Monitoring these KPIs entails a two-stage data collection process. Firstly, it involves establishing a baseline for each building to gather essential data regarding its current state. Subsequently, a second round of data collection is conducted post-renovation. The timeframe for this data collection phase should ideally be defined within the renovation project, typically spanning one year. Further details regarding the data collection methodology are provided in Section 6.1, particularly in the tables under the data collection section. It is imperative to acknowledge and incorporate this information as it contributes to obtaining valuable data for analysis and drawing conclusions.

The approach to data collection is formulated from a holistic standpoint, allowing for data to be sourced from various channels. This approach is adopted due to variations in data availability across different buildings, as well as the absence of standardised regulations across EU countries. In some instances, accessing public data may be necessary to supplement the data collection process.

7.3.1.3. Data Evaluation and Analysis:

Upon collecting baseline and post-renovation data, a thorough evaluation will be conducted to extract meaningful insights. This evaluation aims to establish a comprehensive database outlining the strengths and weaknesses observed during the renovation process. These findings will be instrumental in deriving conclusions regarding the effectiveness of the renovation efforts. Moreover, they will serve as valuable lessons learned for informing future projects.

7.4. Social monitoring

7.4.1. Social Key Performance Indicators (KPIs) Objective:

The Social Key Performance Indicators serve to comprehensively examine the outcomes of renovation projects across various categories, with a primary focus on tenants. These indicators are particularly relevant during the operational phase of the building, acting as essential assessment tools for evaluating enhancements in household living conditions.

7.4.2. Data Collection and Monitoring Approach:

The monitoring and data collection approach for Social KPIs is designed to integrate considerations of household energy poverty, health and safety, accessibility, and security. The data collection should be done to the households through surveys before the renovation and after it. By incorporating these considerations, the evaluation of the social impact of the building renovation will be evaluated, particularly focusing on the well-being of tenants and the community.

7.4.3. Data Evaluation and Analysis:

A scoring system has been implemented for each category and social aspect, drawing upon methodologies developed by CIRCE in previous EU projects such as RINNO, RESPONSE[57], and INCUBE[58]. This scoring system has been adapted to suit the specific requirements of the SUPER-i project. The questionnaire, along with its corresponding scores, has been included to facilitate data collection in section 6.2 of this document . These indicators are analysed both before and after renovation to evaluate data through comparison and assess the effectiveness of implemented renovations. Data provided by the pilots and their inhabitants are considered in this evaluation process.

[57] Assessing Impact, Performance and Sustainability Potential of Smart City Projects: Towards a Case Agnostic Evaluation Framework – RESPONSE. (2021, July 9). https://h2020response.eu/publication-posts/assessing-impact-performance-and-sustainability-potential-of-smart-city-projects-towards-a-case-agnostic-evaluation-framework/

[58] 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, 2046. https://doi.org/10.3390/buildings13082046

8. Conclusion

In conclusion, the comprehensive feasibility assessment for the investment pipeline in Italy, Denmark, and Slovenia underscores the importance of addressing energy efficiency in social housing. The development and application of the energy-saving model for the SUPER-i project pipeline buildings provide a robust framework for reducing energy consumption and environmental impact. This model accurately predicts space heating demand and enables estimation of energy, fuel, and emissions savings associated with retrofitting, thereby facilitating informed decision-making.

Financially, the analysis reveals significant disparities in energy efficiency needs and funding availability across the three countries. While ageing infrastructure in Italy and Slovenia necessitates substantial investments for renovations, Denmark's buildings require comparatively less extensive upgrades. Despite substantial funding from both EU and national levels, a financial gap remains in all three countries. This highlights the need for strategic planning and collaboration to bridge shortfalls and maximise the impact of energy efficiency initiatives. Various funding sources, including EU-level initiatives and country-specific programs, offer financial support for sustainable development and energy efficiency improvements. Innovative financing solutions such as public-private partnerships and energy supply contracts provide mechanisms for financing EE renovation projects, aiming to address energy poverty concerns and promote energy efficiency improvements in social housing across Europe.

Furthermore, the integration of Life Cycle Assessment (LCA) and Social Life Cycle Assessment (SLCA) methodologies ensures a comprehensive evaluation of environmental and social impacts. Environmental KPIs and Social KPIs monitor key metrics, fostering collaboration among stakeholders and ensuring equitable access to energy resources. This holistic approach enhances understanding of the social impact of building renovations and contributes to sustainability goals.

Overall, the SUPER-i project represents a significant step towards achieving energy efficiency and sustainability in social housing across Europe.