Ref. Ares(2024)7238188 - 11/10/2024

SUPERSHINE

D4.1 Feasibility studies for the lighthouse districts – Part 1

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Funded by the European Union

Innovate UK

Technical references

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

Deliverable No.	D4.1
Dissemination level*	PU
Work Package	WP4 -Demonstration and Validation of the SUPERSHINE solutions in the lighthouse districts
Task	T4.1 - Feasibility Studies for the SUPERSHINE solutions
Lead beneficiary	CIRCE
Contributing beneficiary/ies	CIRCE, UoY, CARTIF, DEMIR
Due date of deliverable	29 February 2024
Actual submission date	29 February 2024

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

v	Date	Beneficiaries	Track changes
1.0	04/01/2024	CIRCE	Draft Development
2.0	23/02/2024	UoY	Revision
3.0	26/02/2024	CIRCE	Revision
3.1	28/02/2024	APRE	Final revision

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1. Introduction

1.1. Purpose of the document

This document serves as a comprehensive feasibility report for the SUPERSHINE solutions, each tailored to one of the three Lighthouse districts: Riga, Trieste, and Herning. It is important to note that this document is the first of a two-part series. As the SUPERSHINE project progresses and more data becomes available, the findings and insights presented in this initial report will be further refined and expanded upon in a subsequent document. This iterative approach ensures that our understanding and evaluation of the solutions remain up-to-date and accurately reflect the evolving realities of the Lighthouse districts.

The purpose is to provide a holistic and standalone set of studies that not only validate the technological viability of the solutions but also assess their impact on energy comfort and poverty, and social needs. It aims to provide a thorough and objective evaluation of the SUPERSHINE solutions, paving the way for informed decision-making and effective implementation of these solutions in the respective Lighthouse districts.

1.2. Interdependencies with other WPs and tasks

This Deliverable is dependent on previous deliverables *D1.2 Engagement strategy and social acceptance KPIs* and *D3.3 of social, environmental, economic, and financial key performance indicators,* from respective WPs since the indicators and methodology explained there serve as a base. At the same time, in this feasibility study, we are utilising the same data from the pilot projects as used in documents D1.2 and D3.3. However, the focus of the analysis has been shifted to align with the objectives of the feasibility studies. Lastly it will be a guideline for the WP4 Deliverables that calculate the Life Cycle Assessment and Social Life Cycle Assessment of the districts, D3.4 – *LCA and SLCA - Part 1* and *Deliverable D3.5 – LCA and SLCA - Part 2*

2. Lighthouses context review for feasibility studies

2.1. Methodology for Reporting Baseline Data in Lighthouse Districts to Evaluate the Feasibility of Technical Interventions

To establish the viability of the different interventions, it is proposed to set an initial context that allows establishing a starting point from which to assess whether these interventions are feasible, suitable, or viable based on a series of technical characteristics.

To accurately evaluate the technical context of lighthouses, it is important to establish the current situation and consider a dual scale. [1]

- **Urban scale:** planning and implementing large-scale sustainable and energy-efficient scenarios.
- **Building scale:** evaluating building stock data collection.

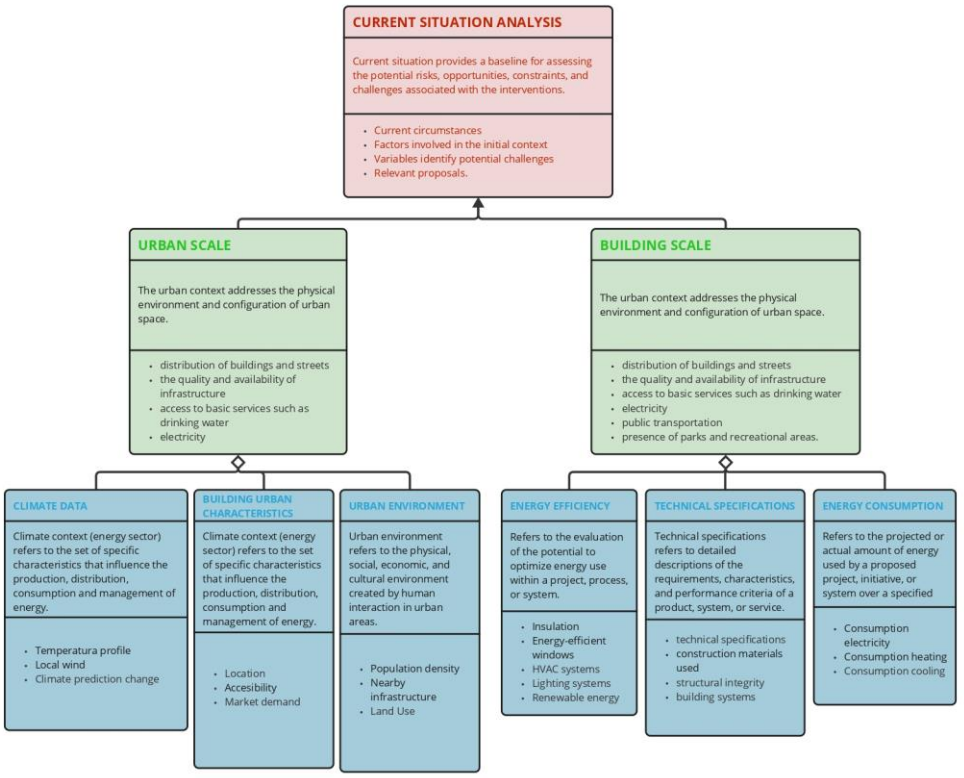

Figure 1 Establishment of the work methodology

[1] Ali, U., Shamsi, M. H., Hoare, C., Mangina, E., & O'Donnell, J. (2021). Review of urban building energy modeling (UBEM) approaches, methods and tools using qualitative and quantitative analysis. Energy and buildings, 246, 111073.

To consider the current situation, the SUPERSHINE district will define five goals or objectives to be achieved through the project's development. These objectives allow the identification of the principal interventions to be developed in different lighthouse districts. [2]

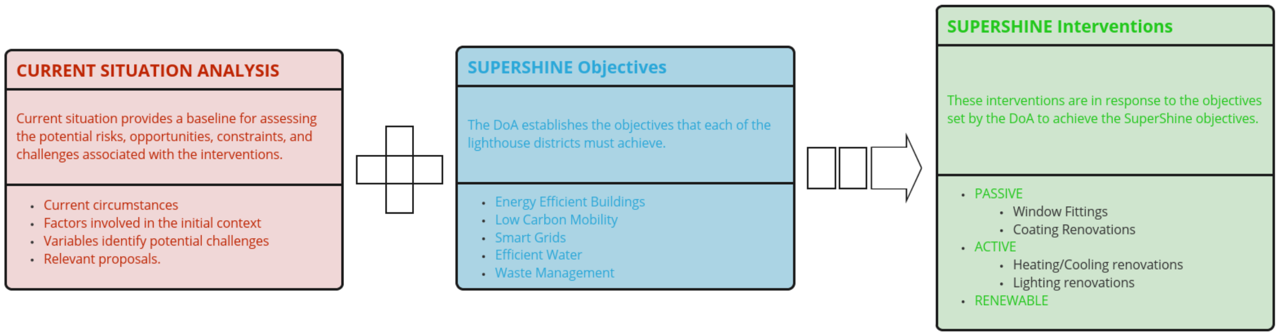

Figure 2 Summary of the work methodology Technical Interventions.

To evaluate the feasibility of the solutions in each area, only characteristics with accurate data are considered, disregarding those for which reliable information is not available[3].

2.2. Italy

2.2.1. Technical

This section discusses the initial characteristics of the Trieste district following the methodology outlined in section 2.1 of this same deliverable. The focus here is on developing an analysis of the current situation and SUPERSHINE objectives in relation to lighthouses districts.

1. Urban Scale

1. Climate data

Temperature profile
Throughout the year, the temperature generally ranges from 3°C to 29°C, rarely dropping below -1°C or rising above 32°C

[2] Johari, F., Peronato, G., Sadeghian, P., Zhao, X., & Widén, J. (2020). Urban building energy modelling: State of the art and prospects. Renewable and Sustainable Energy Reviews, 128, 109902

[3] Super Shine Project. (2022). Description of the action (DoA). 101079963. https://super-i-supershine.eu/supershine/about/

Local wind
The average hourly wind speed in Trieste has slight seasonal variations throughout the year. The windiest period lasts for 6.3 months, from October 4th to April 14th, with average wind speeds exceeding 10.1 kilometres per hour. February is the windiest month of the year in Trieste, with winds averaging 11.9 kilometres per hour. The calmest period of the year lasts for 5.7 months, from April 14th to October 4th. July is the calmest month of the year in Trieste, with winds averaging 8.1 kilometres per hour.
Climate prediction change
The climatic phenomena such as temperature increase, precipitation pattern changes, rising sea levels, and extreme weather events are closely related to oceanic climate. Climate change can intensify these effects, leading to heatwaves, more intense droughts, increased risk of coastal flooding, and more frequent extreme weather events in oceanic areas. These trends can have significant impacts on coastal and oceanic regions, exacerbating coastal erosion and community vulnerability.

2. Urban characteristics of the building

Location
The complex, constructed in 1951 by G.M.A, is slated for a comprehensive building renovation. The primary aim is to address the functional obsolescence and technological inadequacy of the buildings, characterised by minimal housing types and deterioration, through a series of organised redevelopment efforts. These include upgrading utility networks, improving road infrastructure and parking, restoring green spaces, and refurbishing buildings to accommodate diverse housing units meeting contemporary standards and varying sizes suitable for different family compositions and age groups.
Accessibility
The area has good connectivity to key services such as primary schools and recreation centres for children, sports facilities, churches, and commercial centres.
Market demand
To calculate the market demand of the district, the prices of several properties for sale have been considered and compared with the market price in the city. The area shows a decrease of 30% in property value; therefore, it is understood that the demand is low.

3. Urban environment

In the Trieste district, this section about the urban environment is not taken into consideration, as sufficient data were previously available to support the feasibility of the proposed interventions and to further enhance and propose additional interventions in line with this context.

2. Building Scale

1. Energy Efficiency

Insulation
These houses may lack insulation in the vertical walls, ceilings, and floors, resulting in greater heat loss in winter and heat gain in summer.
Energy-efficient windows
It's possible that the windows and doors are not tightly sealed, contributing to greater energy loss in the building.
HVAC systems
The energy system uses gas as a resource through individual production and heat diffusion through radiators. For hot water generation, both electricity and gas are used, with individual production. There is no ventilation system.
Lighting systems
Currently, incandescent lamps are used, with 0% being LED lamps.

In this case, the characteristic of renewable energy is not considered, as it is understood that the area does not incorporate this system as part of its initial baseline.

2. Technical Specifications[4]

This subsection is not further elaborated with additional technical specifications because the description of the type of construction system appears to be rudimentary due to the construction context.

[4] European Union. (2017). Regulation (EU) 2017/1369 of the European Parliament and of the Council of [28.07.2017], regarding energy labelling and product information sheet related to energy-related products, repealing Directive 2010/30/EU of the European Parliament and of the Council and Directives 2009/125/EC of the European Parliament and of the Council and 2010/30/EU of the Council of the Commission [Eu/2017/1369]. Official Journal of the European Union.

3. Energy Consumption[5]

Consumption electricity
16.200 kWh/year
Consumption heating
15.298 kWh/year
Consumption Cooling
2.190.000 l/year

In this case, the consumption will not be taken into account due to the almost ruinous state of the area. The current consumption data does not reflect the actual consumption that would be expected if the buildings were fully operational.

2.2.2. Environmental

2.2.2.1. Possible impacts on different environmental vectors

While interventions to reduce energy poverty in social housing can have significant environmental impacts, these can be managed and mitigated through careful planning and design. It is crucial to consider these impacts in the planning and implementation of such interventions to ensure that they contribute to sustainable development.

The environmental impact generated refers to the consequences of the activity on the environment in its different vectors. Environmental aspects or vectors are the characteristics of that activity that can interact with the environment.
In this point of the documents, we are going to analyse the interventions in the context of their effects on the following categories: Atmosphere, Water, Land, Biodiversity, Waste, and Construction Materials.

Atmosphere
Interventions to reduce energy poverty often involve improving energy efficiency and promoting the use of renewable energy sources. These actions can significantly reduce greenhouse gas emissions, thus contributing to the mitigation of climate change. However, the production and installation of energy-efficient materials and renewable energy systems can also generate emissions, which should be considered in a comprehensive environmental impact assessment.

[5] Mena, V. G., Molina, F. Q., Catalán, M. L., Valdés, D. O., & Serrano, A. (2014). Eficiencia energética en edificaciones residenciales. Revista ESTOA, (5), 63-74.

Water
Water usage can be impacted in two ways. First, energy production, particularly from non-renewable sources, often requires significant water resources. Therefore, reducing energy demand can also reduce water usage. Second, the production of energy-efficient materials and renewable energy systems can require water, potentially leading to increased water demand.

Land
Land use can be affected by the need for space to install renewable energy systems, such as solar panels or wind turbines. While these installations can sometimes be integrated into existing buildings, they may also require additional land. The impact on land use must be carefully managed to avoid potential conflicts with other land uses and to minimise environmental impacts.

Biodiversity
The impact on biodiversity is complex. On one hand, reducing energy demand and shifting to renewable energy can help mitigate climate change, thereby protecting biodiversity. On the other hand, the production and disposal of energy-efficient materials and renewable energy systems can have negative impacts on biodiversity, for example through habitat destruction or pollution.

Waste
Waste is generated during the production and disposal of energy-efficient materials and renewable energy systems. However, these impacts can be mitigated through careful design, for example by using materials that are recyclable or have a long lifespan. Additionally, reducing energy demand can decrease the amount of waste generated by energy production, for example in the form of coal ash or nuclear waste.

Construction Materials
The production of construction materials for energy-efficient refurbishment of buildings and for renewable energy systems can have significant environmental impacts. These include the use of raw materials, energy for production, and emissions from production processes. However, these impacts can be mitigated by using environmentally friendly materials, efficient production processes, and by recycling materials at the end of their life.

Cultural /Social
Stimulation of cultural and creative sectors, fostering economic growth, and promoting social inclusion. However, these impacts can be managed by respecting and preserving the cultural heritage of the districts, ensuring renovations are inclusive and contributing to the well-being of the community. On the social side, renovations can address significant issues such as energy poverty by improving energy efficiency and access to affordable housing. Yet, these impacts can be balanced by ensuring a fair energy transition and sustainable urbanisation, while maintaining a high standard of living for inhabitants.

2.2.2.2. Environmental situation of the lighthouse district

In this point we can see Trieste District starting point and the main environmental impacts in order to define construction solutions that will minimise environmental impacts.

Atmosphere emissions

- This type of impact is caused in the construction phase by heavy machinery used for the work of clearing vegetation cover, excavations, earthmoving, transport and stockpiling of materials, adaptation of existing accesses, prop foundations, placement of supports, wiring, construction, and assembly of buildings, etc.
- The dust emissions resulting from activities indicated will be of moderate relevance and relatively easy to be absorbed by the environment, considering the acceptable atmospheric dispersion of dust in the area.
- The movement of this machinery for the construction of infrastructures will be moderate and very localised in space and time, so it will not have a great impact on the environment. Additionally, as it is an open space, the atmospheric dispersion capacity of pollution is considerable, which helps to minimise the impact on the entire area of action.
- With the application of corrective measures, such as, watering the soils in the area, the impact is considered as compatible.

- Once the works are completed, the buildings minimise emissions into the atmosphere as the modification of heating systems. A single natural gas condensing boiler will supply heat and hot water for each building. Each unit will have an individually metered heating system.
- Additionally, energy consumption will be reduced because the building will be thermally insulated using 100mm 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. Finally, the installation of rooftop solar panels will also minimise energy consumption.

Effects on water quality

- The change of oils and lubricants of the machinery used on site will be done in workshops in the region, only maintenance work, such as filling of tanks and circuits, will be carried out on site, so spills and losses will be scarce or of low intensity.
- There is no possibility of appreciable alteration effect on groundwater, due to the infiltration process and underground flow itself determine the elimination of particles that could be dragged away.
- No accumulation of loose sand is expected in the open, so no surface runoff is expected.
- As it is an already built-up area and in an urban area, the works do not affect biological communities.

In summary the impact due to the construction of the project is considered feasible.

Soils affection

- There is no need to carry out clearing so it is an urban district, but it will be some excavation work due to adaptation of road infrastructure and the creation of new parking spaces.
- In addition, it will be soil affection due to restoration of surrounding green areas.
- Vegetation loss is not expected even if it will increase or improve with the restoration of green areas. It is possible to see the soil affected by the installation and elements of the project that are buried (pipe) or surface elements such as new road infrastructure. This soil affection is not considered permanent or significant due to the small area affected.
- The restoration of the affected land means that the final effects on the vegetation will be insignificant, so the impact could be considered minor.

Biodiversity affection

- No alteration of the habitat is expected as it is already an urbanised area. In the same way there is not a displacement of fauna expected.
- This is not an area that affects any bird colonies or that affects their migration routes.
- Likewise, the installation of higher infrastructures than what already exists that could affect the birds is not foreseen.
- After careful consideration, we conclude that there are no potential significant effects.
- For the conservation of fauna, the impact of the project on this environmental impact is assessed as compatible.

Waste

- During the construction phase, construction and demolition waste will be generated.

- In accordance with current regulations, construction waste produced during the execution of the works will be properly managed by an authorised manager.

- The types and quantities of waste that will be generated will be identified and the appropriate area will be established for their location until they are removed. There is asbestos used in the old buildings which is an important threat to health. Also, the incandescent lambs cannot be recycled so careful attention is needed.

Construction materials

- The materials used will comply with the Quality Assurance Plan and with the certification requirements for their use.
- Likewise, it is expected that the design of the buildings will be as integrated as possible into the environment. To this end, it is recommended to use materials and shapes that are common in the architecture of the area, especially in terms of colour and textures.
- During the use of buildings phase, adequate and periodic maintenance will be carried out, so that their tarnishing does not affect the visual quality of the environment.

Cultural & Social

- There are no deposits or indications that could be affected by the works. In relation to the paleontological heritage, the project does not have a direct impact on known heritage elements.
- Geological formations of great interest are also not affected, so it is not expected to affect flora or fauna fossils.
- There will be no significant impacts. Therefore, the project is compatible with the proper conservation of cultural heritage.

From a social point of view, it is expected to facilitate access to housing for people with lower purchasing power, since the eight buildings` dwellings in use will have a lower economic cost in terms of energy consumption. So, this aspect will have a social impact, but it will be positive.

2.2.2.3. More Significant Environmental interactions and environmental feasibility

The construction work in Trieste will have long term impacts on the environment some of which are positive like the decrease of CO_2 emissions of the building use.

Use Phase Carbon Emissions

In construction and/or renovation projects the emissions of use phase are highly dependent on the climatic conditions of the area and the type of fuels used for heating/cooling. Sometimes it is not easy to have the performance of a newly constructed building by just making renovations. But to be able make an accurate comparison the embodied carbon of the materials for construction and/or refurbishment needs to be taken into account. It is easy to assume that refurbishments is a more promising option and would not need the same level of thermal performance to compete when considered from a whole-life carbon perspective.

In Trieste, the existing buildings will be demolished and reconstructed. We can assume that a newly constructed building will be in use at least fifty years if not even longer periods.

The climate of Trieste is relatively cold and heating energy demand is quite high while the energy source is fossil fuel, natural gas. After the new buildings are constructed GHG emissions are expected to decrease significantly. The energy KPIs of the project can be used with information of the materials used to be able to do the calculations for embodied emissions to have a comparable analysis within the project only energy efficiency measures can be considered in Trieste, to calculate embodied emissions instead of the whole construction materials.

Waste in use phase

During the use phase of the buildings, urban waste will be generated. In the current situation most of the dwellings are empty. After the implementations there will be new tenants and the amount of waste generated will be higher. Infrastructure and services for recycling, composting need to be considered for sustainability. The indicator waste reduction rate in use phase will be evaluated during the project.

Biodiversity after interventions

As stated, there are no expectations of deterioration of fauna or flora. After the removal of vegetation for road infrastructure and for other interventions during the construction phase the restoration of green spaces are planned. It is important to keep track of the increase of biodiversity of the area as well as selecting plant types that are compatible with soil and climate conditions and species that do not need extra irrigation. There is a KPI related to biodiversity.

Wellbeing, Health

Social housing buildings usually have architectural and construction challenges in terms of "energy poverty" which usually leads to lack of indoor air quality and comfort parameters. The new buildings will comply with the current energy standards and the energy efficiency and renewable energy measures are expected to increase the comfort levels increasing the wellbeing of tenants. Indoor air quality parameters are going to be used to monitor the interventions' impact.

2.2.3. Financial

Following the financial data collection process from ATER-Trieste in Italy, we observe that the state of social housing buildings and district in Boito 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. In this section we will outline the financial cost required to install the proposed SUPERSHINE energy efficiency renovations at building and district levels- and evaluate the financial gap between available funding sources, the current available funding sources provided by the government and the extra funding needed to implement the proposed energy efficiency projects.

2.2.3.1. Assessment of the financial needs of the lighthouses

The Italian pilot consists of eight social housing buildings (Boito 1-8) in the region of Trieste managed by ATER-Trieste. According to the initial analysis of the (SUPERSHINE survey financial data collection) on the energy consumption of the buildings, all Boito buildings require demolition and reconstruction of the whole buildings due to old age and the current state of energy efficiency technologies currently installed. Implementing the proposed SUPERSHINNE EE renovations after the demolition and reconstruction of the eight Boito buildings require an investment of 16,500,000 EUR with a construction period of 4 years. 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 17,325,000.00 EUR to include the cost of debt at 5% interest rate. To raise the required funds the social housing company, ATER-Trieste, will cover 85% of the total investment cost using government provided grants while the other 15% will be covered by private financial intermediaries. According to the SUPERSHINE Survey 2,155,200 EUR rent taking into account default in rents and vacant dwellings, ATER-Trieste collects 2,155,200 EUR annually and spends 1,842,560 EUR on operating and maintaining the buildings. Also, once the EE renovations are completed the rent is expected to rise by 5% to 2,284,512 EUR annually, 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 20% in energy consumption costs for residents in Boito. 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 17 years. The reason behind the high payback period for Boito is due to the high costs per metre squared due to the demolition and construction costs. The figure below summarises the data collected from ATER-Trieste in regard to the EE renovation costs and building revenues for Boito.

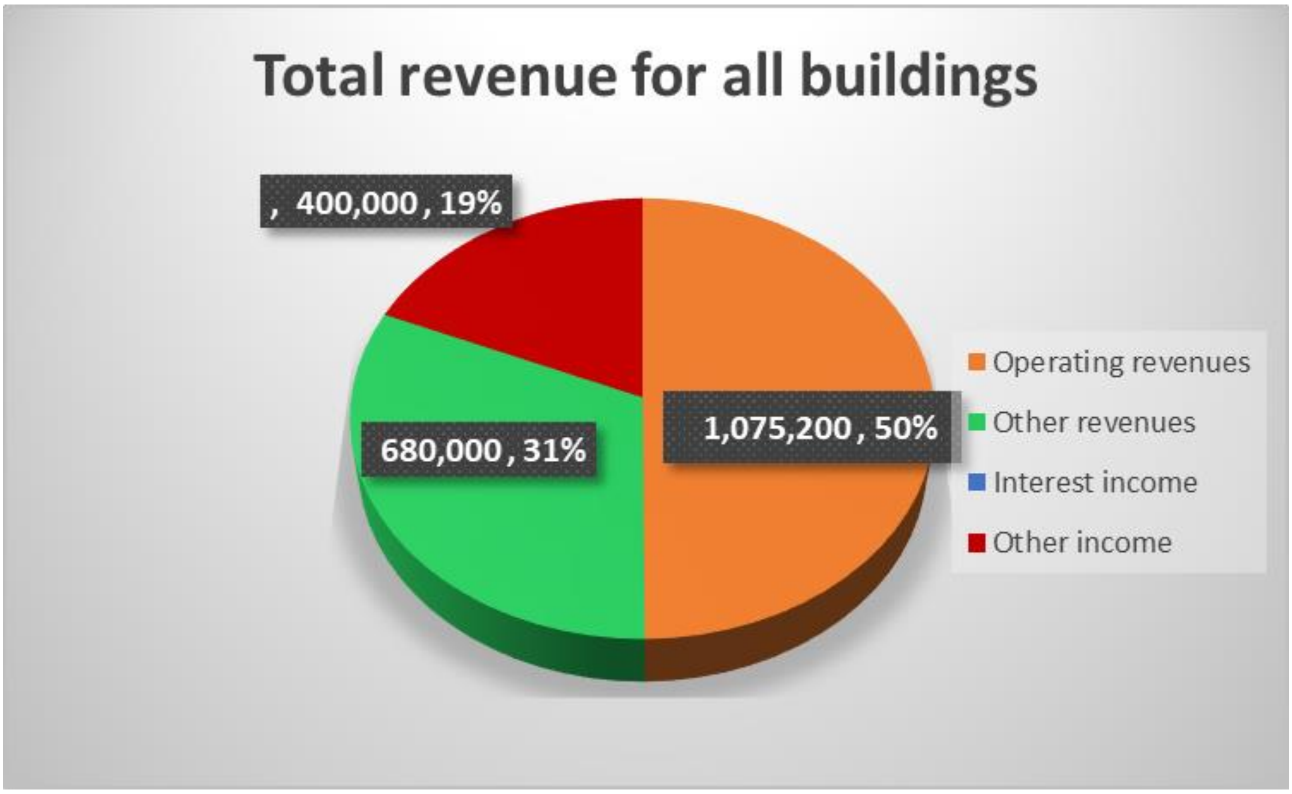

Figure 3 Total revenues for managing the building block in Boito-Trieste

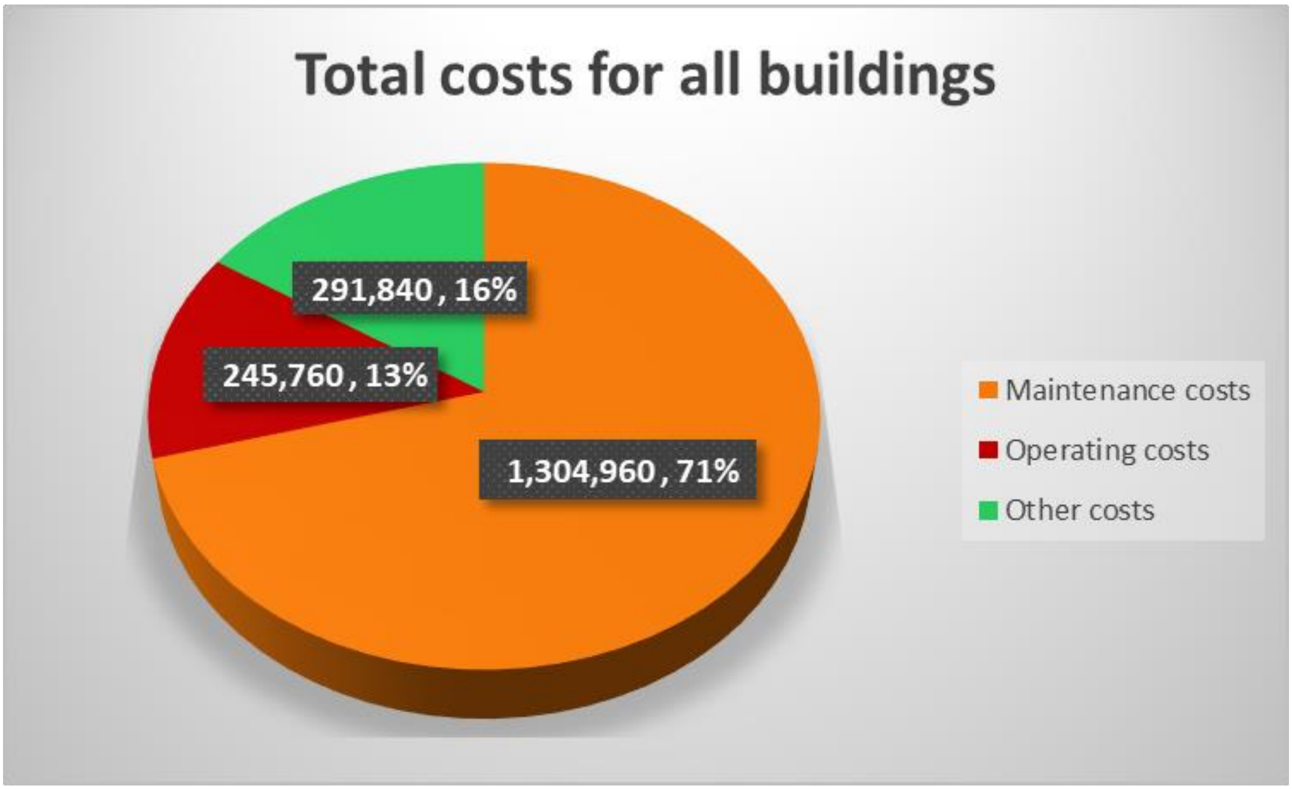

Figure 4 Total revenues for managing the building block in Boito-Trieste

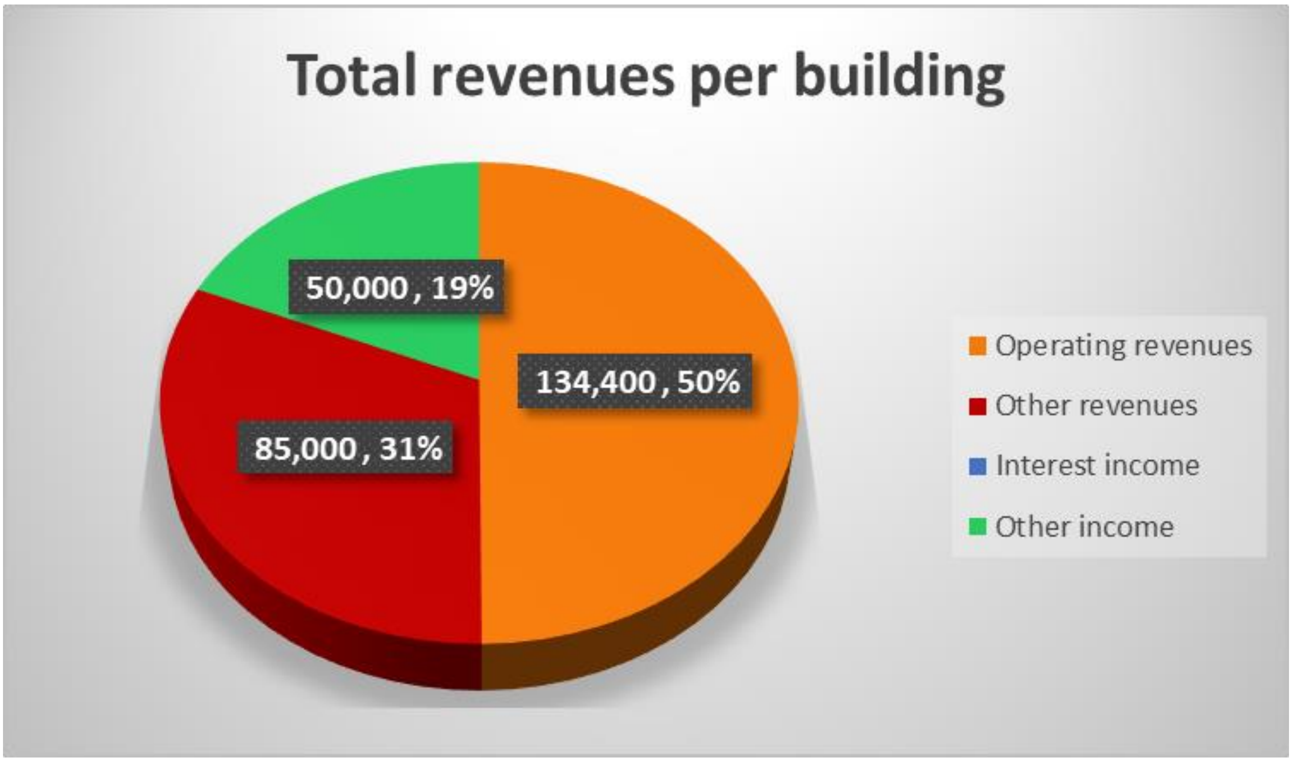

Figure 5 Total revenue per building in Boito-Trieste

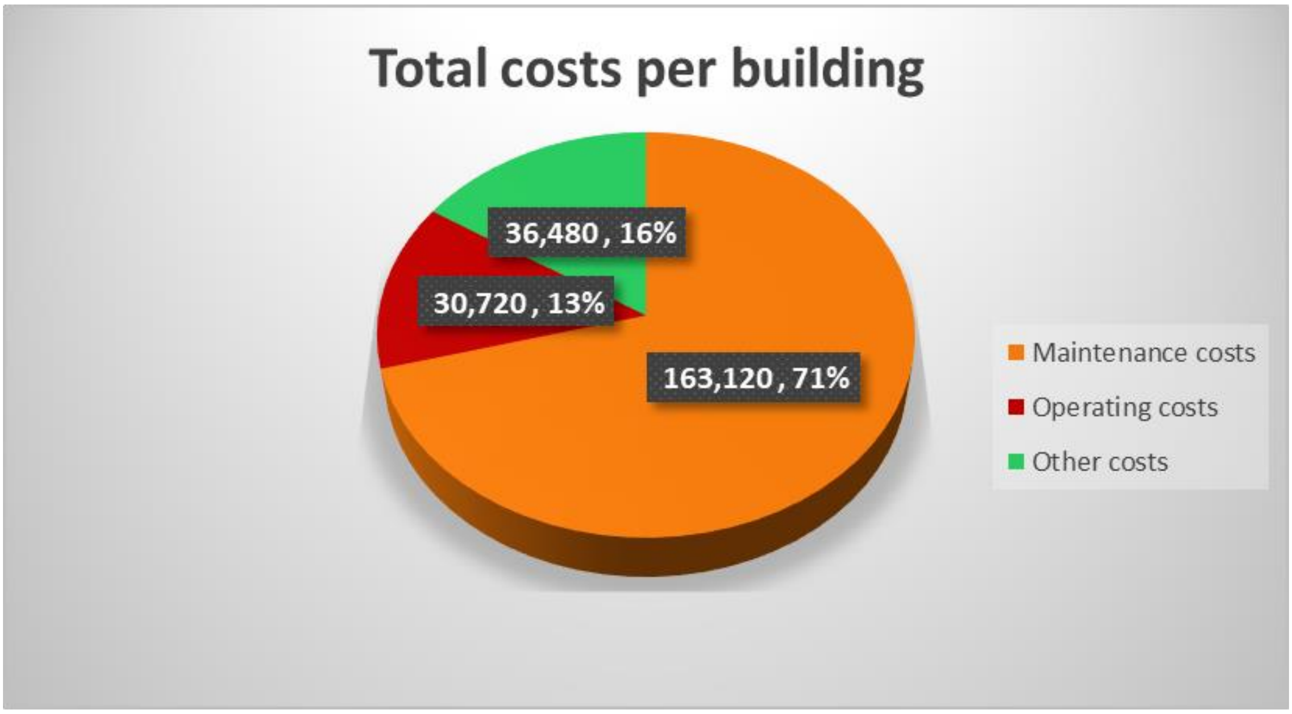

Figure 6 Total costs per building in Boito-Trieste

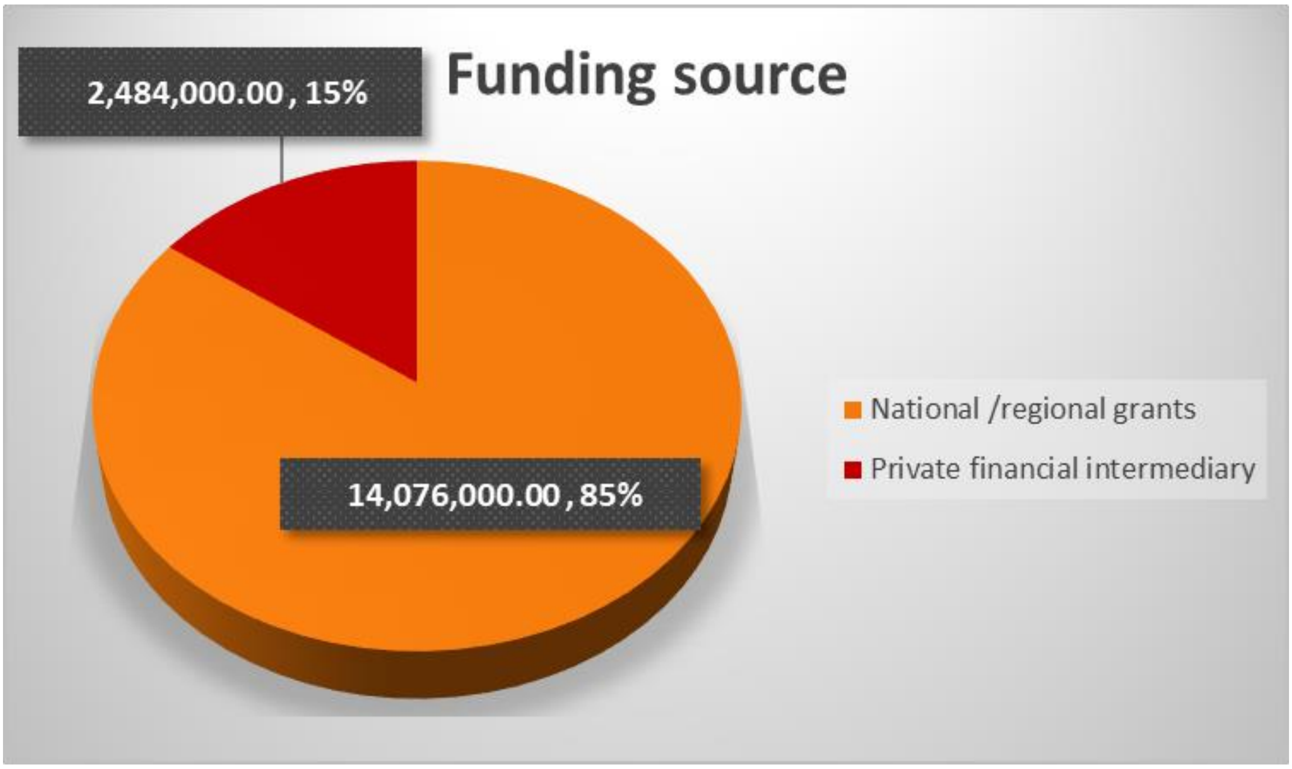

Figure 7 Distribution of the funding sources to cover the investment costs for Boito-Trieste

2.2.3.2. Available funding sources

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:

Ecobonus (Advancing Energy Efficiency and Safety in Italian Buildings): Italy's Ecobonus and Sismabonus initiatives are pivotal in the country's drive to boost energy efficiency and enhance building safety. Introduced as tax incentives, these programs encourage property owners to undertake renovations that not only cut energy consumption but also bolster seismic resilience. The Ecobonus program offers tax deductions to individuals and businesses investing in energy-efficient upgrades, spanning insulation, efficient HVAC systems, and renewable energy installations. By providing financial incentives, the government aims to stimulate investment in sustainable infrastructure, reduce energy costs for property owners, and shrink Italy's carbon footprint. In parallel, the Sismabonus initiative tackles Italy's seismic vulnerability by promoting seismic retrofitting. Similar to the Ecobonus, it offers tax incentives to encourage property owners to reinforce their structures against earthquakes, enhancing public safety and mitigating natural disaster impacts. Together, these initiatives underscore Italy's dedication to fostering resilience and sustainability in its built environment, empowering citizens to contribute to a greener future while safeguarding lives and property.

Superbonus 110%: Italy's Superbonus 110% program represents a groundbreaking approach to incentivizing energy efficiency renovations in buildings. Launched in 2020, this initiative provides a remarkable 110% tax credit for eligible renovation expenses, effectively covering the entire project cost and offering an additional incentive for property owners to invest in sustainability. Unlike traditional tax deductions, which offer partial relief, the Superbonus 110% provides a tax credit surpassing renovation expense, alleviating financial burdens and providing tangible benefits to property owners. Applicable to a wide range of measures including energy-efficient systems, insulation, photovoltaic installations, and seismic retrofitting, the program addresses societal needs from climate action to disaster resilience. Extending beyond residential properties to include commercial and public buildings, it amplifies its impact on Italy's built environment, accelerating progress towards national energy and climate objectives while fostering economic growth and job creation. In essence, Italy's Superbonus 110% program marks a paradigm shift, turning energy efficiency renovations from a financial burden into a compelling opportunity for sustainable investment and societal advancement.

Energy Efficiency Fund: Italy's Energy Efficiency Fund plays a pivotal role in catalyzing sustainable development and transitioning to a low-carbon economy. Established to support energy efficiency projects across sectors including buildings, the fund provides crucial financial resources to expedite the implementation of energy-saving measures and curb greenhouse gas emissions. Through grants, loans, and other incentives, it empowers homeowners, businesses, and municipalities to invest in energy-efficient technologies, fostering long-term energy savings, comfort, and environmental protection. One key objective is to promote innovation and adoption of cutting-edge technologies in buildings, incentivizing investments that push energy efficiency boundaries and pave the way for a sustainable future. Additionally, the fund spurs economic growth and job creation, particularly in the clean energy sector, by stimulating demand for energy efficiency products and services. In summary, Italy's Energy Efficiency Fund embodies the nation's commitment to using financial mechanisms to drive sustainable development and combat climate change, laying the groundwork for a greener, more prosperous future.

Green New Deal: Italy's embrace of a "Green New Deal" signifies a comprehensive strategy for sustainable development, with a significant focus on funding energy efficiency renovations in buildings. This vision integrates environmental considerations into economic policies, positioning Italy as a leader in sustainability and fostering a future where energy-efficient buildings are central to prosperity and environmental stewardship.

European Union (EU) Funding: Italy's access to EU funding for energy efficiency projects enhances the impact of its national initiatives. Programs like Horizon Europe and the ERDF provide additional financial resources, fostering collaboration, knowledge exchange, and best practices sharing across borders, underscoring a collective commitment to addressing climate change and promoting sustainable development.

Regional and Local Incentives: Italy's decentralization of incentives to regional and local levels acknowledges diverse needs and priorities across territories. Regional and local governments tailor incentives to specific challenges and opportunities within their jurisdictions, ensuring benefits of energy efficiency renovations reach all corners of the country. By addressing regional nuances, Italy fosters a more inclusive and adaptable approach to sustainable development, driving a comprehensive nationwide transformation in building practices.

In conclusion, Italy's various funding solutions for energy efficiency renovations in buildings showcase a holistic and ambitious strategy. By combining tax incentives, comprehensive credits, and collaboration at national and international levels, Italy aspires to lead the way in sustainable construction practices, creating a legacy of resilience, efficiency, and environmental responsibility.

2.2.3.3. Evaluation of the financial gap between funding already available and extra funding needed.

Tables shown in Tables 01-02 below provide a detailed snapshot of the investment requirements and available funding sources for energy efficiency renovation projects in Italy. It outlines three primary areas of investment: energy efficiency in public buildings, energy efficiency and renewable energy in district heating, waste, and water management, and sustainable mobility, collectively totalling EUR 60.5 billion. This breakdown underscores the diverse facets of energy efficiency that need attention, spanning from infrastructure upgrades to transportation systems. On the funding front, a comprehensive array of sources is identified, both at the EU and national levels. The EU's commitment is evident through contributions such as the Cohesion Fund and Next Generation EU, amounting to EUR 33.6 billion. At the national level, various funds, including the Italian Energy Efficiency Fund, Invitalia, and the Emilia-Romagna Energy Fund, are enlisted alongside the significant allocation from the Italian National Recovery and Resilience Plan, totalling EUR 25.4 billion. This robust funding landscape reflects a concerted effort to address Italy's energy efficiency challenges. However, despite the substantial available funds, a slight shortfall of EUR 0.97 billion remains when compared to the total investment needs. While this deficit is relatively minor, it underscores the importance of strategic planning and allocation to ensure optimal utilisation of resources. Moreover, it highlights the necessity for continued collaboration between EU and national-level stakeholders to bridge any remaining gaps and maximise the impact of investments.

In conclusion, the table provides a comprehensive overview of the financial landscape surrounding energy efficiency renovation projects in Italy. It underscores the significant investment requirements and the proactive measures taken at both EU and national levels to address these challenges. Moving forward, effective coordination and prudent allocation of resources will be essential to realising the full potential of energy efficiency initiatives and fostering sustainable development in Italy.

Table 1Investment needs to meet Italy's NECP objectives

Summary of investment needs - Italy		
	Energy efficiency	**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**

Table 2 Available funding sources at EU level and national level - Italy

SUPERSHINE

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**

2.3. Latvia

2.3.1. Technical

3. Urban Scale

1. Climate data

Temperature profile
In Riga, summers are comfortable and partly cloudy, while winters are long, icy, snowy, windy, and mostly cloudy. Throughout the year, temperatures typically range from -6°C to 23°C, rarely dropping below -17°C or exceeding 29°C.
Local wind
The windiest part of the year lasts for 5.8 months, from September 26th to March 20th, with average wind speeds exceeding 18.3 kilometres per hour. The windiest month of the year in Riga is January, with winds averaging 21.7 kilometres per hour. The calmest period of the year lasts for 6.2 months, from March 20th to September 26th. The calmest month of the year in Riga is July, with winds averaging 14.8 kilometres per hour.
Climate prediction change
To mitigate the effects of climate change, it is necessary to improve drainage infrastructure, promote sustainable construction practices, implement water conservation measures, develop green areas, and encourage sustainable mobility.

2. Urban characteristics of the building

Location

The Āgenskalna Priedes district, located within the Āgenskalns neighbourhood, covers 9.5 hectares and houses 2,700 inhabitants in 1,283 apartments. It consists of 24 Soviet-era multi-apartment residential buildings built between 1959 and 1961, along with a newly constructed NZEB multi-apartment residential building completed in 2020. The area also features public city parks and inner yards, albeit slightly degraded. Notably, the district has been designated as the renovation wave pilot area under the Sustainable Development Programme of Riga 2021-2027. The Āgenskalns neighbourhood, spanning 461.3 hectares, is home to a population of 27,000 and boasts a mixed-use character with low- and medium-rise buildings, including multi-apartment residential complexes, family housing areas, offices, retail spaces, public services, universities, schools, and kindergartens. Additionally, before the Covid-19 restrictions, around 20,000 individuals, including employees and students, were daily users of the neighbourhood.
Accessibility
The residential demonstration buildings are in the southeastern part of Herning, a city with around 50,000 inhabitants. This area is characterised by its mixed use, which includes a large school, a shopping center, residential villas, medical offices, shops, public transport services, green areas, a rock-climbing center, Kalnciema Kvartāls, and building blocks.
Market demand
No significant differences are observed in the value of the square metre price in the intervention area compared to the rest of the city area. Therefore, it is understood that the space has urban quality and presents commercial appeal to the population.

3. Urban environment

Population Density
160 tenants are living in Department 16, yielding a density of 41 m² per resident. This value represents a high level compared to the rest of the European density ratios.
Land use
The area predominantly features residential use, with apartment typologies having a usable area of 74 square metres per unit. The district primarily serves a residential function, with peripheral services.
Nearby infrastructure
• Public underground waste sorting facility (new, installed in 2023) • Playground for children (new, installed in 2023) • Water and sewerage network

4. Building Scale

1. Energy Efficiency

Insulation
These houses may lack insulation in the vertical walls, ceilings, and floors, resulting in greater heat loss in winter and heat gain in summer.
HVAC systems
All buildings within the Āgenskalna priedes district are linked to a centralised district heating (DH) and domestic hot water (DHW) system, providing the area with combined thermal energy. Basic thermal and electric energy metres are installed in each building within the district.
Lighting systems
The public lighting system in place utilizes sodium-vapor lamps.
Renewable Energy Sources
A portion of the land is owned by the municipality, providing space for the installation of renewable energy generation and storage solutions. Additionally, all building rooftops can be utilised for renewable energy generation.

The carpentry of the buildings is not taken into account because it exhibits optimal quality.

2. Technical Specifications

Technical specifications
Construction materials being used are primarily silicate brick and plaster, and there is no additional insulation incorporated into the building structure.

Construction material uses, building systems and structural integrity are not included because all the materials used in the building are specified in the technical specifications.

3. Energy Consumption

Consumption electricity
30,11 (kWh/m2 annual)

Consumption heating
172,57 (kWh/m2 annual)
Consumption Cooling
No Data

2.3.2. Environmental

2.3.2.1. Possible impacts on different environmental vectors

The impacts that can affect the different environmental vectors are the ones already mentioned in in 2.3.2.1 of this document.

2.3.2.2. Environmental situation of the lighthouse district

The proposed interventions for the building envelope and systems, as well as the installation of renewable energy sources and efficiency-enhancing systems, can have various impacts on different aspects:

Atmosphere: The proposed interventions aim to improve the energy efficiency of the building, which would lead to a reduction in greenhouse gas emissions. The installation of renewable energy sources would further reduce emissions by replacing fossil fuel-based energy sources.

Water: The renovation of the heating system and the installation of heat-reclaiming ventilation systems could lead to a more efficient use of water in the building. However, insulation materials can absorb water when exposed to moisture, which could have an adverse effect on both thermal insulation capacity and surrounding structures.

Land Biodiversity: The use of renewable insulation materials can have fewer environmental impacts than their conventional counterparts, potentially benefiting land biodiversity.

Waste: Building renovation based on circular principles can contribute to waste reduction. For example, the renovation wave plays a key role in upgrading existing EU buildings and making them more energy efficient. However, waste could be generated during the renovation process, especially if old materials are removed and not recycled.

Construction Materials: The renovation process will likely involve the use of new construction materials. If these materials are sustainably sourced and used efficiently, the impact on the environment can be minimized. The use of insulation in the building envelope can reduce the demand for heating and cooling, thus reducing the demand for energy-producing materials.

Cultural/Social: Building renovations can have social impacts, such as temporary displacement of occupants or changes in the use of space. However, these renovations can also lead to improvements in living conditions and energy poverty reduction. The installation of renewable energy sources like rooftop PV panels can contribute to energy independence and community resilience.

2.3.2.3. More Significant Environmental interactions and environmental feasibility

The construction work in Riga will have long term impacts on the environment some of which are positive like the decrease of CO_2 emissions of the building use.

Use Phase Carbon Emissions

Climate of Riga is very cold during winter. The heating energy demand is quite high. Although the energy consumption for heating is expected to decrease significantly, the expected CO_2 reduction might not be as high due to existing use of biomass along with natural gas.

Again, it will be necessary to use embodied carbon of the materials used to be able to see if there is a net CO_2 emission gain of the interventions. If more sustainable and locally produced materials are used the embodied emissions would be less. The insulation materials, the materials that will be used for

The energy KPIs of the project can be used with information of the materials used to be able to do the calculations for embodied emissions.

Waste in use phase

During the use phase of the buildings, urban waste will be generated but it will be no different from that which already exists today as the population of the area will not increase. The indicator waste reduction rate in use phase will be evaluated during the project.

Biodiversity after interventions

In Riga the interventions are being carried out in existing buildings. There will not be any deterioration of land, vegetation, or green areas.

Indoor air quality

By incorporating green spaces and better ventilation systems, renovated buildings can contribute to improved indoor and outdoor air quality, benefiting both human health and the environment.

Refurbishment of window fittings and insulation of the dwellings will have an important impact on the comfort level of tenants. Additionally, Riga is renovating the ventilation system as well.

Preservation of built heritage

The buildings in the demo area are from the 1960s, witnessing a certain historical era of the city (Soviet influenced era). Preserving the social housing buildings and retrofitting according to latest energy and quality standards will increase the wellbeing of the tenants while preserving the historical texture of the city.

2.3.3. Financial

2.3.3.1. Assessment of the financial needs of the lighthouses

This report presents findings from the SUPERSHINE survey conducted to assess the costs, benefits, and challenges associated with energy efficiency renovations in Latvia, particularly focusing on multi-apartment residential buildings. The survey aimed to gather data on refurbishment costs, operating and maintenance expenses, funding sources, and the impact on energy poverty. Refurbishment costs in Latvia vary significantly, with average deep renovation costs ranging from 127 EUR per 1 m2 up to 233 EUR per 1 m2, based on data from over 600 retrofitted multi-apartment residential buildings renovated during 2018 - 2022. However, estimated costs in 2023 increased to up to 400 EUR per 1 m2 due to factors such as the unavailability of basic building materials from Russian, Ukrainian, and Belarusian markets, war and sanctions, and the global energy crisis. Operating and maintenance costs have shown a decrease from 0.2 EUR per 1 m2 before deep renovation to 0.1 EUR per 1 m2 after deep renovation, as indicated by a conceptual study by the Riga Energy Efficiency Fund. The payback period from energy savings to cover the cost of investment is significant, with heat energy consumption decreasing from ~230 kWh/m2/year before renovation to 50 kWh/m2/year after renovation. Regarding funding sources, while national grants, EU grants, loans from financial institutions, private savings, and other sources are available, specific amounts are yet to be determined. Common funding mechanisms include equity of 10% and debt financing, with an expected market value increase of at least 40% after refurbishment. Energy poverty remains a concern, with varying percentages of total yearly income spent on energy by different demographic groups. A significant share of households cannot afford to adequately warm their homes, particularly due to the inability to regulate the amount of received district heat energy individually. However, arrears on energy bills by tenants are insignificant, with less than 10% of tenants experiencing arrears.

The public infrastructure used in the Agenskalna priedes district consists of a public lighting system, a newly installed public underground waste sorting facility, water and sewerage network, and a newly installed playground for children. The key stakeholders involved in the energy efficiency renovation process are residents of the district, house managers, municipal housing maintenance company, and the Riga Municipal Agency to provide technical support in the implementation of the EE refurbishments. Also, the Agenskalna priedes consist of mixed public and private ownership of the land, which acts as a barrier to possible investments by the municipality in district development initiatives and has caused delays of up to 2 years for the adoption of the EE refurbishment in the district. Furthermore, there is no collaboration with local businesses to uptake new technologies targeting social and affordable housing. However, since the launch of the SUPERSHINE project, the residents of the Agenskalna priedes district are planning to establish an NGO for the district. Also, the Riga City Municipality offers several municipal grants to support small-scale community projects for improving public spaces. Furthermore, the Riga municipality is developing, with collaboration from local ESCOs, housing maintenance companies, and Riga city residents, a large-scale fund called the "Riga Energy Efficiency Fund" to accelerate energy renovations of multi-apartment residential buildings in the Riga city. Also, a municipal ESCO service provider is currently managing 23 residential buildings in the district and providing households with various property and infrastructure management services such as building management, cleaning of the staircases and outdoor areas, organising waste management services, and emergency repair services.

In conclusion, the survey findings highlight the significant costs associated with energy efficiency renovations in Latvia, compounded by challenges such as material shortages and the global energy crisis. While funding sources are available, the payback period for investments remains a concern. Additionally, energy poverty persists among certain demographic groups, emphasising the need for targeted interventions to address affordability issues. Further research and policy action are warranted to promote sustainable and inclusive energy efficiency initiatives in Latvia.

2.3.3.2. Available funding sources

- **Selling Emission Allowances**[6]: Latvia is projected to auction around 16 million EU emission allowances throughout the period spanning from 2021 to 2030. The implementation of an emission trading system has the potential to generate a revenue range of EUR 500 to 750 million, which is contingent upon several factors, including the price of European emission allowances. According to the findings of Kamenders et al. (2020), it was determined that over 60% of the revenues generated from the auctions were designated for the purpose of funding energy efficiency and renewable energy initiatives, amounting to a total of EUR 375 million.

[6] Latvia's eight national communication(2022), https://unfccc.int/sites/default/files/resource/78450136_Latvia-NC8-BR5-2-LATVIA_NC8_BR5_Resubmission.pdf

- **Latvian Environmental Protection Fund (Latvijas Vides Aizsardzības fonds)**: The fund is dedicated to financing initiatives that safeguard Latvia's natural environment and promote sustainable development. It supports projects aimed at reducing pollution, conserving natural resources, and enhancing environmental quality. In the context of energy efficiency renovations in social housing, the fund may aid with projects that mitigate carbon emissions, improve indoor air quality, and reduce energy consumption to create healthier and more sustainable living environments.

- **Latvian Investment and Development Agency (LIAA):** LIAA aims to stimulate economic growth, innovation, and competitiveness in Latvia by supporting businesses, municipalities, and entrepreneurs. Its funding programs may include support for projects that enhance infrastructure, create jobs, and foster sustainable development. Regarding energy efficiency renovations in social housing, LIAA may provide financial assistance to improve energy performance, reduce utility costs, and enhance living conditions for residents while promoting local economic development and innovation in the construction sector.

- **Latvian Rural Support Service (LRAD):** LRAD focuses on improving living standards, economic opportunities, and infrastructure in rural areas of Latvia. It administers funding programs that support agricultural development, rural entrepreneurship, and community revitalization. Regarding energy efficiency renovations in rural social housing, LRAD may offer financial assistance to upgrade building infrastructure, enhance energy efficiency, and create more comfortable and sustainable living environments for rural residents, contributing to the overall development and well-being of rural communities.

- **Latvian Green Investment Scheme (LGIS):** LGIS aims to finance projects that reduce greenhouse gas emissions and promote sustainable development in Latvia. It leverages revenue generated from the sale of emission reduction credits to fund initiatives that improve energy efficiency, increase renewable energy deployment, and enhance environmental sustainability. In the context of energy efficiency renovations in social housing, LGIS may support projects that reduce energy consumption, lower carbon emissions, and improve building performance, contributing to Latvia's climate goals while creating more sustainable and resilient communities.

- **Latvian Development Financial Institution ALTUM**: ALTUM provides financing solutions to support various development projects in Latvia, including those related to entrepreneurship, innovation, and infrastructure. It aims to facilitate access to funding for businesses, municipalities, and individuals to stimulate economic growth and promote sustainable development. In the realm of energy efficiency renovations in social housing, ALTUM may offer financial products such as loans, guarantees, and grants to fund upgrades, retrofits, and energy-saving measures that enhance building performance, reduce energy costs, and improve living conditions for residents.

- **Latvian Ministry of Environmental Protection and Regional Development (Vides aizsardzības un reģionālās attīstības ministrija):** The ministry is responsible for formulating and implementing policies and programs that protect the environment, promote sustainable development, and support regional growth and cohesion in Latvia. It focuses on addressing environmental challenges, conserving natural resources, and fostering balanced regional development. Regarding energy efficiency renovations in social housing, the ministry may develop initiatives, provide guidance, and allocate resources to support projects that enhance energy performance, reduce environmental impact, and improve quality of life for residents, contributing to sustainable development and regional prosperity.

- **Latvian Association of Local and Regional Governments (Latvijas Pašvaldību savienība):** The association represents the interests of local and regional governments in Latvia and works to strengthen their capacity, promote cooperation, and advocate for policies that support local development and governance. It may provide support, guidance, and funding opportunities to municipalities undertaking initiatives that enhance community well-being, infrastructure, and sustainability. In the context of energy efficiency renovations in social housing, the association may assist local governments in accessing funding, sharing best practices, and coordinating efforts to improve energy performance, reduce costs, and enhance liveability in social housing developments.

- **Latvian State Regional Development Agency (Vides aizsardzības un reģionālās attīstības ministrija):** The agency is responsible for implementing regional development policies and programs aimed at promoting economic growth, social cohesion, and sustainable development in Latvia. It focuses on addressing regional disparities, supporting infrastructure investment, and fostering innovation and entrepreneurship. In the context of energy efficiency renovations in social housing, the agency may develop regional development strategies, administer funding programs, and provide technical assistance to support projects that enhance energy performance, reduce environmental impact, and promote inclusive and sustainable growth in urban and rural areas.

2.3.3.3. Evaluation of the financial gap between funding already available and extra funding needed.

Tables shown in Tables 03-04 for Latvia present a detailed overview of the investment needs and available funding sources for energy efficiency initiatives. The breakdown of investment requirements highlights three main areas: energy efficiency renovations and circular economy, energy efficiency in public buildings, and energy efficiency and renewable energy in districts, totaling EUR 8.2 billion. This delineation underscores Latvia's commitment to enhancing energy efficiency across various sectors to meet national and European objectives. On the funding side, a diverse range of sources is identified, with both EU and national-level contributions. At the EU level, substantial funding is available through programs like the Modernization Fund, Next Generation EU, the European Regional Development Fund, the Just Transition Fund, the EU Social Fund Plus, and the EU Cohesion Fund, totaling EUR 3.716 billion. These funds underscore the EU's commitment to supporting member states in achieving their energy efficiency goals and transitioning towards sustainable energy systems. At the national level, funds from emission selling, ALTUM loans, and the Latvian Recovery and Resilience Plan contribute an additional EUR 2.212 billion, further augmenting the available resources. This comprehensive funding landscape reflects Latvia's concerted efforts to mobilise financial resources from various sources to address its energy efficiency needs. However, despite the substantial available funds, there remains a gap of EUR 2.272 billion when compared to the total investment needs. While this shortfall poses a challenge, it also underscores the importance of strategic planning and resource allocation to ensure optimal utilisation of available funds. Moreover, it highlights the need for continued collaboration between EU and national-level stakeholders to bridge any remaining gaps and maximise the impact of investments.

In conclusion, the tables provide a comprehensive overview of the financial landscape surrounding energy efficiency initiatives in Latvia. They underscore the significant investment requirements and the proactive measures taken at both EU and national levels to address these challenges. Moving forward, effective coordination and prudent allocation of resources will be essential to realising the full potential of energy efficiency initiatives and fostering sustainable development in Latvia.

Table 3 Investment needs to meet Latvia’s NECP objectives

Summary of investment needs - Latvia		
		Required investments
Energy efficency renovations and circular economoy	Energy efficiency in public buildings	EUR 1.73 billion
	Energy efficiency and renewable energy in districts	EUR 2.71 billion
	Other EE projects to meet NECP objectives	EUR 3.76 billion
	Total investment needs	**EUR 8.2 billion**

Table 4 Available funding sources at EU level and national level -Latvia

Summary of available funding - Latvia		
	available fund	**Budget**
EU level	Modernization fund	EUR 60 million
	Next GenerationEU	EUR 224 million
	European regional development func	EUR 839 million
	Just transion fund	EUR 192 million
	EU Social fund plus	EUR 1.2 billion
	EU cohesion fund	EUR 1.2 billion
National level	Emission selling	EUR 375 million
	ALTUM loans	EUR 18 million
	Latvian RRP	EUR 1.82 billion
	Total available funds	**EUR 5.928 Billion**

2.3.4. Technical

This paragraph delineates the initial attributes of Herning district, employing the methodology specified in section 2.1 of this document. The emphasis lies in conducting a comprehensive analysis of the current state and aligning it with the SUPERSHINE objectives pertinent to lighthouse districts.

5. Urban Scale

1. Climate data

Temperature profile
In Herning, summers are comfortable and partially cloudy; winters are long, very cold, and mostly cloudy. The temperature generally varies from -1°C to 21°C and rarely drops below -9°C or rises above 27°C. The warm season lasts 3.1 months, from June 6 to September 8, and the average daily maximum temperature is over 18°C.
Local wind
There is a significant difference between windy and calm periods. For 5.7 months, from October 10th to April 1st, average wind speeds exceed 20.5 km/h, with January being the windiest month, averaging 23.2 km/h. On the other hand, the calmest period spans 6.3 months, from April 1st to October 10th, with July being the most tranquil month with winds averaging around 17.6 km/h.
Climate prediction change
More heat is expected both in summer and winter, accompanied by a shift in rainfall patterns. Dry periods will be followed by intense rain, potentially leading to floods. This change may result in more frequent occurrences of strong storms and other extreme weather events. The impact of

these phenomena extends to agriculture and public health. Adaptation and improvement of urban infrastructure, including streets, as well as the adoption of more sustainable agricultural practices, are deemed necessary to address these changes.

2. Urban characteristics of the building

Location
The DK-demonstration activities will take place in Herning Municipality (HM), which encompasses an area of 1,323 km2 and has a population of 89,000. Herning city itself has around 50,000 residents. Herning is situated in the Region Midtjylland, which has a total population of 1,321,000 inhabitants, with Aarhus serving as the main city, located 90 km from Herning. The residential demonstration buildings are located in the south-eastern part of Herning. This area features a mix of land use, including a large school, shopping center, residential villas, and building blocks. The district is fully developed, with FaellesBo's buildings constructed between 1954 and 1965 and not renovated since their initial construction.
Accessibility
The area surrounding the district has attracted a "normal level" of investment in schools, medical offices, shops, Culture and art centres, Libraries, building refurbishment, and pedestrian. There have been no special investments in innovation in this area, although Herning, in general, has a high level of investment in innovation in the business sector and at the local university.

In the Herning district, considering market demand isn't important, while the other considerations allow for stabilising a good idea about the urban characteristics of the building.

3. Urban environment

Population Density
0.0284 density per m2
Nearby infrastructure
● District heating. ● Electricity grid. ● Fibre cable grid. ● Public lighting system (LED) ● Domestic water supply network.

6. Building Scale

1. Energy Efficiency

Insulation
The insulation standard is low. This score is not concrete, but it is relevant to understand the actions needed in the implementation of the demo.
HVAC systems
There is a district heating from biomass cogeneration.
Renewable Energy Sources
Increasing local renewable energy (PV) power production.

2. Technical Specifications

Technical specifications, construction material uses, building systems and structural integrity are not included because all the materials used in the building are specified in the technical specifications.

3. Energy Consumption

Consumption electricity
41,5 (kWh/m2 annual)
Consumption heating
69 kWh/m2/year - 3,000 TJ/year of which 2,200 TJ/year
Consumption Cooling
No Data

2.3.5. Environmental

2.3.5.1. Possible impacts on different environmental vectors

The impacts that can affect the different environmental vectors are the ones already mentioned in in 2.3.2.1 of this document.

2.3.5.2. Environmental situation of the lighthouse district

The proposed interventions for the building envelope and systems, as well as the installation of renewable energy sources and efficiency-enhancing systems, can have various impacts on different aspects in Herning district:

Atmosphere emissions

- Herning requires envelope renovation and insulation and upgrading of energy systems, so this type of impact caused in the construction phase is not to impact.
- In the construction phase the impact is caused by heavy machinery used for the work of transport and stockpiling of materials, adaptation of existing accesses, etc.
- The dust emissions resulting from activities indicated will be of moderate relevance and relatively easy to be absorbed by the environment, considering the acceptable atmospheric dispersion of dust in the area.
- The movement of this machinery for the construction of infrastructures will be moderate and very localised in space and time, so it will not have a great impact on the environment. Additionally, as it is an open space, the atmospheric dispersion capacity of pollution is considerable, which helps to minimise the impact on the entire area of action.

- Once the works are completed, the buildings minimise emissions into the atmosphere due to a centralised heat network, powered by a CHP stockpiling. In addition, energy consumption consequently emissions into the atmosphere will be reduced due to the improving insulation and reducing heat loss. This includes replacing the roof, re-insulating the attic space, installing a new shell wall, insulating the facade, replacing basement stairs in conjunction with facade renovation, upgrading windows and doors, insulating the floor deck above the basement, and various other improvements.

- Additionally, the maintenance of a biomass (energy-efficient heating source) cogeneration district heating system will be implemented. The installation of a rooftop PV system will also be considered for generating renewable electricity for common areas and potentially flat units.

- In this district there will be more energy generation with efficient energy systems such as biomass cogeneration and rooftop PV systems whose atmosphere impact will be less significant than classical energy generation systems.

Water

- In the construction phase there will not be a significant water impact due there will not be heavy machinery which could lose some contaminated liquids.

- Additionally, sewage separation is planned to enhance environmental sustainability.

- All these reforms could lead to a more efficient consumption and discharge of water in the building.

Soils affection

- There is no need to carry out clearing or excavation work, so it is an urban district, and it is not a new building construction if not, it is a rehabilitation work.

- In this district because the kind of work there will not have any soils impact.

Biodiversity affection

- No alteration of the habitat is expected as it is already an urbanised area and there are no plans to change the height of buildings or the number of dwellings. In the same way there is not a displacement of fauna expected.
- This is not an area that affects any bird colonies or that affects their migration routes.

After careful consideration, we conclude there are no potential significant effects and there is no biodiversity impact.

Waste

- During the rehabilitation of buildings phase, construction and demolition waste will be generated, and during use phase of the buildings.
- In accordance with current regulations, construction waste produced during the execution of the works will be properly managed by an authorised manager.
- The types and quantities of waste that will be generated will be identified and the appropriate area will be established for their location until they are removed.

Construction materials

- The materials used will comply with the Quality Assurance Plan and with the certification requirements for their use.
- The interior renovation aims to enhance the comfort and aesthetics of the living spaces. This includes the installation of a spacious bathroom with underfloor heating, a floor heating system, and preparations for a wash column. The kitchen is being revamped with options for an open or screened layout, sound insulation is being added to improve acoustics, and new doors, flooring, and electrical installations are planned.
- During the use of buildings phase, adequate and periodic maintenance will be carried out, so that their tarnishing does not affect the visual quality of the environment.

Cultural & Social

- Because there is not a new building construction, the project does not have a direct impact on known heritage elements.
- Geological formations or paleontological fossils have also not been affected either. There will be no significant impacts.
- From a social point of view, it is expected to facilitate access to housing for people with lower purchasing power, since the dwellings in use will have a lower economic cost in terms of energy consumption and they will have better sound insulation. The dwellings will be more comfortable and aesthetic living spaces So this aspect will have a social impact but it will be positive.

2.3.5.3. More Significant Environmental interactions and environmental feasibility

The retrofitting work in Herning/Denmark's energy reduction will reduce CO_2 emissions but it will be less significant since the district already has a biomass-based system. The long-term impacts to the environment are summarised as below.

Use Phase Carbon Emissions

Denmark, known for its ambitious climate goals, emphasises energy efficiency in the building sector as a crucial part of its strategy to become carbon neutral. Herning has a cold climate in winters which is an important reason for the high energy consumption. The expected CO_2 reduction might not be as high as the energy reduction since there is already a biomass district heating system in the area. Additional cogeneration and PV instalments will have a positive impact on reducing the electricity sourced CO_2 emissions causing the decrease of use phase carbon emissions along with other efficiency measures. Again, it will be necessary to use embodied carbon of the materials used to be able to see if there is a net CO_2 emission gain of the interventions. It is already planned to use recycled materials for the interventions which will also decrease the embodied emissions. The energy KPIs of the project can be used with information of the materials used to be able to do the calculations for embodied emissions. It will be very interesting to compare the use phase of carbon emission changes in three demo areas with different technical structures.

Waste in use phase

During the use phase of the buildings, urban waste will be generated but it will be no different from that which already exists today as the population of the area will not increase. The indicator waste reduction rate in use phase will be evaluated during the project.

Biodiversity after interventions

In Herning the interventions are being carried out in existing buildings. There will not be any deterioration of land, vegetation, or green areas.

Indoor air quality

From a social point of view, it is expected to facilitate access to housing for people with lower purchasing power. In dwellings that struggle with energy poverty it is observed that some rooms are not heated enough to save money. Since the houses will have better standards than before the comfort of tenants will be higher.

Also, increasing the number of best practices of energy efficiency and renewable energy tends to increase local job opportunities with high qualifications in the long run increasing the wellbeing of the communities. Since this impact can be seen at a longer term than the project lifetime it will not be monitored.

2.3.6. Financial

2.3.6.1. Assessment of the financial needs of the lighthouses

In general, the housing association is financed through a combination of capital loans from the municipality, residents' deposits, and mortgage loans. The breakdown typically includes 8-12% of the building costs covered by capital loans from the municipality, residents contributing 2% of the building costs as deposits, and mortgage loans with a maximum 40-year depreciation period. These mortgage loans are backed by a municipal guarantee, covering 86-90% of the building costs.

This section reports the findings from the SUPERSHINE survey to assess the costs, benefits, and challenges associated with energy efficiency renovations in Denmark, with a focus on Department 16 building renovation energy measures. The survey aimed to gather data on refurbishment costs, operating and maintenance expenses, funding sources, and the impact on energy poverty. The total costs for Department 16 building renovation energy measures amount to 1,174,201 EUR. However, detailed breakdowns of costs for specific renovation measures such as envelope, windows, wall insulation, etc., are not available. Operating and maintenance costs are estimated at 700,000 EUR per year. Depreciation rates for energy-efficient renovation technologies vary, with building insulation having depreciation rates ranging from 3.3% to 5%, and a life cycle of up to 30 years. The payback period from energy savings to cover the cost of investment is approximately 26 years. Energy savings from building energy renovation measures amount to 45,631 EUR per year, with a total investment of 1,174,201 EUR. Funding sources for the renovation include residents' deposits, municipal loans, and financing through Landsbyggefonden. The average yearly expenditure on energy for residents in 2023 before building renovation is estimated at 1,023 EUR. The fraction of total yearly income spent by residents on energy ranges from 1.2% to 5.2%, depending on income level and household composition. Approximately 20% of households are estimated to be unable to afford to keep their homes adequately warm. Arrears on energy bills by tenants are not available.

However, rent payments from tenants in Department 16 amount to 657,800 EUR per year, with an average of 7,400 EUR per apartment.

To conclude, the survey findings indicate significant costs associated with energy efficiency renovations in Denmark, with a long payback period. Funding primarily relies on National Building Fund (NBF) and residents' deposits, with limited support from national or EU grants. Energy poverty remains a concern for a significant portion of households, highlighting the need for targeted interventions to address affordability issues. Further research and policy actions are necessary to promote sustainable and inclusive energy efficiency initiatives in Denmark.

2.3.6.2. Available funding sources

The National Building Fund (NBF): Operating autonomously with its dedicated board, the NBF represents a significant financial resource, constituting approximately 15% to 20% of Denmark's housing stock. It adheres to legal regulations governing its investment activities. During the financial crisis, the NBF played a vital role in boosting the Danish economy by increasing renovation activities, thus injecting more resources into the construction sector, leading to job creation and economic growth. As original construction loans are repaid, housing departments or organisations redirect their payments to the NBF. The fund comprises distinct components, including the Revolving Renovation Fund (RRF), the housing organisation's own fund, and a fund designated for new construction. While the RRF serves a specific purpose within the NBF, tenants also have the option to initiate renovations directly for their homes.

Energy Savings Agreements (ESA): Denmark's ESA program embodies a proactive approach to enhancing energy efficiency in buildings through collaboration between the government and businesses. Companies participating in ESA commit to implementing energy-saving measures with set targets for reducing energy usage over a defined period. They receive support in the form of financial incentives and technical expertise, including subsidies for energy audits, grants for equipment upgrades, and resources for training. By engaging businesses directly, ESA fosters innovation, knowledge-sharing, and sustainability within the private sector, contributing to substantial energy savings and environmental benefits across Denmark.

Green Loans and Subsidies: Denmark's provision of green loans and subsidies aims to overcome financial barriers and incentivize energy efficiency renovations in buildings. These financial instruments offer favourable terms and subsidies to encourage property owners to invest in energy-saving upgrades such as insulation improvements and heating system upgrades. By reducing upfront investment requirements, green loans and subsidies stimulate demand for sustainable building practices, contributing to lower energy consumption and carbon emissions while enhancing building performance and value.

Energy Renovation Subsidies: Denmark's energy renovation subsidies provide financial assistance for energy-saving measures in buildings, including insulation upgrades and renewable energy installations. These subsidies support energy audits and planning activities, helping property owners identify cost-effective energy-saving opportunities. By making energy efficiency renovations more affordable, Denmark encourages widespread adoption of sustainable building practices, contributing to lower energy consumption and improved building performance.

Tax Credits and Deductions: Denmark's tax incentives for energy efficiency renovations offer financial benefits to property owners, allowing them to deduct eligible expenses or claim tax credits for energy-saving measures. These incentives reduce the overall cost of energy efficiency projects, stimulating investment in sustainable building upgrades and driving innovation in the sector.

Public Funding Programs: Denmark allocates public funding to support energy efficiency projects, making renovations more accessible and affordable for individuals, businesses, and organisations. These programs may take the form of grants, loans, or subsidies, aiming to reduce energy consumption, greenhouse gas emissions, and stimulate economic growth.

Energy Performance Contracts (EPC): Denmark utilises Energy Performance Contracts (EPCs) to finance energy efficiency renovations in buildings. Under EPC arrangements, an energy service company (ESCO) finances and implements energy-saving measures, with the property owner repaying the investment over time through energy cost savings. EPCs provide a risk-free and cost-effective solution for building owners to improve energy efficiency without upfront capital investment, while also benefiting from ongoing technical support and expertise provided by the ESCO.

2.3.6.3. Evaluation of the financial gap between funding already available and extra funding needed.

Tables shown in Tables 05-06 for Denmark provide a comprehensive overview of the investment needs and available funding sources for energy efficiency projects. The breakdown of investment requirements highlights three key areas: energy efficiency renovations and circular economy, energy efficiency in public buildings, and energy efficiency and renewable energy in districts, totaling EUR 21.77 billion. This delineation emphasises Denmark's commitment to advancing energy efficiency and sustainability to meet both national objectives and those outlined in the National Energy and Climate Plans (NECP). On the funding side, a combination of EU and national-level contributions is identified. At the EU level, funds from Next Generation EU and the EU Regional Development Fund amount to EUR 2.238 billion, indicating significant support from European institutions for Denmark's energy efficiency initiatives.

At the national level, Denmark has mobilised substantial resources through various channels. The National Building Fund, Denmark Government Grants, and Denmark Green Future Fund collectively contribute EUR 19.3 billion to the available funds. This demonstrates Denmark's strong commitment to investing in energy efficiency and sustainability at the domestic level. However, despite the substantial available funds, there remains a gap of EUR 2.47 billion when compared to the total investment needs. While this gap presents a challenge, it also underscores the importance of strategic planning and resource allocation to ensure optimal utilisation of available funds. Furthermore, it highlights the need for continued collaboration between EU and national-level stakeholders to bridge any remaining gaps and maximise the impact of investments.

In conclusion, the tables provide a comprehensive overview of Denmark's efforts to advance energy efficiency and sustainability. They underscore the significant investment requirements and the proactive measures taken at both EU and national levels to address these challenges. Moving forward, effective coordination and prudent allocation of resources will be essential to realising the full potential of energy efficiency initiatives and achieving Denmark's environmental and climate goals.

Table 5 Investment needs to meet Denmark's NECP objectives

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 6 Available funding sources at EU level and national level - Denmark

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**

3. Holistic feasibility studies for the SUPERSHINE solutions

3.1. Proposed technical interventions and environmental impact.

In this section, all technical considerations to assess the technical viability in different areas will be included. These concepts aim to promote and summarise all the steps that will be followed to determine the viability of the various interventions.

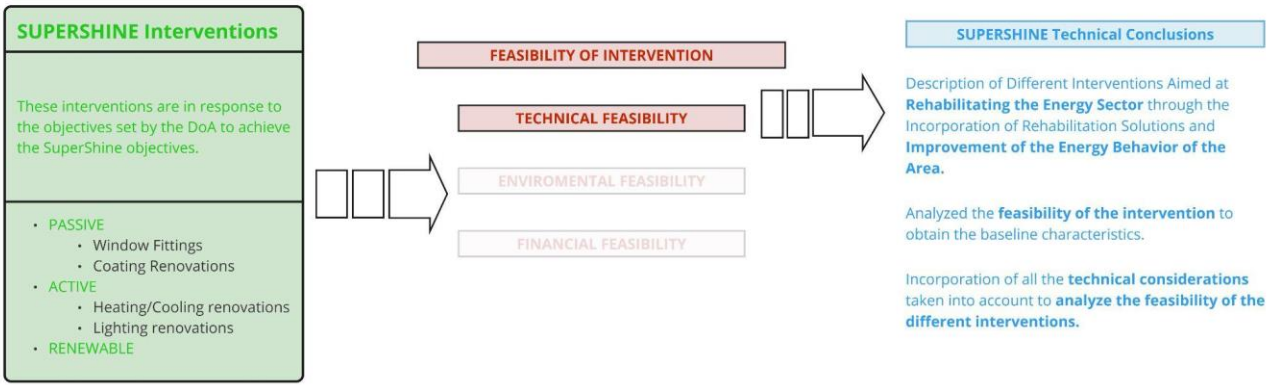

Figure 8 Summary of the feasibility process: Technical interventions.

3.1.1. Italy

Considering the initial analysis conducted on the area, a series of measures have been identified that allow achieving energy savings considering the climatic, technical, and energy conditions of the baseline.

Stable temperatures in the area provide a conducive environment for implementing interventions such as insulating facades or enhancing building envelopes, aiming to improve energy efficiency. Additionally, strategic consideration of wind direction and speed during the planning and design phase of buildings and urban spaces can maximise natural ventilation, thereby reducing reliance on heating and cooling systems. Moreover, anticipating climate change predictions calls for proactive measures, including adjustments in precipitation patterns and resilient urban planning strategies. Considering the historical context of construction materials used in the 1950s, characterised by economic and quality limitations due to post-war circumstances, all proposed measures for area rehabilitation are considered viable, with the overarching goal of enhancing the urban environment. Furthermore, the proximity of key services offers an opportunity for implementing a District Energy Plan (PED) or establishing an energy community within the area. Given that many buildings remain uninhabited, current consumption levels do not accurately reflect reality. Therefore, considering the construction timeline of these structures, energy rehabilitation efforts are necessary to address this discrepancy.

3.1.2. Latvia

The proposed interventions in each building of the Riga area aim to prioritise structural integrity while enhancing functionality. This involves evaluating their structural capacity to withstand modifications. Additionally, significant focus should be placed on improving energy efficiency through measures such as thermal insulation and optimising heating, cooling, and ventilation systems. Moreover, strict adherence to regulatory standards and local building codes concerning safety, accessibility, and zoning is indispensable. Prioritising insulation over cooling, particularly in regions experiencing harsh winter conditions, can significantly contribute to energy conservation efforts. Furthermore, with the majority of the global population concentrated in urban areas, it is paramount to prioritise reducing energy consumption and mitigating CO_2 emissions through comprehensive renovations and insulation implementation in European urban sectors.

3.1.3. Denmark

For the Herning District, the interventions include installing new thermostats, floor heating systems, balanced ventilation, LED lighting, 3-layer low energy windows, and doors. It also involves insulating divisions between floors, pipes, roofs, and the façade, as well as installing PV solar panels for common electricity consumption. The feasibility study would evaluate the potential energy savings, costs, and benefits of these interventions, as well as the viability of supplying electricity to individual flats through rooftop PV systems.

3.2. Proposed financial solutions.

Considering the investment gaps in Italy, Latvia, and Denmark for energy efficiency projects, we propose several innovative funding solutions to fill the funding GAP with a focus on Public-Private Partnership (PPP) funding contracts.

3.2.1. Public Private Partnerships (PPPs)

Public-Private Partnerships (PPPs) involve long-term collaborations aligning government service delivery objectives with private profit objectives, as defined by the OECD in 2008. In times of constrained financial resources, PPPs become essential 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 flourished in European countries such as the UK, Spain, France, Germany, Italy, and Portugal. Mutual benefits accrue to both the private and public sectors through PPPs: the private sector gains guarantee to manage project risks, while the public sector receives capital investment and management expertise. However, PPP transactions have slowed due to unfavourable conditions in capital markets. The advantages 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. Nonetheless, 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 employed as the private party, raising finance through a combination of equity and debt. Equity investors, typically comprising project developers, construction companies, and private equity funds, assume higher risks and seek higher returns. PPP financing frequently involves non-recourse project finance, where lenders are compensated from project revenues without recourse to equity investors, allowing equity investors to absorb project losses initially. Non-recourse project finance structures often entail a significant proportion of debt, typically ranging from 70% to 95% of total finance. Although project finance is advantageous for large projects, it comes 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 such as step-in rights or government participation can help reduce the cost of finance for PPPs.

3.2.2. Classification of PPP financing mechanisms

The commonly used PPP contracts in the EU to fill the funding gap in energy efficiency renovations in affordable housing and districts are:

Guaranteed savings contract

In the guaranteed savings contract, the social housing association assumes the responsibility of financing 100% of the investment costs required for executing the energy efficiency (EE) renovation project. Meanwhile, the ESCO company is tasked with executing the EE renovations and designing the project. Additionally, the ESCO company bears the expenses related to the installed EE technologies and assumes full financial and technical risks associated with the project. Under this agreement, the social housing company is assured a fixed predetermined energy savings equivalent to the debt obtained to fund the EE project. If the energy savings from the implemented EE renovations exceed the guaranteed energy savings, the social housing company receives the fixed minimum guaranteed energy savings plus 20% of the surplus energy savings, while the ESCO company obtains the remaining 80%. Conversely, if the energy savings fall short of the guaranteed amount, the social housing company retains all generated energy savings, and the ESCO covers the shortfall, absolving the social housing company of any financial risk.

Shared savings contract

In the shared savings contract, the ESCO assumes full responsibility for financing 100% of the investment costs needed for the energy efficiency (EE) renovation project, along with implementing the renovations and designing the project. The social housing company provides the equity in the form of the building. Additionally, the ESCO bears the expenses associated with the installed EE technologies and takes on all financial and technical risks associated with the project. Under this agreement, the ESCO is assured a fixed predetermined energy savings. If the energy savings exceed the guaranteed amount, the social housing company receives 35% of the surplus energy savings, while the ESCO obtains 65% of the surplus energy savings in addition to the guaranteed energy savings. However, if the energy savings fall short of the guaranteed amount, the ESCO retains all generated energy savings and considers the shortfall between the guaranteed and actual savings as a financial loss, with no energy savings allocated to the social housing company.

In both Public-Private Partnership (PPP) contracts, energy efficiency improvements are implemented through either a loan or facilitated by an ESCO. When loans are utilised, the building owner selects the energy efficiency improvements, often from an approved list of measures. However, without the support and expertise of an ESCO, the chosen measures may not always be the most effective use of financing for energy efficiency. ESCOs, being experts in energy efficiency measures, are incentivized to maximise energy efficiency savings for minimum cost, often through a savings guarantee. Nevertheless, there are barriers to the ESCO model, including limited public awareness of their benefits, which can hinder their widespread adoption. This issue can lead to challenges in generating profits for ESCOs unless they secure many contracts. To address these challenges, larger ESCO business models, such as super ESCOs, offer more stable business models, especially in markets lacking an established ESCO industry. Super ESCOs can make energy efficiency improvements to entire building stocks as cost-effectively as possible, mitigating the risk of ESCO failure due to their government support and financial certainty from larger contracts.

Direct Credit Line

DCL, introduced by public entities such as government bodies, non-profit organisations, and banking foundations, acts as a vital funding mechanism for Energy Efficiency (EE) projects in partnership with private financial institutions. Typically, these private financial institutions encompass banks or investment funds, providing supplementary financing, co-financing, for EE initiatives. This financing strategy strategically deploys funds from government sources, international financial institutions (IFIs), or donor agencies to stimulate increased lending by Local Financial Institutions (LFIs) dedicated to EE projects. The aim is to address the challenge of inadequate or non-existent lending to EE projects, primarily due to LFIs' limited knowledge and understanding of the distinctive characteristics and benefits associated with such projects.

Under this mechanism, the public partner disburses funds to LFIs at generally favourable interest rates, creating an incentive for these private-sector entities to extend further loans for EE projects. As the on-lending by LFIs typically occurs at higher interest rates (often in line with market rates, as observed in World Bank credit lines), LFIs stand to generate profits from these loan transactions. The collaborative agreement between the public and private partners commonly mandates that LFIs co-finance the loans, effectively amplifying and bolstering the overall financing pool available for EE projects. This collaborative approach, exemplified by initiatives like the World Bank in 2008, tackles the crucial challenge of expanding financial backing for EE projects by actively engaging private financial institutions in advancing sustainable and energy-efficient initiatives.

Energy Supply Contract

Energy supply contracts (ESCs) represent an ESCO business model closely resembling traditional energy suppliers. In this arrangement, social housing companies opt to install energy efficiency measures and finance them through their energy or utilities bill. Under this contract, both the social housing company and the ESCO company share the financing of the EE renovation project costs, with no party guaranteed a minimum level of energy savings. The financial risk is thus distributed between the ESCO and the social housing company. Additionally, the energy savings resulting from the EE renovations are apportioned between the two parties based on the percentage of investment costs covered by each, typically ranging between 50% to 90% for the ESCO company and 10% to 50% for the social housing company. It's noteworthy that in this contract, the debt typically remains tied to the meter, meaning that if the social housing company sells the building, the new owner inherits the contract.

4. Implementation of the solutions

4.1. Application of proposed energy solutions and their environmental impact

This table provides a comprehensive, high-level assessment of the anticipated environmental impacts associated with the proposed interventions. The assessment is grounded in the outcomes typically observed in Life Cycle Assessments (LCAs) for comparable interventions. Since this is a preliminary analysis, the findings will be refined and updated with additional data in the forthcoming iteration of the feasibility studies (***D4.2 Feasibility Studies for the Lighthouse Districts-Part 2***).

Table 7: Preliminary Benchmarking for Feasibility Assessment

INTERVENTION DESCRIPTION	ENVIRONMENTAL ASPECT	ENVIRONMENTAL IMPACT	COUNTRY		
			Italy	**Latvia**	**Denmark**
Window Fittings	Atmosphere	Potential for greenhouse gas emissions	Moderate	High	Moderate
	Water	Potential for water pollution due to manufacturing	Low	Low	Low
	Land	Potential for land degradation due to raw material extraction	Low	Low	Low
	Biodiversity	Potential for biodiversity loss 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

	Cultural / Social	Potential for cultural impact due to installation	Low	Moderate	Low
External / Internal Coating	Atmosphere	Potential for greenhouse gas emissions	Moderate	Moderate	Moderate
	Water	Potential for water pollution due to production and application	Low	Low	Low
	Land	Potential for land degradation due to raw material extraction	Low	Low	Low
	Biodiversity	Potential for biodiversity loss 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
	Cultural / Social	Potential for cultural impact due to application	Low	Low	Low
Heating Cooling Renovations	Atmosphere	Potential for greenhouse gas emissions	High	High	High
	Water	Potential for water consumption due to manufacturing	Low	Low	Low
	Land	Potential for land degradation due to raw material extraction	Low	Low	Low
	Biodiversity	Potential for biodiversity loss 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
	Cultural / Social	Potential for cultural impact due to installation	Moderate	Moderate	Moderate
Lighting renovations	Atmosphere	Potential for greenhouse gas emissions	High	High	High
	Water	Potential for water pollution due to manufacturing	Low	Low	Low
	Land	Potential for land degradation due to raw material extraction	Low	Low	Low
	Biodiversity	Potential for biodiversity loss due to raw material extraction	Low	Low	Low
	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	Moderate	Moderate	Moderate
	Cultural / Social	Potential for cultural impact due to installation	Low	Low	Low
Renewable Sources. Solar panels	Atmosphere	Potential for greenhouse gas emissions	High	High	High
	Water	Potential for water consumption due to manufacturing	Moderate	Moderate	Moderate
	Land	Potential for land degradation due to raw material extraction	Moderate	Moderate	Moderate
	Biodiversity	Potential for biodiversity loss 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
	Cultural / Social	Potential for cultural impact due to installation	Moderate	Moderate	Moderate

4.2. Energy comfort, poverty, and social needs

When developing feasibility studies for a district retrofit project, these two aspects, the SLCA and the data elaboration strategy, provide a comprehensive approach to addressing energy comfort, poverty, and social needs. They ensure that the project is not only technically and financially viable but also socially beneficial. This comprehensive approach is essential for conducting feasibility studies for the project, ensuring that the project is not only technically and financially viable but also socially beneficial. This alignment of technical, financial, and social aspects is crucial for the success of district retrofit projects.

4.2.1. Social LCA

The SLCA is the result of a collaborative effort dedicated to designing a dynamic engagement roadmap that encapsulates the distinctive renovation objectives and social ambitions of each LH. It will be implemented introducing the methodology designed in WP1 and reflected in ***D1.2 Engagement strategy and social acceptance KPIs.*** The evaluation framework is designed to facilitate a comprehensive assessment of the community's acceptance of these renovations and the effectiveness of the implemented engagement activities in achieving predefined engagement targets. Are intended to facilitate the modification and optimization of engagement strategies throughout the implementation phase. It’s important to note that these engagement strategies are dynamic and may undergo changes and improvements as the implementation of the Life Cycle Assessment (LCA) in the lighthouses progresses.

4.2.2. Elaboration of data from the lighthouses

Given the dynamic nature of renovation projects, it's crucial to collect data at various stages of the project. This ongoing data collection allows for the monitoring of changes and the timely updating of feasibility studies. Key areas for ongoing data collection might include:

- **Regulatory Compliance**: Regular updates on changes in relevant regulations can help ensure the project remains compliant and can help identify necessary adjustments early.
- **Technological Trends:** Keeping abreast of the latest technological advancements can allow for their incorporation into the project, potentially improving efficiency and outcomes.

- **Economic Indicators:** Regular monitoring of relevant economic indicators can help in forecasting costs and returns, allowing for more accurate budgeting and financial planning.
- **Environmental factors:** Ongoing collection of environmental data can help identify changes that might impact the project and can inform adjustments to mitigate negative impacts,
- **Stakeholder Feedback:** regular collection of stakeholder feedback can help ensure the project continues to meet the needs and preferences of the community and can inform adjustments to improve satisfaction.

In conclusion, the dynamic nature of renovation projects necessitates ongoing data collection and regular updates to feasibility studies. By staying responsive to changes in regulations, technology, economics, the environment, and stakeholder input, these projects can better adapt to changing circumstances and deliver improved outcomes for all stakeholders.

4.3. Application of proposed financial solutions

Implementing a Public-Private Partnership (PPP) funding contract to finance energy efficiency renovation in social housing buildings involves several key steps:

Identification of Stakeholders: Identify relevant stakeholders, including government agencies responsible for social housing, private investors, energy service companies (ESCOs), and potentially community organisations or residents.

Project Preparation: Conduct a comprehensive assessment of the social housing buildings to determine the scope of renovation needed and the potential energy efficiency measures to be implemented. Develop a detailed project plan outlining the objectives, timeline, budget, and expected outcomes of the renovation project.

Legal and Regulatory Framework: Establish the legal and regulatory framework governing the PPP arrangement, including contractual agreements, risk allocation, and compliance with relevant laws and regulations. Ensure transparency and accountability in the procurement process and adhere to public procurement guidelines.

Financial Structuring: Determine the financing structure for the project, including the contribution of public funds, private investment, and potentially other sources such as grants or subsidies. Negotiate terms and conditions of the funding contract, including revenue-sharing mechanisms, repayment terms, and risk-sharing arrangements between public and private partners.

Selection of Private Partners: Conduct a competitive procurement process to select private partners, such as ESCOs or project developers, with expertise in energy efficiency renovation and financing. Evaluate proposals based on criteria such as technical capabilities, financial viability, experience, and alignment with project objectives.

Contract Negotiation and Execution: Negotiate the terms of the PPP contract, including performance targets, payment mechanisms, warranties, and dispute resolution mechanisms. Ensure that the contract includes provisions for monitoring, reporting, and evaluation to track project progress and outcomes.

Project Implementation: Coordinate the activities of public and private partners to ensure smooth project implementation, including procurement of materials and equipment, construction, installation of energy efficiency measures, and quality assurance. Monitor project milestones and performance indicators to track progress and address any issues or deviations from the project plan.

Operation and Maintenance: Establish procedures for the operation and maintenance of energy efficiency measures post-construction, including regular maintenance checks, performance monitoring, and addressing any maintenance issues promptly.

Monitoring and Evaluation: Implement a monitoring and evaluation framework to assess the effectiveness of the energy efficiency measures in achieving the desired outcomes, such as energy savings, carbon emissions reduction, and improvements in indoor comfort. Use feedback from stakeholders and performance data to inform future decision-making and improve the efficiency of future projects.

Communication and Stakeholder Engagement: Maintain open communication channels with stakeholders throughout the project lifecycle, including residents, community organisations, local authorities, and other relevant parties. Engage stakeholders through outreach activities, workshops, and feedback mechanisms to ensure their participation and support for the project.

By following these steps, social housing companies can collaborate with governments and private investors effectively to finance energy efficiency renovation in social housing buildings and districts through PPP arrangements, leveraging expertise, resources, and incentives from both sectors to achieve sustainable and cost-effective outcomes.

5. Conclusions

Building retrofit interventions can have a significant impact on the energy and environmental footprint of a district. The specific impacts can vary based on the location and the specific interventions implemented. After analysing the available data about the potential impacts in Trieste, Italy; Riga, Latvia; and Herning, Denmark:

In Trieste, and all over Italy, there is an increasing interest in the renovation and improvement of both listed and unlisted existing buildings. The Italian National Institute of Statistics observed the increase in family commuting and the attractiveness of marginal territories. The Government's approval of the National Recovery and Resilience Plan (2021) has strengthened this process of traditional building retrofit. However, since the residential units of the district are going to be rebuilt, this is an opportunity to explore the creation of dwellings that are sustainable from an environmental, social and economic perspective.

In Riga, the uneven development and centralization of the city pose challenges for retrofit interventions. The lack of appropriate investments and resources stand in the way of implementing the plans presented by the Ministry of Environmental Protection and Regional Development. The retrofit interventions might include energy efficiency actions and fiscal incentives. However, these interventions might change the moisture dynamics of historic envelopes, which might lead to moisture damages when combined with more extreme precipitation events.

In Herning, the retrofit is the one that is more advanced for a series of factors such as a larger proportion of social housing, a high level of public awareness about the importance of energy efficiency and strong government support. However, like Latvia, retrofit solutions will change the moisture dynamics of historic envelopes, which might lead to moisture damages when combined with more extreme precipitation events.

The assessment of financial needs for lighthouses in Italy, Denmark, and Latvia reveals common challenges and diverse strategies in promoting energy efficiency renovations. Italy showcases a holistic and ambitious approach, leveraging various funding sources like Ecobonus and Superbonus 110% to support extensive renovation projects in social housing buildings. Despite slight financial gaps, Italy demonstrates a commitment to sustainable construction practices and reducing carbon emissions. Similarly, Denmark faces significant costs and long payback periods for energy efficiency renovations. With sources like the National Building Fund and Energy Savings Agreements, Denmark exhibits proactive measures to promote energy efficiency. However, a gap in funding highlights the importance of strategic planning and collaboration between EU and national stakeholders. Latvia confronts challenges such as material shortages and the global energy crisis in its energy efficiency renovation efforts. Despite diverse funding sources like emission allowances and the Latvian Environmental Protection Fund, a substantial gap in funding persists. Addressing energy poverty and promoting inclusive initiatives are essential priorities, necessitating collaboration between EU and national stakeholders to bridge remaining gaps and advance sustainable development goals.

Furthermore, Public-Private Partnerships (PPPs) offer promising solutions to address funding gaps in energy efficiency renovations, particularly in Denmark, Italy, and Latvia. These collaborations between public and private sectors provide avenues for accessing finance, reducing capital expenditure, and leveraging expertise. Through mechanisms like Guaranteed Savings Contracts, Shared Savings Contracts, and Direct Credit Lines, PPPs facilitate effective resource management and promote sustainable development. However, challenges such as limited awareness and complexity persist. Initiatives like super ESCOs and Direct Credit Lines offer stable models to overcome these challenges and advance energy efficiency goals, contributing to a greener future in Denmark, Italy, Latvia, and beyond.

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