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SUPERSHINE

D3.1 Analysis of bottom-up business models, Cost Benefit Analysis (extended with environmental impact) and crowdfunding strategy

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Technical references

Project Acronym	SUPERSHINE
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v	Date	Beneficiaries	Track changes
1.0	01/05/2024	UoY	First Draft
1.1	14/05/2024	CARTIF	Technical Lighthouse Interventions
1.2	20/05/2024	DEMIR, CIRCE	Environmental and social impact
1.3	20/05/2024	UoY	Cost benefit analysis, Bottom up business model
1.4	24/05/2024	Tender Capital	Crowdfunding
1.5	28/05/2024	UoY	Revision
2.0	30/05/2024	APRE	Final draft

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Acronyms

CO_2: Carbon Dioxide

CVaR: Conditional Value at Risk

DH: District Heating

EE: Energy Efficiency

ESCO: Energy Service Company

GHG: GreenHouse Gas

kWh: Kilowatt-hour

NCF: Net Cash Flow

NPV: Net Present Value

PPP: Public-Private Partnership

ROI: Return on Investment

SDR: Social Discount Rate

SRTP: Social Rate Time Preference

SPV: Special Purpose Vehicle

TJ: Terajoule

WAM: Weighted Average Method

Executive summary

The SUPERSHINE project is a comprehensive initiative designed to address the urgent need for energy efficiency renovations across Europe. Focused on Italy, Latvia, and Denmark, this project employs financial and statistical analyses within the framework of Public-Private Partnerships (PPPs) and crowdfunding to facilitate energy efficiency projects and foster sustainable development. This document covers the following:

Technical analysis: This section focuses on the technical analysis framework developed to assess energy efficiency renovation projects in Italy, Latvia, and Denmark. The document outlines the methodology employed, starting with the energy savings modelling process. This involves data collection, baseline assessment, intervention simulation, and result analysis to predict energy consumption reductions and CO2 emissions reductions post-renovation.

Financial and bottom-up business model: The bottom-up business model developed within the SUPERSHINE project offers a comprehensive approach to analysing and financing energy efficiency renovation projects. It comprises several methodical steps. First, the model utilises the SUPER-i energy savings model to predict energy consumption reductions post-renovation by assessing data, baseline energy profiles, and intervention impacts. Next, a stochastic volatility modelling simulates future financial variables to understand economic conditions affecting project feasibility. The model then calculates the social discount rate, determining the true cost of capital by considering private investment returns and savings/consumption rates. Following this, financial and socio-economic impact analysis evaluates ROI, NCF, NPV, and risk-adjusted extra return to gauge project profitability and viability. The approach extends to block-level and district-level replication, assessing collective impacts of interventions at larger scales, providing comprehensive outlooks for blocks and districts. Additionally, benchmark comparison ensures findings align with established indices, ensuring financial soundness. The SUPERSHINE bottom up business model guides stakeholders in selecting the most financially viable interventions based on risk-adjusted returns, ROI, and the SDR, aiming to facilitate informed decision-making and promote sustainable energy practices.

The financial analysis methodology evaluates the feasibility and economic viability of energy efficiency renovation projects within Public-Private Partnership (PPP) funding schemes and crowdfunding. This methodology encompasses a comprehensive analysis of key economic indicators and financial variables, including energy market bid price, inflation rate, interest rate on debt, property value growth rate, rent growth rate, default rate on rent, and socio-economic variables. Through advanced stochastic volatility modelling and the calculation of the Social Discount Rate (SDR), the methodology provides a robust framework for assessing financial returns, risk-adjusted extra returns, and conditional value at risk (CVaR). By integrating detailed financial analysis with socio-economic considerations, the SUPERSHINE project aims to facilitate informed decision-making and optimise funding solutions for energy efficiency projects in Italy, Latvia, and Denmark.

Environmental impact analysis: This section focuses on the environmental impact assessment of district retrofit interventions in Italy, Latvia, and Denmark. These interventions aim to improve energy performance, reduce carbon emissions, and promote sustainable practices. The methodology involves evaluating the energy savings potential, assessing related costs, and emphasising waste management strategies, such as utilising local agricultural waste and promoting recycling. Despite substantial upfront costs, the long-term benefits, coupled with potential carbon credits and voluntary carbon market support, make these interventions economically viable and environmentally sustainable. Through rigorous environmental assessment and mitigation strategies, SUPERSHINE seeks to drive positive environmental outcomes and contribute to the transition towards a more sustainable future.

Social impact analysis: Energy efficiency and renewable measures can yield numerous substantial social ramifications beyond their immediate effects on energy efficiency and cost. Frequently, these implications are disregarded due to the challenge of quantifying their value. The section related with social impact emphasises this aspect of the measures.

1. Introduction

Purpose of the document

This deliverable outlines the methodology and framework developed by the SUPERSHINE project to analyse and finance energy efficiency renovation projects through Public-Private Partnership (PPP) funding and crowdfunding schemes. It covers the financial, technical, environmental, and social aspects of these projects, focusing on pilot implementations in Italy, Latvia, and Denmark. This deliverable highlights the project's bottom-up business model and its detailed multi-step approach to financial analysis, technical feasibility, environmental impact, and social benefits. This deliverable covers:

__Technical Analysis of the Lighthouses:__ This section delves into the technical analysis conducted on the lighthouse projects in Italy, Latvia, and Denmark. Each country has unique focus areas for their retrofit interventions. In Latvia, the emphasis is on historic buildings, considering climate impacts, heritage conservation, and occupant comfort. Italy focuses on public residential buildings, using materials derived from local agricultural waste, thereby promoting recycling and waste management. Denmark targets public housing with green renovations, aligning with its climate-neutral goals for 2050. The technical analysis evaluates the potential for energy savings, the effectiveness of various energy efficiency measures, and the application of sustainable technologies.

__The Bottom-Up Business Model and Funding Sources:__ The deliverable details the bottom-up business model, which is central to the SUPERSHINE project. This model integrates several methodical steps to provide a comprehensive assessment of energy efficiency interventions, starting from individual buildings and scaling up to district-wide analyses. Steps include:

- Energy Savings Modelling: Estimating expected energy savings from proposed interventions by collecting data, establishing baselines, simulating interventions, and analysing results.
- Stochastic Volatility Modelling: Simulating future values of key financial variables such as energy prices, inflation rates, interest rates, property values, rent growth, and socio-economic factors.
- Calculating the Social Discount Rate (SDR): Using the weighted average method to balance private savings and investment returns, reflecting the opportunity cost of public investment.
- Financial Impact Analysis: Assessing metrics such as ROI, NCF, NPV, risk-adjusted extra returns, and CVaR to evaluate the profitability and viability of the projects.

- Block-Level and District-Level Replication: Aggregating results from individual buildings to block and district levels to understand broader impacts.
- Benchmark Comparison: Comparing findings against benchmark investments like the S&P 500 index, adjusting for risk to ensure financial soundness.
- Ranking Funding Solutions: Ranking funding solutions based on risk-adjusted extra returns, ROI, and the social discount rate.

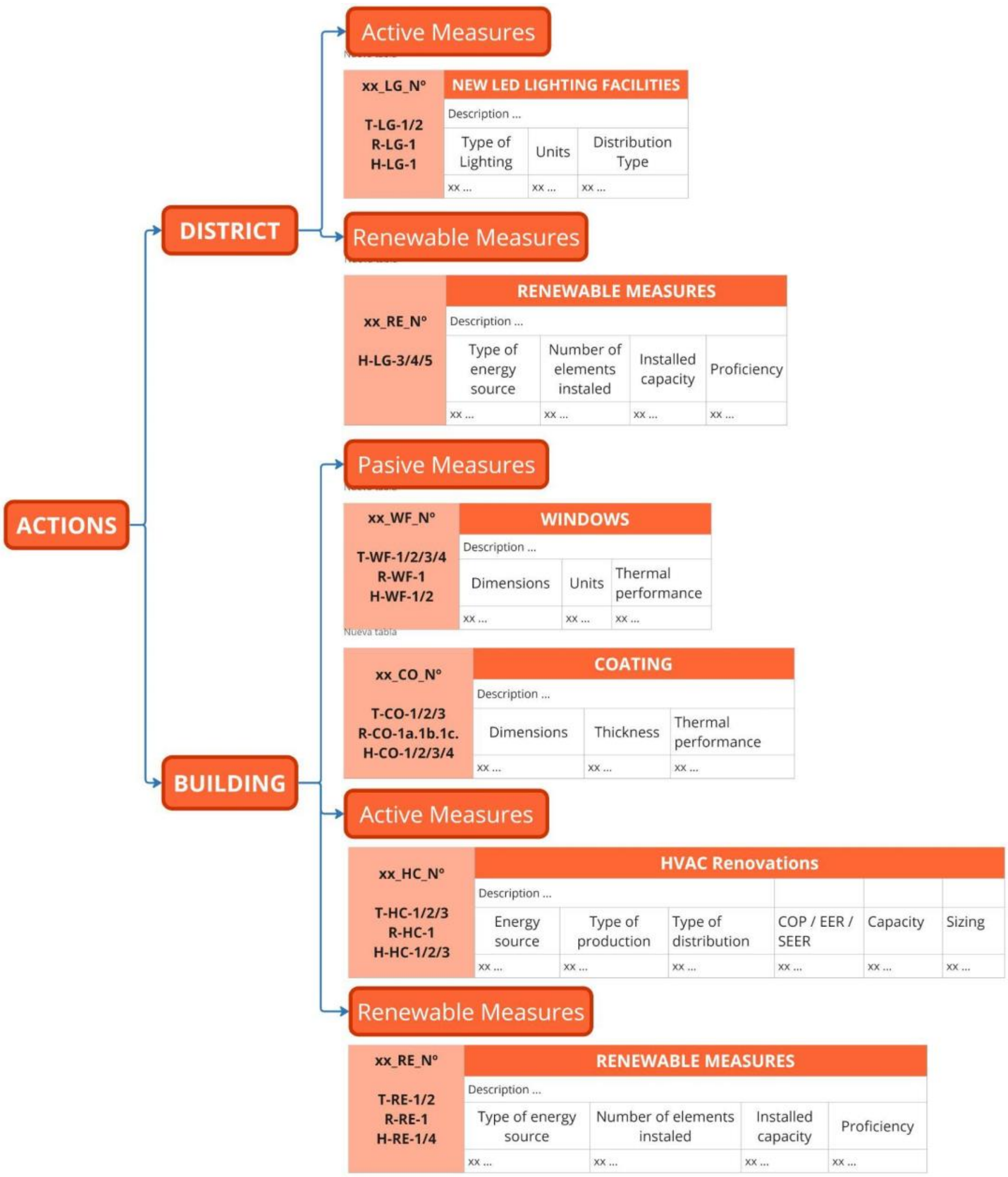
Financial Analysis: This section provides a detailed description of the financial analysis methodology used in the SUPERSHINE project, beginning with the energy savings model. The energy savings model involves collecting data, establishing baselines, simulating interventions, and analysing the expected energy savings in terms of kWh saved and CO2 emissions reduced. Following this, stochastic volatility modelling simulates future values for key financial variables. The social discount rate is calculated using a weighted average method to balance private savings and investment returns. The financial and socio-economic impact analysis uses these findings to evaluate metrics such as ROI, NCF, NPV, risk-adjusted extra returns, and CVaR, determining the profitability and viability of the projects.

Environmental Analysis: The environmental impact assessment focuses on the benefits of retrofit interventions in the pilot countries. It discusses the reduction in energy consumption and carbon emissions, the use of sustainable materials, and the potential for carbon credits. Waste management, particularly in Italy, where local agricultural waste is used in construction, is also highlighted. Despite the substantial upfront costs, long-term benefits and potential funding from carbon credits make these interventions viable and sustainable.

The social impact analysis: examines the broader benefits of energy efficiency renovations. Improvements in accessibility, health, and comfort, job creation, and support for low-income citizens are discussed. Measures include enhanced indoor air quality, temperature control, and initiatives to support individuals with special needs. The analysis emphasises how these measures enhance the quality of life, stimulate economic activity, and promote social inclusion.

2. Lighthouses interventions

The SUPERSHINE project developed methodology, organises actions by their implementation in either buildings or districts. These actions are classified into three categories based on their area of intervention. Each category follows a standardised table template that details the essential values for each technical action.



2.1. District level

2.1.1 ITALY TRIESTE (Ater)

In the ATER district, planned interventions aim to enhance energy efficiency and environmental sustainability through extensive renovations. A modern district heating (DH) and domestic hot water (DHW) systems using natural gas condensing boilers will be developed, significantly reducing energy consumption and carbon emissions. Additionally, a consumption measurement system for each housing unit will be implemented, enabling better control and management of energy usage.

	HEATING CONSUMPTION		
nº	Baseline Data (kWh/m2 Year)	Final Consumption (kWh/m2Year)	percentage of reduction
Boito 1	131	32.75[1]	75%[2]
Boito 2	131	32.75	75%
Boito 3	131	32.75	75%
Boito 4	131	32.75	75%
Boito 5	131	32.75	75%
Boito 6	131	32.75	75%
Boito 7	131	32.75	75%
Boito 8	131	32.75	75%

1 *Estimated value, in reference of the certificate building change (G-A+)*

2 *Smart Building, 2024, Energy class A+ houses; The energy class A+ houses we construct offer substantial energy and money saving, 16.05.2024 y https://smartbuilding.gr/en/eco-technologies/energy-class-a-houses/*

ACTIVE MEASURES

Lighting renovations.

T-LG-1-2	LOW-CONSUMPTION LAMP		
	Urban lighting facilities are being updated from incandescent to LED, which significantly improves energy efficiency. LED lamps convert electrical energy directly into light, which is why energy consumption is reduced by 80%.		
	Type of lighting	Units[3]	Distribution Type
	LED	60	Longitudinal Lateral Distribution

2.1.2 LATVIA RIGA (Āgenskalna priedes)

In Riga, ambitious city level interventions are underway, focusing on expanding the district heating network and integrating smart and digital solutions. These measures aim to address social challenges, enhance quality of life, and foster the development of an open, participatory, democratic, and sustainable society. SUPERSHINE is also creating an "economic system" through one-stop shops to facilitate access to energy services.

	HEATING CONSUMPTION		
nº	Baseline Data (kWh/m2 Year)	Final Consumption (kWh/m2 Year)	percentage of reduction
Dreiliņu 20	212.94	85.18	60%
Dreiliņu 18	200.44	80.18	60%
Dreiliņu 16	203.91	81.56	60%
Dreiliņu 14	227.65	91.06	60%
Kristapa 8	-	-	-

[3] *The street measures 155.56 m by 7.71 m. With a lighting density of 0.05 units/m², the number of light fixtures needed for the area is calculated.*

	HEATING CONSUMPTION		
Kristapa 8A	271.10	108.44	60%
Kristapa 8B	271.10	108.44	60%
Kristapa 10	264.75	105.90	60%
Kristapa 14	238.66	95.46	60%
Kristapa 18	211.23	84.49	60%
Kristapa 20	237.71	95.08	60%
Melnsila 19	235.62	94.25	60%
Melnsila 21	200.47	80.19	60%
Melnsila 23	200.73	80.29	60%
Melnsila 25	192.47	76.99	60%
Āgenskalna 22C	205.79	82.32	60%
Āgenskalna 22B	208.97	83.59	60%
Āgenskalna 22	213.78	85.50	60%
Āgenskalna 24	-	-	-
Āgenskalna 22A	211.64	84.66	60%
Kristapa 16C	198.92	79.57	60%
Kristapa 16B	198.23	79.29	60%
Kristapa 16A	196.13	78.45	60%
Kristapa 16	211.85	84.74	60%
Kristapa 12	214.09	85.65	60%

ACTIVE MEASURES

Lighting renovations.

R-LG-1	NEW LED LIGHTING IN COMMON AREAS		
	Urban lighting is being upgraded to LED. While these lamps do not achieve 100% energy efficiency, they are 90% efficient. Nevertheless, LED lamps consume less energy, which reduces both costs and energy consumption.		
	Type of lighting	Unit[4]	Distribution Type
	LED	2043	Individual, 90%

2.1.3 DENMARK HERNING (VERDO)

In Herning, renovation actions are being implemented at the district and building levels, with the main goals of improving energy efficiency and the quality of life for district residents. The district area covers 55,101 m², where a biomass district heating (DH) system and PV solar panels have been installed. These initiatives aim to achieve a significantly improved U-value through the installation of triple-glazed windows, which offer a U-value of 0.87 W/m²K, and the re-insulation of roofs with 400 mm of rock wool, providing a U-value of 0.2 W/m²K.

	HEATING CONSUMPTION			ELECTRICITY CONSUMPTION		
nº	Baseline Data (MWh/Year)	Final Consumption (MWh/Year)	percentage of reduction	Baseline Data (MWh/Year)	Final Consumption (MWh/Year)	percentage of reduction
16	789,00	37,00	97%	666,00	27,7	98%
19	2.882,00	40,60	95%	802,00	38,90	83%

4 *Illuminating Engineering Society. (n.d.). IES lighting library. Retrieved from https://www.ies.org/standards/standards-in-public-review/. Lighting Design Lab. (2013). Footcandle lighting guide. Retrieved from https://www.lightingdesignlab.com/sites/default/files/pdf/Footcandle_Lighting%20Guide_Rev.072013.pdf and Elite Lighting. (2020). IES footcandle recommendations. Retrieved from https://iuseelite.com/wp-content/uploads/2020/03/Elite-Lighting_IES-Footcandle-Recommendations.pdf*

	HEATING CONSUMPTION			ELECTRICITY CONSUMPTION		
21	1.561,00	35,40	97%	354,00	34,50	88%
24	3.975,00	68,00	90%	1.480,00	64,90	73%

ACTIVE MEASURES

Lighting renovations.

H-LG-1	NEW LED LIGHTING IN COMMON AREAS		
	Incandescent lamps, which have a tungsten filament, are energy inefficient (less than 5% of energy converted to light) and have a short lifespan (1,000-2,000 hours). In contrast, LED lamps use light-emitting diodes, converting up to 70% of energy into light and lasting much longer (25,000-50,000 hours).		
	Type of lighting	**Unit**	**Distribution Type**
	LED	160	Longitudinal Lateral Distribution

RENEWABLE MEASURES

Energy from renewable energy sources renovations

H-RE-3	WIND TURBINES			
	In Herning, Denmark wind turbines play a crucial role in the DH system. The wind turbines generate electricity that powers heat pumps and other components of the DH system, thus decreasing reliance on fossil fuels. This integration not only enhances energy efficiency but also helps in lowering greenhouse gas emissions, aligning with Denmark's ambitious climate goals.			
	Type of energy source	Number of elements installed	Installed capacity	Proficiency
	Wind	101	883 TJ/year	30%

H-RE-4	SOLAR THERMAL PV

	Solar panels are installed on the rooftops of 5 buildings, with the optimal orientations being South and East. It is estimated that the eaves facing South are entirely covered, while those facing East are covered at 80%.			
	Type of energy source	Number of elements installed	Installed capacity	Proficiency
	Thermal	1000	415 W	21,25%

H-RE-5	**DH**			
	Herning's DH system exemplifies how integrating renewable energy sources and advanced technologies into district heating can lead to significant improvements in energy efficiency and sustainability.			
	Type of energy source	Number of elements installed	Installed capacity	Proficiency
	Biomass	Solar Panels (Production)	78.00 MW	

2.2 Building level

2.2.1 ITALY_ TRIESTE (Ater)

At the city level, the Boito project aligns with Trieste's municipal goals to promote sustainability and energy efficiency in urban infrastructures. Renovations in Boito, such as the installation of solar panels and the use of low environmental impact construction materials. These actions are crucial not only for reducing the city's carbon footprint but also for setting a precedent for future urban renewal projects in other areas, promoting a transition towards a greener and more resilient economy in Trieste.

PASSIVE MEASURES

Windows Fitting

T-WF-1/2/3/4	**WINDOWS**

	Double glazed windows with aluminium and wood frames		
	Dimensions	Units	Thermal performance
	1,80 m2	160	1,00 W/m2 K

External / Internal Coating renovations

T-CO-1	INSULATED USING 100 MM (EXTERNALLY TO THE WALLS)		
	External plaster, thermal insulation, hollow thermal brick and internal plaster		
	Dimensions	Thickness	Thermal performance
	0,46	0.405 m	0,25 W/m2 k

T-CO-2	INSULATED USING 100 MM (INSULATING PANELS ON THE FLOOR)		
	Tiles, cementitious waterproof coating, thermoacoustic panel, isolation panel, air gap and plasterboard sheets		
	Dimensions	Thickness	Thermal performance
	0,83	0.42 m	0,663 W/m2 k

T-CO-3	INSULATING INTER-FLOORS		
	Tiles, cementitious waterproof coating, thermoacoustic panel, isolation panel, air gap and plasterboard sheets		
	Dimensions	Thickness	Thermal performance
	0,83	100 m	0,20 W/m2 k

ACTIVE MEASURES RENEWABLE MEASURES

Energy from renewable energy sources renovations

T-RE-1	**INSTALLATION OF SOLAR PANELS AND THERMAL**			
	Photovoltaic solar panels and solar technologies are designed to reduce the building's energy consumption by harnessing renewable energy sources. Additionally, the integration of a condensing boiler system that works in conjunction with these panels is detailed. This setup facilitates a synergistic approach, enhancing energy efficiency by combining both solar power and heat recovery.			
	Type of energy source	Nº of elements installed	Installed capacity	Proficiency
	Solar Thermal	30	415 W	21,25%

T-RE-2	**INSTALLATION OF FLOW AND RETURN CURCUITS**			
	The flow and return circuits are designed to maximise the efficiency of the installed solar panels, effectively managing the distribution of thermal energy produced through the building's central heating and hot water system. These circuits are part of a centralised heating system that also integrates hot water production, facilitating more efficient control and reducing overall energy consumption.			
	Type of energy source	Nº of elements installed	Installed capacity	Proficiency
	Solar Thermal	1	415 W	21,25%

2.2.2 LATVIA_ RIGA (Āgenskalna priedes)

In the Āgenskalna priedes district specifically, interventions are focused on infrastructure renovation and the adoption of renewable energies. Although there are currently no renewable energy production systems, projects have been planned to utilise municipal properties for the installation of these systems, helping to combat energy poverty among district residents. These efforts are aligned with a vision of urban renewal that seeks not only energy efficiency but also the social and economic revitalization of the district.

PASSIVE MEASURES

Windows Fitting

R-WF-1	REPLACEMENT OF WINDOW FITTINGS		
	In the context of the "Āgenskalna priedes" district in Riga, aluminium windows and doors with thermal break and thermal glass will be implemented, further improving thermal insulation. Additionally, the installation of building-applied photovoltaic (BAPV) systems on the windows is planned, contributing to the building's energy self-sufficiency.		
	Dimensions	Units	Thermal performance
	20.925 m2	5.516,90	1,00 W/m2 K

External / Internal Coating renovations

R-CO-1a	INSULATION WALL			
	External plaster, thermal insulation, hollow thermal brick and internal plaster			
	Dimensions		Thickness	Thermal performance
	768,00 m2	Type 1 (60 apartment)	12 cm	0.037 W/m2 K
		Type 2 (40 apartment)	12 cm	0.037 W/m2 K
		Type 3 (40 apartment)	12 cm	0.037 W/m2 K

R-CO-1b	INSULATION ROOF			
	External plaster, thermal insulation, hollow thermal brick and internal plaster			
	Dimensions		Thickness	Thermal performance

	200,00 m2	Type 1 (60 apartment)	65 cm	0,12 W/m2 K
		Type 2 (40 apartment)	65 cm	0.04 W/m2 K
		Type 3 (40 apartment)	65 cm	0.12 W/m2 K

R-CO-1c	INSULATION FLOORS			
	External plaster, thermal insulation, hollow thermal brick and internal plaster			
	Dimensions		Thickness	Thermal performance
	200,00 m2	Type 1 (60 apartment)	48 cm	0,037 W/m2 K
		Type 2 (40 apartment)	48 cm	0,037 W/m2 K
		Type 3 (40 apartment)	48 cm	0,039 W/m2 K

ACTIVE MEASURES

HVAC Renovations

R-HC-1	HEATING/COOLING UPDATING					
	Update of heating and cooling systems to enhance energy efficiency and reduce energy consumption in selected buildings					
	Energy Source	Type of production	Type of distribution	COP / EER / SEER	Capacity	Sizing
	Installation of high-efficiency heat pumps and improved control by smart thermostats, a reduction in heating demand of about 25-30% is projected.	For a total updated building area of 2,192 m², and assuming an initial heating demand of 100 kWh/m² per year (a generic estimate), the demand could be				

		reduced to approximately 70-75 kWh/m² per year.				

RENEWABLE MEASURES

Energy from renewable energy sources renovations

R-RE-1	INSTALLATION OF SOLAR PANELS			
	Riga focusing on the integration of renewable energy technologies in residential buildings. Riga is awaiting the approval of specific legislation on energy communities that would facilitate the installation and use of solar photovoltaic systems for both community and individual consumption.			
	Type of energy source	Nº of elements installed	Installed capacity	Proficiency
	Solar	2687	360 W	

2.2.3 DENMARK_HERNING (VERDO)

Proposed building interventions will be implemented in the FællesBo department at building numbers 16, 19, 21, and 24. The actions will include renovation of façades, basements, and balconies, as well as the replacement of windows and doors to improve thermal insulation and reduce energy consumption.

PASSIVE MEASURES

Windows Fitting

H-WF-1	3-LAYER LOW ENERGY WINDOWS		
	Three-layer low-energy windows consist of three panes of glass with insulating gas, such as argon or krypton, filling the spaces between the panes.Triple-pane windows can achieve U-values as low as 0.8 W/m²K.		
	Dimensions	Unit	Thermal performance

	380,00 m2	1558	0,87 W/m2 K

H-WF-2	NEW DOORS IN BALCONIES AND ANTRANCE		
	Doors for balconies and entrances are designed to enhance both energy efficiency and aesthetic appeal. High-quality options often include glass doors from manufacturers like Velfac, which are known for their durability and thermal performance.		
	Dimensions	Units	Thermal performance
	7,50 m2	117	1,2 W/m2 K

External / Internal Coating renovations

H-CO-1	INSULATION OF FLOORS AND CELLAR		
	The floor is composed of a 15 cm concrete slab, with a 4 cm ceramic finish. In the renovation of the building, a 24 cm natural insulator is added.		
	Dimensions	Thickness	Thermal performance
	2.192,00 m2	24 cm	0,65 W/m2 K

H-CO-2	PIPE INSULATION OF HEATING AND DHW		
	Wooden joists over 80mm not insulated concrete floor.		
	Dimensions	Thickness	Thermal performance
	5.536,80 mL	80 mm	0,04 W/m2 K

H-CO-3	INSULATION OF ROOF

	The roof is made up of 8 cm asbestos tile with fire-resistant plastic insulation over a 25 cm wooden structure and 8 cm of natural thermal insulation.		
	Dimensions	Thickness	Thermal performance
	3.076,06 m2	0.36 m	0,16 W/m2 K

H-CO-4	NEW INSULATION OF THE FAçADE		
	Insulated brick facade using the External Thermal Insulation Composite System (ETICS) with a thickness of 20 cm, featuring a 0.05 m ventilated cavity, fire-resistant insulation, and a waterproofing layer.		
	Dimensions	Thickness	Thermal performance
	2.665,60 m2	0.60 m	0,20 W/m2 K

ACTIVE MEASURES

HVAC Renovations

H-HC-2	NEW FLOOR HEATING SYSTEM			
	Type of energy source	Nº of elements installed	Installed capacity	Proficiency
	Water	300 mL *89	658,60 kW	

RENEWABLE MEASURES

Energy from renewable energy sources renovations

H-RE-4	**SOLAR THERMAL PV**			
	In Herning, Verdo focuses on integrating solar thermal PV technology into their energy network to enhance efficiency and sustainability.			
	Type of energy source	Nº of elements installed	Installed capacity	Proficiency
	Solar	1537	153.700 L	60%

3. Bottom-up business models

3.1 Single intervention level

Energy Saving Model Development: The first step involves application of the SUPER-i energy-saving model to estimate the expected energy savings from each proposed intervention. This process begins with conducting on-site audits to gather baseline data on current energy usage and building characteristics. Utilising software tools and simulation techniques, the model evaluates the impact of various energy efficiency interventions, considering factors such as building type, existing energy systems, and climatic conditions. The model's accuracy is validated through historical data and pilot studies.

3.2 Building level

Simulation of Financial and Socio-Economic Variables: In the second step, a stochastic volatility model is used to project future values of critical financial and socio-economic variables. These include the energy market bid price, inflation rate, interest rate on debt, property value growth rate, rent growth rate, and the default rate on rent. Additionally, socio-economic variables such as regional employment rates, national income growth rates, earning rates on personal savings, corporate taxes, private investment, private consumption, and government spending are simulated. Historical data from reliable sources are gathered to develop and calibrate the model. By running multiple simulations, future scenarios for each variable are generated, allowing for a comprehensive assessment of potential risks and uncertainties.

Calculation of the Social Discount Rate (SDR): The third step involves calculating the social discount rate (SDR) using the weighted average method (WAM). The SDR is a combination of the social rate of time preference (SRTP), which measures private savings/consumption, and the social opportunity cost of capital (SOC), which measures private investment. The formula for SDR is: SDR = WAM = (a)SOC + (1-a) SRTP, where 'a' represents the proportion of project cost funded by private investment and (1-a) by public investments. The simulated socio-economic variables are used to derive the SRTP and SOC, ensuring that the SDR reflects the socio-economic context of each region.

Financial and Socio-Economic Impact Analysis: In the fourth step, the financial and socio-economic impacts of the interventions for each building are analysed using the energy savings model findings, the simulated financial variables, and the social discount rate. Financial viability is assessed through metrics such as Return on Investment (ROI), Net Cash Flow (NCF), Net Present Value (NPV), risk-adjusted extra return, and Conditional Value at Risk (CVaR). Socio-economic benefits, including job creation, improved living conditions, and environmental impact, are also evaluated. This comprehensive analysis ensures that the interventions are both financially viable and socially beneficial.

3.3 District level

Replication at Building Block Level: The fifth step involves scaling up the analysis from individual buildings to building blocks. Data from individual buildings are aggregated to re-assess financial and socio-economic impacts at this higher level of aggregation. This process identifies potential synergies and economies of scale, enhancing the overall effectiveness and efficiency of the interventions. By combining data from multiple buildings, the model is adjusted to account for interactions between them, providing a holistic view of the impacts at the building block level.

Replication at District Level: In the sixth step, the analysis is extended to the district level. Data from multiple building blocks are aggregated to evaluate the financial and socio-economic impacts across the entire district. This broader analysis identifies community-wide benefits and systemic improvements, offering insights into how large-scale energy efficiency renovations can contribute to regional sustainability goals. The model is further adjusted for district-wide interactions and infrastructure considerations, ensuring that the interventions are effective on a larger scale.

Benchmark Comparison: The seventh step involves comparing the findings against a benchmark, such as the S&P 500 index. This comparison evaluates the performance of energy efficiency investments relative to traditional investment benchmarks. Metrics such as ROI, NPV, and other financial indicators are used to assess risk-adjusted returns and overall viability. This comparative analysis highlights the relative performance of energy efficiency investments, providing a clear picture of their financial attractiveness.

Ranking of Funding Solutions: The final step ranks the proposed funding solutions based on risk-adjusted returns, using the ROI and the social discount rate. This ranking considers the overall impact on energy efficiency, financial returns, and socio-economic benefits. By prioritising solutions that offer the best balance of risk and return, the analysis provides actionable recommendations for policy and investment strategies. This ensures that the most effective and sustainable funding solutions are identified and implemented.

4. Cost Benefit analysis

4.1. Energy savings

In this section, we apply the energy savings model developed in the SUPER-i project to calculate the expected energy savings from the proposed EE interventions on energy use, fuel costs, and greenhouse gas (GHG) emissions at building level, and how these improvements will be modelled. This model measures the potential energy savings from the proposed improvements in terms of fuel saved (measured in kWh of gas not burned or electricity not used), cost (the price of the saved fuel), and carbon emissions (the CO2 emissions avoided). The SUPER-i energy savings model is designed to return meaningful results using basic information, requiring no technical expertise or training, can be run for specific years, allowing calibration of the model and assessment of inter-annual variation, and allows the calculation of heating and cooling demands.

4.1.1. Methodology

- Data collection:
  - *Building information:* To accurately assess the energy performance of the buildings, detailed data is collected through the SUPERSHINE survey. The data collected includes the building's dimensions (such as height, width and depth), geometry (including roof angle and floor area), and material composition (types of walls, windows, roofs and floors). These parameters are essential for evaluating thermal performance and identifying areas where energy efficiency can be improved. The data requested in the SUPERSHINE survey is simple and obtainable by the social housing associations, and does not require extensive technical expertise.

  - *Weather data:* The SUPER-i energy savings model uses weather data from the NASA langley research centre, which provides hourly data on temperature, dew point, and solar insolation. The weather data ensures that the model accurately reflects local climatic conditions, which has a significant impact on heating and cooling demands.

- Building thermal performance calculation:

  - *Heat Loss/Gain*: The model calculates the building's heat loss or gain by summing the thermal transmittance (U-values) of various building components (walls, windows, roof, floor), weighted by their respective areas. U-values, which measure how well a building component conducts heat, are critical for determining how much energy is needed to maintain comfortable indoor temperatures. Accurate U-values are sourced from CIBSE data tables and applied to each component of the building to ensure precise energy assessments.

  - *U-Values:* U-values are specific to each type of material used in the building's construction. For example, modern double-glazed windows have lower U-values compared to single-glazed windows, indicating better insulation properties. By accurately determining the U-values for each building component, the model can provide a realistic estimate of energy losses through the building envelope.

- Comfort Range and Energy Demand:
  - *Comfort Temperature Range*: The model sets a default comfort range, typically between 15.5°C and 22°C, within which no heating or cooling is required. This range can be adjusted based on regional variations in thermal comfort expectations. By using time series data for ambient temperatures, the model calculates the hourly heating and cooling demands, factoring in how often temperatures fall outside this comfort range. This approach ensures that the energy demand reflects real-world conditions and user comfort.
  - *Hourly Energy Demand:* The model calculates the hourly energy demand for heating and cooling by determining the difference between the ambient temperature and the comfort range. This granular approach allows the model to account for daily and seasonal variations, providing a more accurate estimate of the building's energy needs.

- Annual Energy Demand:
  - *Total Demand Calculation:* The annual energy demand for heating and cooling is calculated by summing the hourly demands over the course of a year. This comprehensive approach ensures that the model captures the full range of seasonal and daily variations, providing a realistic assessment of the building's energy needs. By considering both extreme weather conditions and average temperatures, the model offers a detailed view of annual energy consumption.
  - *Solar Gains:* The model also accounts for solar gains, which can significantly impact heating demand by providing natural warmth. Solar gains depend on the building's orientation, window size, and materials, as well as geographic location. For example, buildings with large, south-facing windows will experience higher solar gains compared to those with smaller,

north-facing windows. Accurate modelling of solar gains helps in assessing the potential benefits of passive solar heating.

- Energy Savings Calculation:
  - *Baseline vs. Improved Scenarios*: The model compares the energy use of the building before and after the proposed improvements. This comparison highlights the potential energy savings from various interventions, such as enhanced insulation, upgraded windows, and more efficient heating systems. By simulating both scenarios, the model provides a clear picture of the expected benefits of each improvement.
  - *Quantifying Savings*: Savings are quantified in terms of fuel saved (kWh of gas or electricity), cost savings (based on current and projected market prices), and CO2 emissions avoided (based on the carbon intensity of the fuels used). These metrics provide a comprehensive view of the impact of the proposed improvements, helping decision-makers prioritise interventions based on their effectiveness.
- Economic and Environmental Impact:
  - *Fuel Cost Savings*: The model calculates monetary savings by inputting specific fuel types and market prices. This allows for a detailed assessment of cost reductions resulting from lower energy consumption. By adjusting for the efficiency of heating systems and incorporating time-variable fuel prices, the model provides an accurate estimate of cost savings.
  - *Carbon Emissions Reduction*: The model estimates the reduction in CO2 emissions based on improved energy efficiency and the carbon intensity of the fuels used. This information is crucial for assessing the environmental benefits of the proposed improvements and supporting sustainability goals. The model also considers the carbon intensity of electricity, which varies throughout the day and year, providing a detailed view of emissions reductions.

4.2. Financial analysis of Funding sources

Given the investment gaps in Italy, Latvia, and Denmark for energy efficiency projects, we propose several innovative funding solutions to bridge the funding gap. Our focus is on Public-Private Partnership (PPP) funding contracts and crowdfunding.

4.2.1. PPPs contracts

Public-Private Partnerships (PPPs) are long-term funding contracts that align government service delivery objectives with private body profit goals, as defined by the OECD in 2008. In times of constrained financial resources, PPPs become essential for accessing finance and reducing capital expenditure on energy infrastructure projects. The European Commission distinguishes between contractual and institutionalised PPPs. Over the past two decades, PPPs and project finance have been widely adopted in European countries such as the UK, Spain, France, Germany, Italy, and Portugal.

Benefits of PPPs: PPPs offer mutual benefits for both the private and public sectors. The private sector gains risk management guarantees, while the public sector receives capital investment and management expertise. PPPs ensure necessary investments are made, public resources are effectively managed, services are provided on time, and long-term remuneration is secured for the private sector. Additionally, PPPs leverage private sector expertise and often allow assets to be classified off the public balance sheet.

Drawbacks of PPPs: However, PPPs have drawbacks, including potential cost increases, negative impacts on fiscal indicators, longer and more expensive procurement procedures, and inflexibility due to the complexity and long-term nature of agreements. PPP transactions have slowed due to unfavourable conditions in capital markets.

PPP Financing Structures: In PPP finance structures, a Special Purpose Vehicle (SPV) is often used by the private party, raising finance through a mix of equity and debt. Equity investors, such as project developers, construction companies, and private equity funds, assume higher risks and seek higher returns. Non-recourse project finance is frequently employed, where lenders are compensated from project revenues without recourse to equity investors, allowing them to absorb initial project losses. Typically, debt comprises 70% to 95% of total finance in these structures, though higher interest rates than government borrowing apply. Alternatives include corporate guarantees, full-recourse corporate finance, and limited recourse project finance. Governments may participate by providing finance as lenders or guaranteeing project debt, with additional credit support mechanisms like step-in rights or government participation to reduce costs.

4.2.2. 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 of these 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 a large number of 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 are capable of making 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.

4.2.3. Application of PPP contract to each country

Italy

Following the information provided by ATER-Trieste for the Italian pilot, we consider the following characteristics in developing the PPP contracts:

- Social housing stock in Italy is usually co-owned by social housing companies and private owners.
- The tenants will receive all the financial benefits from the energy savings generated by the proposed EE renovations.
- The government benefits from reduced CO2 emissions
- The local funding institutions receives the payments to cover the cost of debt from the social housing company

Public Private Partnership (PPP): Direct Credit Line
Involved parties: Social Housing, and Funding institution. **Source of funding**: Social housing is responsible for covering the investment costs using financial institutions or government loans.

Investment risk: is taken by the Social Housing association
Social housing: **Benefits** ❖ **energy savings** (which are transferred to the **tenants**) ❖ **increased value of the building** **Cost** ❖ **investment cost** ❖ **maintenance and operating costs** of running the energy efficiency technologies.
Private owners (under the assumption that some of the dwellings are privately owned) **Benefits** ❖ **energy savings** ❖ **increased value of the building** **Cost** ❖ **investment cost** ❖ **maintenance and operating costs** of running the energy efficiency technologies
Tenants **Benefits** ❖ **energy savings** **Cost** ❖ **0**
National or local government **Benefits** ❖ **Lower CO_2 emissions for society** **Cost** ❖ **Grants towards energy efficient refurbishment**

Public Private Partnership (PPP): Energy Supply Contracts
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The ESCO and social housing are responsible for covering the investment costs. **Investment risk**: is taken by the ESCO and Social Housing association

Social housing: **Benefits** ❖ $(1-\gamma)$ ***of energy savings***, $(50\% < \gamma < 90\%)$, *(which are transferred to the* ***tenants****)* ❖ **increased value of the building** **Cost** ❖ $(1-\gamma)$ **maintenance and operating costs** of running the energy efficiency technologies. ❖ $(1-\gamma)$ **investment cost**
Private owners (under the assumption that some of the dwellings are privately owned) **Benefits** ❖ $(1-\gamma)$ ***of energy savings*** ❖ **increased value of the building** **Cost** ❖ $(1-\gamma)$**maintenance and operating costs** of running the energy efficiency technologies. ❖ $(1-\gamma)$**investment cost**
Tenants **Benefits** ❖ $(1-\gamma)$ **of energy savings** **Cost** ❖ **0**
National or local government **Benefits** ❖ **Lower CO2 emissions** for society **Cost** ❖ **Grants** towards energy efficient refurbishment
ESCO **Benefits** ❖ γ **of energy savings** . **Cost** ❖ γ **maintenance and operating costs** of running the energy efficiency technologies. ❖ γ **investment cost**

Public Private Partnership (PPP): Shared savings
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The ESCO is responsible for covering the investment costs. **Investment risk**: is taken by the ESCO
Social housing: **Benefits** ❖ **energy savings** (which are transferred to the **tenants**) ➢ *if energy savings > minimum guaranteed savings,* **gets 35% (energy savings - minimum guaranteed savings)** ➢ *if energy < minimum guaranteed savings,* **gets 0** ❖ **increased value of the building**
Private owners (under the assumption that some of the dwellings are privately owned) **Benefits** ❖ **energy savings** ➢ *If energy savings > minimum guaranteed savings,* **gets 35% (energy savings - minimum guaranteed savings)** ➢ *if energy < minimum guaranteed savings,* **gets 0** ❖ **increased value of the building**
Tenants **Benefits** ❖ **energy savings** **Cost** ❖ **0**
National or local government **Benefits** ❖ **Lower CO2 emissions** for society **Cost** ❖ **Grants** towards energy efficient refurbishment

ESCO

Benefits

- **Energy savings:**
  - *If energy savings > minimum guaranteed savings*, they get **minimum guaranteed savings + 65% (energy savings - minimum guaranteed savings)**
  - Otherwise, they get **energy savings.**

Cost

- **maintenance and operating costs** of running the energy efficiency technologies.
- **investment cost**

Public Private Partnership (PPP): Guaranteed savings

Involved parties: Social Housing, ESCO and Funding institution.

Source of funding: The social housing is responsible for covering the investment costs.

Investment risk: is taken by the ESCO

Social housing:

Benefits

- **energy savings** (which are transferred to the **tenants**)
  - if *energy savings > minimum guaranteed savings,* gets **minimum guaranteed savings + 20% (energy savings - minimum guaranteed savings)**
  - if *energy savings < minimum guaranteed savings,* gets **minimum guaranteed savings.**
- **increased value of the building**

Cost

- **investment cost**

Private owners (under the assumption that some of the dwellings are privately owned)

Benefits

- **energy savings**
- **increased value of the building**

Cost

- **investment cost**

Tenants **Benefits** ❖ **energy savings** **Cost** ❖ **0**
National or local government **Benefits** ❖ **Lower CO2 emissions** for society **Cost** ❖ **Grants** towards energy efficient refurbishment
ESCO **Benefits** ❖ **Energy savings:** ➢ *If energy savings > minimum guaranteed savings*, they get **80% (energy savings - minimum guaranteed savings)** ➢ otherwise, **(energy savings - minimum guaranteed savings)** **Cost** **maintenance and operating costs** of running the energy efficiency technologies.

Denmark

Following the information provided by Danish partners for the Danish pilot, we consider the following characteristics in developing the PPP contracts:

- Social housing stock in Denmark is fully owned by social housing company
- The tenants will receive part of the energy savings generated by the proposed EE renovations.
- The tenants covers 2% of the investment costs of the EE renovations
- The tenants rents goes to the national building fund
- The government benefits from reduced CO2 emissions
- The local funding institutions receives a portion from the financial benefits from the energy saving

Public Private Partnership (PPP): Direct Credit Line

Involved parties: Social Housing, and Funding institution. **Source of funding**: Social housing is responsible for covering the investment costs using financial institutions or government loans. **Investment risk**: is taken by the Social Housing association
Social housing: **Benefits** ❖ **energy savings** (part is transferred to the **tenants**) ❖ **increased value of the building** **Cost** ❖ **98% of the investment cost** ❖ **98% of the maintenance and operating costs** of running the energy efficiency technologies.
Tenants **Benefits** ❖ **Part of the energy savings** **Cost** ❖ **2% of the investment costs** ❖ **2% of the maintenance and operating costs**
National or local government **Benefits** ❖ **Lower CO2 emissions for society** **Cost** ❖ **Grants towards energy efficient refurbishment under the national building fund**

Public Private Partnership (PPP): Energy Supply Contracts
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The ESCO and social housing are responsible for covering the investment costs. **Investment risk**: is taken by the ESCO and Social Housing association

Social housing: **Benefits** ❖ $(0.98-\gamma)$ ***of energy savings***, $(50\% < \gamma < 90\%)$, *(part is transferred to the* ***tenants****)* ❖ **increased value of the building** **Cost** ❖ $(0.98-\gamma)$ **maintenance and operating costs** of running the energy efficiency technologies. ❖ $(0.98-\gamma)$ **investment cost**
Tenants **Benefits** ❖ **Part of the energy savings** **Cost** ❖ **2% of the investment cost** ❖ **2% of the maintenance and operating cost**
National or local government (NBF) **Benefits** ❖ **Lower CO2 emissions** for society **Cost** ❖ **Grants**
ESCO **Benefits** ❖ γ **of energy savings** . **Cost** ❖ γ **maintenance and operating costs** ❖ γ **investment cost**

Public Private Partnership (PPP): Shared savings
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The ESCO is responsible for covering the investment costs. **Investment risk**: is taken by the ESCO

Social housing:

Benefits

- **energy savings** (part is transferred to the **tenants**)
  - *if energy savings > minimum guaranteed savings,* **gets 35% (energy savings - minimum guaranteed savings)**
  - *if energy < minimum guaranteed savings,* **gets 0**
- **increased value of the building**

Tenants

Benefits

- **Part of the energy savings**

Cost

- **2% of the investment cost**

National or local government (NBF)

Benefits

- **Lower CO2 emissions** for society

Cost

- **Grants** towards energy efficient refurbishment

ESCO

Benefits

- **Energy savings:**
  - *If energy savings > minimum guaranteed savings*, they get **minimum guaranteed savings + 65% (energy savings - minimum guaranteed savings)**
  - Otherwise, they get **energy savings.**

Cost

- **maintenance and operating costs** of running the energy efficiency technologies.
- **98% of investment cost**

Public Private Partnership (PPP): Guaranteed savings
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The social housing is responsible for covering the investment costs. **Investment risk**: is taken by the ESCO

Social housing:

Benefits

- **energy savings** (part is transferred to the **tenants**)
  - if *energy savings > minimum guaranteed savings,* gets **minimum guaranteed savings + 20% (energy savings - minimum guaranteed savings)**
  - if *energy savings < minimum guaranteed savings,* gets **minimum guaranteed savings.**
- **increased value of the building**

Cost

- **98% of investment cost**

Tenants

Benefits

- **Part of the energy savings**

Cost

- **2% of the investment cost**

National or local government (NBF)

Benefits

- **Lower CO_2 emissions** for society

Cost

- **Grants** towards energy efficient refurbishment

ESCO

Benefits

- **Energy savings:**
  - *If energy savings > minimum guaranteed savings*, they get **80% (energy savings - minimum guaranteed savings)**
  - otherwise, **(energy savings - minimum guaranteed savings)**

Cost

maintenance and operating costs of running the energy efficiency technologies.

Latvia

Following the information provided the Riga partners for the Latvian pilot, we consider the following characteristics in developing the PPP contracts:

- Social housing stock is fully owned by social housing company
- The tenants will receive all of the energy savings generated by the proposed EE renovations.
- The government benefits from reduced CO2 emissions
- The local funding institutions receives a portion from the financial benefits from the energy saving

Public Private Partnership (PPP): Direct Credit Line
Involved parties: Social Housing, and Funding institution. **Source of funding**: Social housing is responsible for covering the investment costs using financial institutions or government loans. **Investment risk**: is taken by the Social Housing association
Social housing: **Benefits** ❖ **energy savings** (transferred to the **tenants**) ❖ **increased value of the building** **Cost** ❖ **100% of the investment cost** ❖ **100% of the maintenance and operating costs** of running the energy efficiency technologies.
Tenants **Benefits** ❖ **Part of the energy savings** **Cost** ❖ **0% of the investment costs** ❖ **0% of the maintenance and operating costs**

National or local government **Benefits** ❖ **Lower CO_2 emissions for society** **Cost** ❖ **Grants towards energy efficient refurbishment**

Public Private Partnership (PPP): Energy Supply Contracts
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The ESCO and social housing are responsible for covering the investment costs. **Investment risk**: is taken by the ESCO and Social Housing association
Social housing: **Benefits** ❖ $(1-\gamma)$ ***of energy savings***, $(50\% < \gamma < 90\%)$, *(transferred to the **tenants**)* ❖ **increased value of the building** **Cost** ❖ $(1-\gamma)$ **maintenance and operating costs** of running the energy efficiency technologies. ❖ $(1-\gamma)$ **investment cost**
Tenants **Benefits** ❖ **Part of the energy savings** **Cost** ❖ **0% of the investment cost** ❖ **0% of the maintenance and operating cost**
National or local government **Benefits** ❖ **Lower CO_2 emissions** for society **Cost** ❖ **Grants**

ESCO **Benefits** ❖ γ **of energy savings** . **Cost** ❖ γ **maintenance and operating costs** ❖ γ **investment cost**

Public Private Partnership (PPP): Shared savings
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The ESCO is responsible for covering the investment costs. **Investment risk**: is taken by the ESCO
Social housing: **Benefits** ❖ **energy savings** (transferred to the **tenants**) ➢ *if energy savings > minimum guaranteed savings,* **gets 35% (energy savings - minimum guaranteed savings)** ➢ *if energy < minimum guaranteed savings,* **gets 0** ❖ **increased value of the building**
Tenants **Benefits** ❖ **Part of the energy savings** **Cost** ❖ **0% of the investment cost**
National or local government **Benefits** ❖ **Lower CO2 emissions** for society **Cost** ❖ **Grants** towards energy efficient refurbishment

ESCO

Benefits

- **Energy savings:**
  - *If energy savings > minimum guaranteed savings*, they get **minimum guaranteed savings + 65% (energy savings - minimum guaranteed savings)**
  - Otherwise, they get **energy savings.**

Cost

- **100% of the maintenance and operating costs** of running the energy efficiency technologies.
- **100% of investment cost**

Public Private Partnership (PPP): Guaranteed savings
Involved parties: Social Housing, ESCO and Funding institution. **Source of funding**: The social housing is responsible for covering the investment costs. **Investment risk**: is taken by the ESCO
Social housing: **Benefits** ❖ **energy savings** (transferred to the **tenants**) ➢ if *energy savings > minimum guaranteed savings,* gets **minimum guaranteed savings + 20% (energy savings - minimum guaranteed savings)** ➢ if *energy savings < minimum guaranteed savings,* gets **minimum guaranteed savings.** ❖ **increased value of the building** **Cost** ❖ **100% of the investment cost**
Tenants **Benefits** ❖ **Part of the energy savings** **Cost** ❖ **0% of the investment cost**

SUPERSHINE

National or local government

Benefits

- **Lower CO2 emissions** for society

Cost

- **Grants** towards energy efficient refurbishment

ESCO

Benefits

- **Energy savings:**
    - *If energy savings > minimum guaranteed savings*, they get **80% (energy savings - minimum guaranteed savings)**
    - otherwise, **(energy savings - minimum guaranteed savings)**

Cost

100% of the maintenance and operating costs of running the energy efficiency technologies.

4.2.3.1. Methodology

In the SUPERSHINE project, we develop a comprehensive financial and statistical analysis for the selected Public-Private Partnership (PPP) funding schemes currently available in Europe to finance energy efficiency renovation projects in Italy, Latvia, and Denmark. This is accomplished using a detailed bottom-up business model comprising several methodical steps:

- *Step 1: Energy Savings Modelling*

  First, we utilize a sophisticated energy saving model to estimate the expected energy savings from each proposed intervention for each building. This involves:

    - Data Collection: Gathering detailed information about the building's structure, materials, and current energy use.
    - Baseline Assessment: Establishing a baseline energy consumption profile by analyzing historical energy usage data.
    - Intervention Simulation: Applying the proposed energy efficiency measures within the model to predict the impact on energy consumption. This includes upgrades such as improved insulation, energy-efficient windows, and modern heating systems.

- Result Analysis: Comparing the baseline and post-intervention energy usage to quantify the expected savings in terms of kWh saved and reductions in CO_2 emissions.

- *Step 2: Stochastic Volatility Modelling*

  Next, we simulate future values for key financial variables using a powerful stochastic volatility model. This involves:

  - Energy Market Bid Price: Estimating future energy prices by considering market trends, regulatory changes, and historical price volatility.
  - Inflation Rate: Projecting future inflation rates based on economic forecasts and historical data, impacting the cost of energy and construction materials.
  - Interest Rate on Debt: Simulating future interest rates to assess borrowing costs, considering central bank policies and market conditions.
  - Property Value Growth Rate: Estimating future property values influenced by economic conditions, urban development trends, and market demand.
  - Rent Growth Rate: Projecting changes in rental income, taking into account regional housing market conditions and economic indicators.
  - Default Rate on Rent: Assessing the risk of tenants defaulting on rent payments based on historical data and economic forecasts.
  - Socio-Economic Variables: Including employment rates, national income growth, earnings on personal savings, corporate taxes, private investment, private consumption, and government spending. These factors help calculate the Social Discount Rate (SDR), reflecting the opportunity cost of public investment.

- *Step 3: Calculating the Social Discount Rate (SDR)*

  Using the simulated socio-economic variables, we calculate the social discount rate through the weighted average method (WAM). This involves:

  - Private Savings/Consumption Rate (SRTP): Representing the rate at which individuals prefer current consumption over future consumption, indicating time preference.

- Private Investment (SOC): Reflecting the return on private investment, indicating the opportunity cost of capital.
- Weighted Average Method (WAM): Combining SRTP and SOC to derive the SDR:

  SDR = WAM = (a)SOC + (1-a)SRTP

  where a is the proportion of project cost funded by private investment and (1-a) is funded by public investments. This balance helps assess the true cost of capital for public projects.

- *Step 4: Financial and Socio-Economic Impact Analysis*

  Using the findings from the energy savings model, simulated financial variables, and the social discount rate, we analyze the financial and socio-economic impact of each intervention. This includes:

  - Return on Investment (ROI): Measuring the profitability of the interventions by comparing the net benefits to the investment costs.
  - Net Cash Flow (NCF): Calculating the difference between incoming and outgoing cash flows over the project lifecycle.
  - Net Present Value (NPV): Determining the value of future cash flows discounted back to present value, reflecting the profitability and viability of the project.
  - Risk-Adjusted Extra Return: Evaluating the additional return of the project after adjusting for risk, compared to a risk-free rate or alternative investments.
  - Conditional Value at Risk (CVaR): Assessing the potential losses in the worst-case scenarios to ensure financial stability and risk management.

- *Step 5: Block-Level Replication*

  We replicate the financial and energy savings analysis at the building block level, aggregating the results of individual buildings to understand the impact on a larger scale. This includes:

  - Data Aggregation: Compiling data from multiple buildings within a block to evaluate collective energy savings, financial returns, and socio-economic impacts.

    - Intervention Analysis: Assessing how block-level interventions, such as district heating systems or communal solar installations, enhance energy efficiency and reduce costs.
    - Block-Level Financial Metrics: Calculating aggregate ROI, NCF, NPV, risk-adjusted returns, and CVaR to provide a comprehensive financial outlook for the entire block.

- *Step 6: District-Level Replication*

  We extend the analysis to the district level, encompassing multiple blocks, to assess broader impacts and potential benefits. This involves:

    - District Data Compilation: Gathering and integrating data from all blocks within a district to create a district-wide energy and financial profile.
    - District-Wide Interventions: Evaluating large-scale interventions, such as district-wide energy management systems, smart grids, and large renewable energy projects.
    - District Financial Metrics: Calculating overall ROI, NCF, NPV, risk-adjusted returns, and CVaR for the district, providing a macro-level perspective on the effectiveness and sustainability of the energy efficiency projects.

- Step 7: Benchmark Comparison

  To ensure that the proposed interventions are financially sound, we compare our findings against a benchmark investment, such as the S&P 500 index. This comparison includes:

    - Benchmark Performance Analysis: Reviewing historical performance data of the S&P 500 to establish a baseline for comparison.
    - Relative Performance Assessment: Evaluating the financial returns of the energy efficiency projects relative to the S&P 500, considering factors like volatility, risk, and long-term growth potential.
    - Risk-Adjusted Comparison: Adjusting the performance metrics for risk to provide a fair comparison between the energy efficiency investments and the benchmark.

- *Step 8: Ranking Funding Solutions*

Finally, we rank the funding solutions based on the proposed model, using risk-adjusted extra returns, ROI, and the social discount rate. This process involves:

- Risk-Adjusted Returns: Calculating the additional returns of each funding solution after accounting for associated risks, providing a clearer picture of the true profitability.
- ROI Comparison: Comparing the ROI of different funding solutions to identify the most financially viable options.
- Social Discount Rate Application: Applying the social discount rate to assess the broader socio-economic impacts of each funding solution, ensuring that public benefits are maximized.
- Ranking Criteria: Establishing criteria for ranking, such as financial returns, risk levels, socio-economic benefits, and alignment with sustainability goals.
- Final Ranking: Producing a ranked list of funding solutions, guiding stakeholders in selecting the best options for financing energy efficiency renovations.

Through these detailed steps, the SUPERSHINE project provides a robust framework for analysing and financing energy efficiency projects, ensuring that investments are both financially sound and socially beneficial.

Below we provide a brief description of the simulation methodology for the socio-economic and financial variables:

The first step in our financial analysis is the simulation of key economic indicators affecting the profitability and economic feasibility of the energy efficiency refurbishment in each pilot country. In this simulation study, we first simulate 1000 values per year for the next 25 years for the inflation rate using a stochastic volatility model. This stochastic volatility model allows us to link the daily observations of stochastic economic variables with macroeconomic variables, sampled at lower frequencies, in order to examine directly the macroeconomic variables' impact on the stochastic economic variable's volatility. Once the simulated values for the inflation rate per country are obtained, we then simulate the interest rate on debt using the inflation rate as an external economic indicator in the GARCH-MIDAS model due to its known impact in the literature of macroeconomics. Then, using the inflation rate with the unemployment rate of the past 20 years as external economic indicators we simulated 1000 values of default rate on rent and the rent growth rate for the next 25 years. Then we simulated 1000 values of the building market value growth rate for the next 25 years, using the average increase in market value of the buildings due to the energy efficiency refurbishment projects for the past 14 years (2010-2023).

Risk-return trade off analysis of each PPP funding scheme

ROI:

In this evaluation methodology we investigate the yearly ROI, CVaR and RP for the next 25 years using as input data the simulated key economic indicators specific to each pilot country, and the data obtained from the SUPERSHINE partners in Italy, Latvia, and Denmark specific to each building. Therefore, to investigate the current value of these three measures, in each for the next 25 years, today, we need to calculate the continuous discount factor for each country which is given by:

$$discount\ factor = e^{-r(t)}$$

where the r is the real interest rate which is given by:

$$r = \left(\frac{1+i}{1+\pi_{(e)}}\right) - 1$$

where i is the nominal interest rate, and $\pi_{(e)}$ is the expected inflation rate.

After computing the discount factor, we then calculate the ROI for each simulation using the discount factor and social discount rate as follows:

- First we calculate the Cash inflow of the project for each involved party in the PPP funding scheme:

$$Cash\ Inflow_t = \frac{revenue\ from\ rent_t\ + growth\ from\ increased\ building\ value_t\ + Profitshare\ from\ energy\ savings_t}{(1+Social\ discount\ rate)^t}$$

  where then $Profit\ share\ from\ energy\ savings$ is changing according to the characteristics of each PPP funding scheme for more information refer to section 3 of the deliverable.

- We calculate the Cash outflow of the project as follows:

$$Cash\ Outflow_t = \frac{Operating\ cost_t + maintenance\ cost_t\ + cost\ of\ running\ EE\ technologies}{(1+Social\ discount\ rate)^t}$$

where the cost of running EE technologies is covered by a specific party depending on the PPP funding scheme.

- Net cash flow if given by:

$$Net\ Cash\ flow_t = Cash\ in\ flow_t - Cash\ out\ flow_t$$

- Lastly, the ROI is given by:

$$ROI_t = \frac{Net\ cash\ flow_t}{investment\ cost_t}$$

Value at risk (VaR) & Expected shortfall (CVaR)

Using the obtained ROI for each involved party in the PPP scheme, we measure the yearly VaR and CVaR, to determine the possible loss in the worst case scenarios that the project might face, such as increasing inflation rate, increasing default rate , decreasing rent growth rate and or the cost of running the EE technologies installed in the buildings. The Value at Risk (VaR) is a metric used to determine the extent and probabilities of potential financial losses. In other words, it is the maximum loss that will not be exceeded at a given confidence level. Richtarik (2015) defined VaR at follows:

''Let X be a random variable representing loss. Given a parameter 0 < α <1, the α -VaR of X is:

$$VaR_\alpha(ROI_{\square}) = \{c: P(ROI_{\square} \le c) \ge \alpha\}$$

interpretations of VaR:

- $VaR_\alpha(ROI_{\square})$ is the α-quantile of the distribution of X, which provide the the minimum loss that will not be exceeded with probability α.

According to Richtarik (2015) CVaR the Conditional Value at Risk is the expected loss, conditional on the fact that the loss exceeds the VaR at the given confidence level:

''Let X be a continuous random variable representing loss. Given a parameter 0 < α < 1, the

α-CVaR of X is:

$$CVaR_\alpha(ROI) = E[ROI|ROI \ge VaR_\alpha\ (ROI)]$$

The CVaR in this study is calculated as:

$$CVaR_\alpha(ROI_{\square}) = \frac{1}{1-\alpha} * mean(VaR_\alpha(ROI_{\square}))$$

To sum up, the VaR represents a worst-case loss associated with a probability and time horizon, while the CVaR is the expected loss if the worst case threshold is crossed. For more information refer to the appendix.

Risk adjusted extra return(RP):

The risk adjusted extra return is a financial investment measure which determines the expected investment return that exceeds the risk free rate of return. That is, RP represents the level of compensation that the investor receives for taking the extra risk associated with a given investment. The Risk adjusted extra return (RP) is given by:

$$Risk\ adjusted\ extra\ return\ = \frac{E(ROI)\ -\ Risk\ free\ rate}{\sigma_{ROI}}$$

where $E(ROI)$ is the expected value of ROI which is approximated by the sample average, σ_{ROI} is the standard deviation of the ROI, which is obtained by taking the square root of the variance of ROI's, where the variance is given by:

$$variance(ROI) = E[(ROI - E(ROI))^2]$$

The table below reports the ranking approach for risk adjusted extra returns.

Ranking for risk adjusted extra returns (RP)		
0.75 < RP < 0.95	5	reasonable
0.95 < RP < 1.5	6	very reasonable
1.5 < RP< 2	7	good
2 < RP < 3	8	very good
RP > 3	9	excellent

Crowdfunding

Within task 3.1 the role of Tendercapital involves the definition and implementation of a Crowdfunding strategy for SUPERSHINE lighthouse districts.

To achieve this purpose Tendercapital advises using **Concrete Investing** platform. It is an equity crowdfunding portal authorised and supervised by Consob that offers private investors –

professional and retail – investment in high-level real estate projects and serves real estate developers (companies) to raise venture capital for their real estate development projects.

Operational steps for a crowdfunding offer
PRE-OFFER:

Sharing documentation: the crowdfunding process begins with an initial approach between Concrete Investing and the developer through the sharing of information and documents useful in better framing the transaction and its characteristic elements. For this purpose, Concrete Investing asks to provide the below information for each of the three pilots:

- Will the exit of the assets be fractional sale, block sale, rental of the apartments or the repayment of the loan?
- What is the estimated Return on Investment?
- Will the issuer hold ownership of a single pilot or all three?
- As stated in the Grant Agreement, 45% of the requirement will be covered by institutional investors. Are they already committed?

At the end of this phase Concrete Investing provides a preliminary opinion on the possibility of carrying out the fundraising.

Bid Construction: this phase normally involves a discussion with the bidder in order to establish the riskiness and therefore the return of the transaction.

Compliance necessary for the offer: Once the terms and conditions of the offer have been defined and agreed upon, formal steps are taken preparatory to the start of the collection, such as:

- third-party evaluation of the transaction;
- Signing of the SPV's letter of accession to the framework agreement;
- Opening of the escrow accounts in the name of the SPV, necessary for crowdfunding collection, with Financial Intermediary;
- Possible statutory amendment of the SPV;
- Resolution of capital increase reserved for investors who will intervene through Concrete Investing.

During this phase, Concrete Investing will support the proponent in every step so that the formalities are completed quickly and correctly.

OFFER:

Once the documentary setup is complete, the offer is published on the portal and subscriptions are opened accordingly. The duration of the fundraising process is about **60 days.** At this stage Concrete

Investing will handle the collection and pre-packaging of orders. When the orders have been finalised (transfer made by investors) and at least the minimum fundraising target has been reached, the capital can be released, which will be made available in the proponent's bank account. Finally, the proposer will proceed to finalise the capital increase so that the funds are fully available.

POST-OFFER:

The offering includes a semi-annual reporting to be sent to investors in Concrete Investing format. The developer will have to report, every 6 months, on the progress of the operation (permitting process, construction site, sales, deviations from business plan, etc.) by filling out a template provided by Concrete Investing, which will layout the report and convey it to investors.

4.2.3.2. Lighthouse adaptation:

Italy: Trieste lighthouse

Taking the case study just presented as a reference, Tendercapital tried to carry out a simulation of the Trieste, Herning and Riga lighthouse projects. The data used were taken from the survey responses of ATER Trieste.

Description of the project: The SUPERSHINE Italian lighthouse district is composed of 8 buildings, each comprising 4 stores and 16 dwellings. The total floor space is 4,417 m2 with an energy consumption for heating of 131 kWh/m2. ATER Trieste plans to demolish and rebuild these buildings. The objective is to overcome the functional obsolescence of the district, attributable to the state of deterioration of the buildings, and to overcome the technological inadequacy with an organic series of redevelopment interventions. The complex was built in 1951 by the AMGOT (Allied Military Government of Occupied Territories) and will be subject to a complete building recovery.

The **objective** of the overall intervention is to overcome the functional obsolescence of the complex, attributable both to the minimum types of housing and the state of deterioration of the buildings, and to eliminate the technological inadequacy of the buildings with an organic series of redevelopment interventions through:

- the renewal of the plant networks;
- the adaptation of roads and the creation of parking spaces;
- the restoration of green areas;
- the recovery of buildings to eliminate building degradation and create housing units that are adequate to current standards and of different sizes and surfaces that allow the establishment of families differentiated by composition and age groups.

Location: The complex is located in an area with the same characteristics, and the presence of other ERP complexes and without obvious differences in social status, financial capacity and the possibility of accessing local services.

Services available in the neighbourhood: primary schools and recreation center for children, sport facilities, church, commercial centers.

OVERVIEW TABLE: THE REAL ESTATE OPERATION

Main destination	Residential
Address	Via Boito 1, 2, 3, 4, 5, 6, 7 e 8
Area	Trieste Boito
Intervention	Demolition and rebuilding
Commercial surface	7.202 mq
Property	ATER Trieste
Sponsor (Public Institution)	Municipality of Trieste - National funding

ADDITIONAL USEFUL DATA:

Scheduled start date for the renovation: 2024

KEY FEATURES OF THE OFFER

The transaction under the Offer involves raising debt capital through the equity crowdfunding portal authorised by Consob and managed by Concrete S.r.l.

Offeror	An SPV will be created
Financial instrument	TENDER imagine a bond issue
Expected holding period	20 years
Total Asset	€ 16,560,000

Denmark: Herning lighthouse

The data used were taken from the survey responses of FællesBo.

Description of the project: The SUPERSHINE Danish lighthouse district is in Herning Municipality (part of the Midtjylland Region). Heat to the district is provided by Herningværket, a wood chip CHP plant with a power capacity of 78 MW and heat capacity of 200 MW, supplying heat to 48,000 households through a user-owned cooperative utility, Verdo.

Location: The residential demonstration buildings are placed in the south-eastern part of Herning (around 50,000 inhabitants) in an area of mixed utilisation including large school, shopping centre, residential villas and building blocks. The district is fully built out. FaellesBo's buildings were built 1954-65 and have not been refurbished since the new building. The area surrounding the district has attracted "normal level" of investments to schools, refurbishment of buildings and infrastructure. No special investment in innovation in this area, although Herning in general has high investment in innovation in the business sector and in the local university.

OVERVIEW TABLE: THE REAL ESTATE OPERATION

Main destination	Residential
Address	FaellesBo social housing company's 4 departments: 16, 19, 21 and 24.
Area	FaellesBo, Herning, Denmark
Intervention	Renovation
Commercial surface	55101 m2
Property	FællesBo Social Housing Company

KEY FEATURES OF THE OFFER

The transaction under the Offer involves raising debt capital through the equity crowdfunding portal authorised by Consob and managed by Concrete S.r.l.

Offeror	An SPV will be created

Financial instrument	TENDER imagine a bond issue
Expected holding period	26 years
Total capital	€ 75,500,000

Latvia: Riga lighthouse

The data used were taken from the survey responses of Riga Energy Agency.

Description of the project: The SUPERSHINE Latvian lighthouse district "Āgenskalna priedes" is situated in Riga with 627,763 inhabitants and an area of 304 km2. It is located in the core residential area in the Āgenskalns borough and is composed of 24 Soviet-era multi-apartment residential buildings (1959-1961) and 1 new NZEB multi-apartment residential building (2020). The district is composed of 1,283 apartments for affordable housing and is home to 2,700 inhabitants. In addition, it has been marked by the municipality as the renovation wave pilot area in its Sustainable Development Programme 2021-2027. Āgenskalns neighbourhood is a mixed-use area including low- and medium-rise buildings: multi-apartment residential buildings and family housing areas, offices, retail spaces, public services, universities, schools and kindergartens.

Location: Āgenskalns, the historical neighbourhood of Riga, is best known for its extensive architecture and landscaped parks, ponds, and waterfront of the river Daugava. This area is a truly diverse neighbourhood, a balanced mix of historical buildings and new developments. There are cobbled streets with historical wooden buildings, pre-war red brick buildings and post-war buildings. Starting from the 19th century, Āgenskalns experienced a rapid change in housing development. Wooden housing developments were supplemented with the construction of multi-storey brick buildings. The neighbourhood faced its second large transformation in Soviet-era from 1960s to 1980s, when several multi-residential block houses were built. The Āgenskalns market has a landmark status of the neighbourhood and it is the third largest market of Riga constructed over 100 years ago. There were no any significant refurbishments made in the "Āgenskalna priedes" district since its establishment (in 1958-1962).

The Āgenskalns neighbourhood is facing rapid transformation: new residential housing and office space development projects, regeneration of Āgenskalns market territory, new commercial areas (offices, supermarkets) have been built over the last years. The neighbourhood hosts two leading universities of Latvia – Riga Stradiņa university and its campus, as well as a few faculties of the Riga Technical University known as one of the greenest universities of the world.

OVERVIEW TABLE: THE REAL ESTATE OPERATION

Main destination	Residential
Address	Kristapa iela 12, Riga, Latvia
Area	"Āgenskalna priedes" district
Intervention	Renovation
Commercial surface	42,007 m2
Property	LLC "Rīgas namu pārvaldnieks" (RNP)
Sponsor (Public Institution)	Riga City Municipality

ADDITIONAL USEFUL DATA:

Expected market value of the buildings after refurbishment: at least a 40% increase of market value

KEY FEATURES OF THE OFFER

The transaction under the Offer involves raising debt capital through the equity crowdfunding portal authorised by Consob and managed by Concrete S.r.l.

Offeror	An SPV will be created
Financial instrument	TENDER imagine a bond issue
Total capital stack	Up to 16,802,800

4.3. Environmental impact

4.3.1. Environmental overview and related costs

District retrofit interventions in Latvia, Italy, and Denmark have a significant impact on the environment. These interventions aim to improve the energy performance of buildings, reducing their carbon emissions and energy consumption. In Latvia, retrofit interventions focus on historic buildings, which account for more than one-quarter of Europe's existing building stock. The interventions consider the impact of climate change on retrofitted historic buildings in terms of occupants' comfort, heritage conservation, and energy performance. In Italy, the focus is on the retrofit of public residential buildings. The objective is to improve the energy performance of these buildings using construction materials from local agricultural waste and by-products. This approach not only reduces energy consumption but also promotes recycling and waste management. Finally, Denmark has set ambitious climate targets, aiming to be a climate-neutral society by 2050. Retrofit interventions in Denmark focus on public housing, with investments allocated for green renovation. These renovations aim to improve the climate impact from public housing[5].

The environmental overview of these retrofit interventions involves assessing the energy performance of buildings and the potential reduction in carbon emissions. The related costs include the expenses involved in implementing the retrofit interventions, which can vary depending on the specific measures undertaken.
Waste management is a crucial aspect of these retrofit interventions. In Italy, for example, the interventions aim to use construction materials derived from local agricultural waste and by-products. This approach promotes recycling and reduces waste.

Retrofit interventions aim to reduce energy consumption in buildings. In Latvia and Italy, these interventions have shown potential in reducing the yearly energy consumption for heating by up to 36%. In Denmark, retrofit interventions are part of the country's strategy to reduce greenhouse gas emissions.The upfront costs of these retrofit interventions can be substantial, given the scale of the projects and the technologies involved. However, these costs can be offset over time through the energy savings achieved.

[5] *What Are the Implications of Climate Change for Retrofitted Historic Buildings? A Literature Review* https://www.mdpi.com/2071-1050/12/18/7557

4.3.2. Optional Carbon Credits - Saving Calculation Estimate

Carbon credits can play a significant role in offsetting the costs of retrofit interventions. By verifying the emission reductions achieved through these interventions, carbon credits can provide additional funding for housing retrofit[6].

Carbon credits offer a promising approach for developing countries to achieve renewable energy targets and contribute to carbon mitigation efforts. By integrating carbon market potential into local projects, local governments can leverage financial resources for sustainable development initiatives.[7].

4.3.2.1. Voluntary Carbon market

The voluntary carbon market (VCM) can also play a crucial role in supporting retrofit interventions. The VCM allows the generation, buying, and selling of carbon credits on a voluntary basis. This can incentivize private capital and accelerate technology adoption, thereby supporting the scaling up of retrofit interventions[8].

4.4. Social impact

In evaluating the financial feasibility and potential economic returns of projects, certain intangible externalities, such as health benefits or enhanced comfort, are difficult to quantify in monetary terms. If it were possible to assign a monetary value to these advantages, projects that currently appear unviable might actually offer greater value than initially anticipated.

All three lighthouses have implemented various measures to enhance accessibility for individuals with special needs, improve indoor air quality and temperature control, and create new jobs through refurbishment projects. Additionally, they offer special discounts and other support and inclusion initiatives for low-income citizens, such as reduced utility costs, and financial assistance.

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6 Introduction to international voluntary carbon markets https://unfccc.int/sites/default/files/resource/Session%204%20Introduction%20to%20International%20VCMs.pdf

7 Making Carbon Markets Work for Your City: A Guide for Cities in Developing Countries https://e-lib.iclei.org/wp-content/uploads/2015/05/Making-Carbon-Markets-Work-for-Your-City-A-Guide-for-Cities-in-Developing-Countries.pdf

8 Scaling Voluntary Carbon Markets: A Playbook for Corporate Action https://www3.weforum.org/docs/WEF_Scaling_Voluntary_Carbon_Markets_2023.pdf

These efforts not only improve the quality of life for residents but also stimulate economic activity, reduce healthcare costs, and promote social inclusion. Each country's approach to these issues reflects a commitment to building a stronger, more resilient economy while ensuring the well-being of all citizens.

The information presented regarding the accessibility improvements, health and comfort measures, job creation and support for low-income citizens in the three lighthouses is based on responses given in the surveys conducted under WP2.

Accessibility

Improving building accessibility through renovations can have substantial economic benefits for tenants and residents in all three lighthouses.

Italy has implemented comprehensive measures, including accessible parking, pick-up points, curb ramps, and building accessibility, resulting in improved mobility and participation for individuals with special needs. Italy's approach of rebuilding without architectural barriers when demolishing buildings demonstrates a forward-thinking strategy that reduces future retrofitting costs and ensures long-term accessibility. In Italy, renovations that enhance accessibility can increase property values, benefiting homeowners and landlords. This can lead to greater mobility for individuals with special needs, enabling them to participate more actively in the community and potentially increasing their economic opportunities.

Improved mobility and participation for individuals with special needs have also been achieved in Denmark through the implementation of comprehensive measures, including accessible parking, pick-up points, curb ramps, and building accessibility. In Denmark, renovations that improve accessibility can lead to lower maintenance costs over time, benefiting both tenants and landlords. Accessible buildings can also improve the quality of life for residents with special needs, potentially reducing healthcare costs and improving overall well-being.

In contrast, Latvia's lack of such measures highlights a significant gap in accessibility, potentially limiting the participation and quality of life for individuals with special needs. Renovations that improve accessibility in Latvia could make properties more attractive to potential tenants, potentially leading to higher occupancy rates and increased rental income. This can also improve residents' quality of life, potentially leading to higher satisfaction and longer tenancies.

Health and Comfort

In Italy, residents can control the temperature and humidity of their homes and autonomous systems are planned for the project, so residents will have full control and management of their heating system leading to greater comfort and potentially reducing energy costs. This, along with improved indoor air quality, can also lead to better health outcomes, reducing healthcare costs for residents and the healthcare system while promoting environmental sustainability.

Similarly, in Denmark, residents have similar control over their indoor environment, which can lead to energy savings, lower utility bills and improved well-being.

In Latvia, there is only district heating installed in all buildings of the district, ensuring that the minimal temperature during winter does not go below +16°C. However, in Latvia, where residents do not have the same level of control, there may be increased energy consumption and discomfort, potentially leading to higher healthcare costs and reduced energy efficiency. Therefore, ensuring residents' control over temperature and humidity, along with improving indoor air quality, can result in economic benefits such as reduced healthcare costs, lower energy consumption, and improved overall well-being.

The project also includes KPIs related to health and comfort measures, such as temperature and humidity control, and indoor air quality measures, including CO_2, PM2.5, and VOC levels, which will be monitored during the project for all lighthouses.

Job Creation

Job creation from refurbishment projects can provide economic benefits in Denmark and Latvia. In Denmark, refurbishment projects are expected to create new jobs in construction, renovation, and related industries, stimulating the local economy. Some of these jobs are expected to last beyond the refurbishment period, providing ongoing economic benefits to the community.

Similarly, in Latvia, refurbishment projects are also expected to create new jobs, which can stimulate economic growth. These jobs may also last beyond the refurbishment period, providing long-term economic benefits.

However, in Italy, refurbishment projects are not expected to create new jobs, so the economic benefits in terms of job creation may be limited compared to Denmark and Latvia.

Other Externalities

In Italy, Ater offers housing to low-income inhabitants, with rents fixed by regional law based on income. The state and local governments in Italy also provide income support measures and levy state and local charges for energy bill payments.

In Denmark, the municipality provides support for low-income households by helping them pay their rent, and elderly people receive financial support called "ældrechecken."

In Latvia, the municipality offers housing support to low-income residents to help them pay their bills for housing-related services. Criteria for these supports are set by law and municipal regulations.

By providing these benefits and supports, governments and organisations can improve the quality of life for low-income citizens, reduce poverty levels, and stimulate economic activity. Additionally, these initiatives can lead to cost savings for individuals, allowing them to allocate more of their income towards other essential needs, which can have a positive impact on local economies.

5. Conclusions

The SUPERSHINE project presents a comprehensive and multidimensional approach to energy efficiency renovations, integrating technical, financial, environmental, and social analyses into a cohesive framework. Each part of the methodology contributes to a deeper understanding of the impacts and benefits of energy efficiency interventions. The technical analysis ensures that the interventions are feasible and effective. The bottom-up business model and cost benefit analysis provide a detailed assessment of economic viability and investment potential. The environmental and social analyses highlight the broader benefits, including sustainability and improved quality of life. Together, these elements form a robust foundation for guiding stakeholders in making informed decisions about energy efficiency investments, ensuring that projects are both economically sound and socially beneficial.

The technical analysis of the lighthouses in Italy, Latvia, and Denmark demonstrates the diverse approaches taken to enhance energy efficiency in buildings while addressing local needs and conditions. In Latvia, the focus on historic buildings highlights the importance of preserving heritage while improving energy performance and occupant comfort. Italy's innovative use of local agricultural waste for construction materials not only boosts energy efficiency but also promotes sustainability through recycling. Denmark's commitment to green renovations in public housing aligns with its ambitious climate-neutral goals for 2050, showcasing how energy efficiency measures can contribute to broader environmental targets.

The bottom-up business model developed by the SUPERSHINE project provides a detailed and scalable framework for assessing and financing energy efficiency interventions. By starting at the individual building level and expanding to block and district levels, the model ensures a comprehensive understanding of energy savings and financial impacts. The incorporation of stochastic volatility modelling and the calculation of the social discount rate (SDR) add depth to the financial analysis, accounting for future uncertainties and socio-economic factors. The model's ability to compare various funding solutions against benchmarks like the S&P 500 and rank them based on risk-adjusted returns and ROI offers stakeholders a clear and actionable roadmap for investment decisions. This thorough approach ensures that energy efficiency projects are not only technically feasible but also financially viable and sustainable in the long term. Furthermore, the cost-benefit analysis methodology provides a robust framework for evaluating the economic feasibility of energy efficiency renovations. Starting with detailed energy savings modelling, the project estimates the potential reductions in energy consumption and CO2 emissions. The subsequent stochastic volatility modelling of key financial variables like energy prices, inflation, and interest rates adds to the financial projections. The calculation of the SDR through the weighted average method balances private and public investment considerations, reflecting the true cost of capital for public projects. By assessing metrics such as ROI, NCF, NPV, risk-adjusted extra returns, and CVaR, the analysis ensures a comprehensive evaluation of the financial and socio-economic impacts of the interventions. This detailed financial analysis confirms that energy efficiency renovations can provide significant economic returns while mitigating financial risks.

The environmental impact analysis underscores the broader benefits of energy efficiency renovations beyond mere financial gains. Environmentally, the retrofit interventions in Latvia, Italy, and Denmark contribute to substantial reductions in energy consumption and carbon emissions. These interventions reduce energy consumption, promote waste management, and contribute to the reduction of carbon emissions. Despite the upfront costs, the long-term benefits, coupled with the potential for carbon credits and the support of the voluntary carbon market, make these interventions a viable and sustainable approach to achieving environmental goals.

Italy, Denmark and Latvia demonstrate a commitment to enhancing accessibility, improving health and comfort, creating jobs and supporting low-income citizens. These efforts not only improve the quality of life for residents but also stimulate economic activity, reduce healthcare costs and promote social inclusion. While each country has its approach and challenges, such as Italy’s comprehensive accessibility measures, Denmark’s focus on resident control over indoor environments and Latvia’s district heating system, all aim to build stronger, more resilient economies while ensuring the well-being of all citizens. Assigning a monetary value to these intangible benefits could reveal that projects deemed unviable may, in fact, offer greater value than initially anticipated.