ANNEX 75

EBC

Energy in Building and Communities Programme

International Energy Agency

Success Stories of Cost-effective Building Renovation at District Level Combining Energy Efficiency & Renewables

Summarizing report

Energy in Buildings and Communities Technology Collaboration Programme

May 2023

Technology Collaboration Programme by iea

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Summarizing report

Energy in Buildings and Communities Technology Collaboration Programme

May 2023

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Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives - The strategic objectives of the EBC TCP are as follows:

- reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
- improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
- the creation of 'low tech', robust and affordable technologies;
- the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
- the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

Means - The strategic objectives of the EBC TCP will be achieved by the means listed below:

- the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle analysis (LCA);
- benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
- improving smart control of building services technical installations, including occupant and operator interfaces;
- addressing data issues in buildings, including non-intrusive and secure data collection;
- the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

Annex 1: Load Energy Determination of Buildings (*)

Annex 2: Ekistics and Advanced Community Energy Systems (*)

Annex 3: Energy Conservation in Residential Buildings (*)

Annex 4: Glasgow Commercial Building Monitoring (*)

Annex 5: Air Infiltration and Ventilation Centre

Annex 6: Energy Systems and Design of Communities (*)

Annex 7: Local Government Energy Planning (*)

Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)

Annex 9: Minimum Ventilation Rates (*)

Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: ☼ Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: ☼ Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: ☼ Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: ☼ Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy and CO2 Emissions Optimization in Building Renovation (*)
Annex 57: Evaluation of Embodied Energy and CO2 Equivalent Emissions for Building Construction (*)
Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60: New Generation Computational Tools for Building and Community Energy Systems (*)
Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (*)
Annex 62: Ventilative Cooling (*)
Annex 63: Implementation of Energy Strategies in Communities (*)
Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (*)
Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems (*)
Annex 66: Definition and Simulation of Occupant Behavior in Buildings (*)
Annex 67: Energy Flexible Buildings (*)
Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings (*)

Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale
Annex 71: Building Energy Performance Assessment Based on In-situ Measurements
Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings
Annex 73: Towards Net Zero Energy Resilient Public Communities
Annex 74: Competition and Living Lab Platform
Annex 75: Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables
Annex 76: ☼ Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions
Annex 77: ☼ Integrated Solutions for Daylight and Electric Lighting
Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
Annex 79: Occupant-Centric Building Design and Operation
Annex 80: Resilient Cooling
Annex 81: Data-Driven Smart Buildings
Annex 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems
Annex 83: Positive Energy Districts
Annex 84: Demand Management of Buildings in Thermal Networks
Annex 85: Indirect Evaporative Cooling
Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings
Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
Annex 88: Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings (*)
Working Group - Cities and Communities (*)
Working Group - Building Energy Codes
(*) – completed working groups

Executive Summary

Fifteen success stories from seven European countries have been collected within the framework of IEA EBC Annex 75 (available online in an interactive map: https://annex75.iea-ebc.org/success-stories). These success stories are exemplary interventions (mainly publicly owned, which largely condition the results of this report) involving district-based solutions for renewable energy use and energy efficiency measures. The scope of the renovation varies from one success story to another, and, in some cases, it was limited to measures either on the energy systems or on the thermal building envelope. It is documented to what extent the combination of energy efficiency measures on the building envelopes and renewable energy systems has been considered in the selected cases investigated and to what extent grid-based solutions were considered advantageous concerning individual heating or cooling solutions in the district. A special emphasis on the decision-making process as well as on challenges and lessons learned regarding their implementation is made.

The main goals of the success stories were to gather relevant information for other work packages within the IEA EBC Annex 75 and for future interventions that promote cost-effective building renovation at the district level combining energy efficiency and renewable energy systems.

The success stories document that district renovation is a complex activity due to the large number of stakeholders involved, the broad knowledge, and the large financial resources needed.

The success stories have shown that achieving a high energy and emissions reduction by combining energy efficiency at the building or energy system level and renewable energy is possible. In those interventions that have striven to reach this goal, the energy efficiency levels and renewables implemented exceed the minimum requirements set in the national regulations. In most cases, the balance between energy efficiency measures and renewable energy use is based on expert estimations and not on calculations. This is also cited as the main challenge or bottleneck during the design phase. Therefore, there is potential for improvement, and the methodology developed in the IEA EBC Annex 75 can help in decision-making and contribute to greater emission reductions in district renovation.

An important goal of most interventions was the improvement of comfort and the buildings' adaptation to a contemporary standard of living, as well as the improvement of the quality of the open space, the attractiveness, and the image of the district. Improving the quality and increasing the value of the building stock to ensure profitability while maintaining affordability (without or with a reasonable increase in rent or low investment cost for the owners) and improving the social diversity and cohesion in the neighbourhood were also drivers in several interventions.

In most success stories, either a centralised energy supply system was newly installed, or an existing centralised energy system was renovated to improve its efficiency or incorporate renewable energy sources. There is only one success story in which geothermal heat pumps replaced a centralised system to reduce operational costs and become more environmentally friendly.

In the success stories, district renovation has been mainly initiated by the willingness and support of the municipality, a housing association, a residents' association, or the wish of the inhabitants. Therefore, these were key actors during the whole process. Investors and tenants/residents are also key actors in the implementation of the renovation. Usually, the investors are a building association that owns the buildings, individual building owners, a public body, an energy service company (ESCO), or a real estate development company in one of the districts. It is important to note that many district renovations described in the success stories are partly financed through public money, either as direct financing or via subsidies.

Citizens' engagement and communication with tenants from the early stages of the project led to a higher overall satisfaction rate. They were considered key for the entire renovation process in the success stories. Effectively communicating the reason why a renovation is needed, what measures will be performed, and what are the expected results is essential. Including tenants in the process, explaining the renovation goals, and asking for opinions and approval of the proposed changes is advantageous. Success is determined, in many cases, by the existence of a coordination figure, a facilitator.

The main barrier to a district renovation is funding. However, many challenges can hinder or make the process difficult, such as the coordination of all stakeholders, the difficulty in finding the optimal renovation measures, the need to relocate the tenants during the renovation works, as well as other technical aspects such as unforeseen problems, the location of the energy production systems and the pipe laying of a district heating system in a built area. Some of these challenges can be overcome with an appropriate business model, such as a market intermediation model, a one-stop-shop, or an ESCO. Other challenges, such as the synchronization of district energy supply measures and building-related renovation cycles or unclear framework conditions/dynamic legal framework, are more difficult to overcome.

The following are the main take-away messages from the lessons learned in the presented success stories.

- Energy-efficient measures for district renovation can be combined with renewable energy measures and, beyond that, with social or other improvements at the urban scale or in the infrastructure to bring more value to the intervention and make more efficient use of the financial resources available.
- There are no big technological barriers to district renovation. On the contrary, there are technological opportunities, such as accessing a renewable source, like a lake, which could not be done through individual heating solutions or by providing the opportunity to make use of innovative heat pumps with high efficiency and low non-carbon-related greenhouse gas emissions. However, there is a lack of technical knowledge and protocols to simplify such a complex process (including which entity initiates and coordinates the whole process, what steps are necessary from idea to implementation, etc.) and a lack of resources to carry out related coordination work. This aspect will also largely depend on the district and the structure of buildings and owners. The heterogeneity and complexity of the district will influence the magnitude of the technological barriers that may arise.
- Costs and fragmented interests, and revenue streams are significant barriers. The availability of financial resources is essential. European funding or other public funding can be key in the process as they cover part of the investment costs and bring knowledge and experience in the field in such consortia. An ESCO can also finance the intervention, but they tend to invest in projects that are only linked to energy production systems.
- Good coordination between all stakeholders is needed to follow the schedule and ensure a successful renovation. Furthermore, flexibility is required because such complex projects can hardly be developed exactly as planned. Project phases are also required to overlap to shorten long project timelines. For that reason, the support of regional and local authorities, building associations, or management teams that act as facilitators of the processes for coordinating all the agents involved, the definition of proposals, funding, agreement, information, and dissemination is vital. Such services could be covered through a one-stop-shop. In case district renovation involves more extensive infrastructure solutions and decision-making processes, the municipality has a crucial role. It could be that linking overarching energy supply and infrastructure planning and individual measures on buildings is a major challenge that is not covered by a one-stop-shop but needs integrated planning and municipal action.
- Citizen and tenant engagement is necessary for the process to run smoothly. This is achieved through clear and effective communication from before the start of the intervention and throughout the project, incorporating the feedback received by the citizens. This task is time-consuming and can be supported by a neighbour's association or other social stakeholders in the district who support the project.
- Overall, public support is crucial to facilitate funding of district projects and enable sufficient stakeholder dialogue and coordination work to successfully realise district renovation projects, particularly if they combine energy efficiency and renewable energy measures.

Abbreviations

Abbreviations	Countries
AT	Austria
CH	Switzerland
DK	Denmark
ES	Spain
IT	Italy
PT	Portugal
PV	Photovoltaics
SE	Sweden

Abbreviations	Meaning
DH	District heating
DHN	District heating network
DHW	Domestic hot water
EPC	Energy performance certificate
ESCO	Energy service company
EU	European Union
HVAC	Heating, ventilation, and air conditioning
NGO	Non-governmental organization
PV	PV panels

Table of contents

1. Introduction

IEA EBC Annex 75 focuses on cost-effective building renovation at the district level combining energy efficiency & renewables. The success stories present good practice examples of different strategies for reducing carbon emissions of the existing building stock by improving energy efficiency and implementing renewable energy solutions. These success stories include transforming previously existing district heating systems and creating district heating systems based on renewable energy in districts previously heated with decentralised installations. Furthermore, this includes success stories for the mass renovation of thermal envelopes in a specific district.

1.1 Geographical distribution

The present report collects fifteen success stories from seven European countries (**Figure 1**). The success stories are spread throughout Europe, especially in three core areas: Central Europe (Northern Italy, Switzerland, and Austria), Northern Europe (Sweden and Denmark), and Southern Europe (Spain and Portugal). Information about these success stories is available online on an interactive map: https://annex75.iea-ebc.org/success-stories.

Figure 1. Overview of the location of the collected success stories with the main building use of the renovated area. Source: https://annex75.iea-ebc.org/success-stories.

1.2 Basic information

The success stories include a wide range of interventions whose main characteristics are listed in Table 1. Success stories PT2 and PT3 include exclusively applying energy efficiency measures in the building envelope and installing renewable energy systems without substituting the existing ones. The success stories IT1, IT3, IT4, IT5, CH, and SE2 only include energy systems measures as these building envelopes have been previously renovated. Many of the renovations include measures that are not related to energy efficiency but to improving the quality of life and image, accessibility, social cohesion of the neighbourhood, etc. It may be said that the success stories IT1, IT4, and IT5 are not examples of best practices in terms of cost-effective implementation of building renovation and renewables. However, considering that they are energy system interventions at a district scale in a unique context, related experiences may be relevant to other similar interventions.

The urban area contemplated in the renovations ranges from 8,000 m^2 to 24 million m^2. The average age of the districts under renovation is approximately 50 years. One exception is IT4, an intervention in the historical context of Venice, with buildings dating from the second half of the 17th century. Another is PT3, where the rehabilitated buildings are 25-30 years old. The duration of the renovation ranges from 6 months to 10 years. However, the average duration of the renovations in which the buildings' thermal envelope and the energy systems are renovated is 5 years.

Table 1. Main characteristics of the studied success stories. In white, energy systems and building envelopes were renovated. In grey, only energy systems were renovated. In yellow, only building envelopes were renovated (although in some cases, renewable energy sources have been installed).

<table>
<tr><th>Nomenclature</th><th>Country</th><th>City</th><th>Use</th><th>Urban Area (m²)</th><th>Year of construction</th><th>Year of renovation</th></tr>
<tr><td>AT</td><td>Austria</td><td>Salzburg</td><td>R</td><td>45,000</td><td>1950-1965</td><td>2008-2018</td></tr>
<tr><td>DK</td><td>Denmark</td><td>Aalborg</td><td>R</td><td>540,000</td><td>1970s</td><td>2014-2020</td></tr>
<tr><td>IT1</td><td rowspan="5">Italy</td><td>Modena</td><td>R, E and O</td><td>147,000</td><td>1950-1970</td><td>1970-ongoing</td></tr>
<tr><td>IT2</td><td>Varese</td><td>RI</td><td>7,542 (1,066 3 buildings under major renovation)</td><td>End 1960s - Early 1970s</td><td>2015</td></tr>
<tr><td>IT3</td><td>Valdastico</td><td>E, R and O</td><td>8,000</td><td>-</td><td>2014</td></tr>
<tr><td>IT4</td><td>Venice</td><td>E, O</td><td>11,000</td><td>2nd half 17th century, 1880s & 1920s</td><td>2017</td></tr>
<tr><td>IT5</td><td>Turin</td><td>E, O and OT</td><td>24,000,000</td><td>-</td><td>1982-ongoing</td></tr>
<tr><td>PT1</td><td rowspan="3">Portugal</td><td>Porto</td><td>R, E</td><td>19,700</td><td>1953</td><td>2009-2014</td></tr>
<tr><td>PT2</td><td>Vila Nova de Gaia</td><td>R, E</td><td>170,000</td><td>1984-1986</td><td>2009-2015</td></tr>
<tr><td>PT3</td><td>Lisbon</td><td>R, CO, CL and E</td><td>55,000</td><td>1960/1970 & 1980-1999</td><td>2013 (6 months)</td></tr>
<tr><td>ES1</td><td rowspan="2">Spain</td><td>Vitoria-Gasteiz</td><td>R, O and CL</td><td>89,100</td><td>1960s-1970s</td><td>2016-2021</td></tr>
<tr><td>ES2</td><td>Tudela</td><td>R</td><td>25,000</td><td>1954-1972</td><td>2010-2012</td></tr>
<tr><td>CH</td><td>Switzerland</td><td>Weggis</td><td>R, CO and E</td><td>250,000</td><td>-</td><td>2016-2020</td></tr>
<tr><td>SE1</td><td rowspan="2">Sweden</td><td>Lund</td><td>R</td><td>90,300</td><td>1969-1972</td><td>2014-2017</td></tr>
<tr><td>SE2</td><td>Malmö</td><td>R</td><td>25,000</td><td>1967</td><td>2017-2018</td></tr>
</table>

Uses: R – residential, E – educational; O – office, CO – commercial, CL – cultural, OT – other.

Table 2 summarizes the ownership type of buildings and energy supply systems. Both the type of ownership of buildings and energy supply systems are mixed, with a higher proportion of public ones. The type of ownership of buildings does not change after renovation; in the case of the energy supply system, there are two interventions (IT1 and IT5) in which a private system becomes public and one success story (ES1) in which the proportion of private ownership becomes higher.

Table 2. Type of ownership (public or private) of the buildings and energy systems. In grey - only energy systems were renovated. In yellow – only building envelopes were renovated (although, in some cases, renewable energy sources have been installed without substituting the energy supply systems). n. a. = not available.

<table>
<tr><th rowspan="2">Nomen-clature</th><th colspan="2">Property of buildings</th><th colspan="2">Property of energy supply system</th></tr>
<tr><th>Before</th><th>After</th><th>Before</th><th>After</th></tr>
<tr><td>AT</td><td colspan="2">50% private, 50% public</td><td colspan="2">100% private (city as a shareholder)</td></tr>
<tr><td>DK</td><td colspan="2">100% public</td><td colspan="2">100% private</td></tr>
<tr><td>IT1</td><td colspan="2">50% private, 50% public (not renovated)</td><td>100% private</td><td>100% public</td></tr>
<tr><td>IT2</td><td colspan="2">100% public</td><td colspan="2">100% public</td></tr>
<tr><td>IT3</td><td colspan="2">100% public (not renovated)</td><td colspan="2">100% public</td></tr>
<tr><td>IT4</td><td colspan="2">100% public (not renovated)</td><td colspan="2">100% public</td></tr>
<tr><td>IT5</td><td colspan="2">n. a.</td><td>100% private</td><td>100% public</td></tr>
<tr><td>PT1</td><td colspan="2">100% public</td><td colspan="2">n. a.</td></tr>
<tr><td>PT2</td><td colspan="2">n. a.</td><td colspan="2">n. a. (not renovated)</td></tr>
<tr><td>PT3</td><td colspan="2">90% public, 10% private</td><td colspan="2">n. a. (not renovated)</td></tr>
<tr><td>ES1</td><td colspan="2">84.1% private, 15.9% public</td><td>80.9% public, 19.1% private</td><td>41.9% public, 58.1% private</td></tr>
<tr><td>ES2</td><td colspan="2">100% private</td><td colspan="2">100% private</td></tr>
<tr><td>CH</td><td colspan="2">n. a. (not renovated)</td><td>100% private (individual owners)</td><td>100% public (corporation)</td></tr>
<tr><td>SE1</td><td colspan="2">100% public</td><td colspan="2">100% public</td></tr>
<tr><td>SE2</td><td colspan="2">100% private (not renovated)</td><td colspan="2">100% private</td></tr>
</table>

1.3 Key parameters

The analysis of the success stories is performed by collecting the following information:

- Schematic figure or areal overview
- Description of the situation before the renovation
- Description of the renovation goal
- Description of the renovation concept
- Main data concerning:
    - Area and number of buildings
    - Building use and property of the buildings and energy supply systems (public or private)
    - Size of the building mix
    - Energy demand and consumption
    - Renewable energy production
    - Investment costs
- Description of the technical highlight(s) and innovative approach(es)
- Decision and design process
- Lessons learned and of interest findings

2. Objectives

2.1 General objectives of IEA EBC Annex 75

IEA EBC Annex 75 aims to investigate cost-effective strategies for achieving far-reaching reductions of carbon emissions and energy use in city buildings at the district level, combining energy efficiency and renewable energy measures. The objective is to provide guidance to policymakers, companies working in the energy transition field, and building owners for cost-effectively transforming the city's energy use in the existing building stock towards low-emission and low-energy solutions.

In light of the Paris Agreement and the objective to undertake efforts to limit climate change to a temperature increase of 1.5 °C above pre-industrial levels, it is particularly interesting to investigate strategies that allow achieving cost-effectively zero emissions and 100% renewable energy-based solutions as present targets.

Given the limitations due to available financial resources and the large number of investments needed to transform the cities' energy use in buildings, identifying cost-effective strategies is important for accelerating the transition towards low-emission and low-energy districts.

The planned project focuses on the following objectives:

- Give an overview of various technology options, taking into account existing and emerging energy efficiency technologies as well as renewable energy technologies with the potential to be successfully applied within that context, and how challenges specifically occurring in an urban context can be overcome;
- Develop a methodology that can be applied to urban districts to identify such cost-effective strategies, supporting decision makers in the evaluation of the efficiency, impacts, cost-effectiveness, and acceptance of various strategies for renovating urban districts;
- Illustrate the development of such strategies in selected case studies, gather related best-practice examples, and explore, in particular, interactions between energy efficiency and renewable energy measures.
- Give recommendations to policymakers and energy-related companies on how they can influence the uptake of cost-effective combinations of energy efficiency and renewable energy measures in building renovation at the district level and guide building owners/investors on related cost-effective renovation strategies.

The present report focuses on the third of the objectives indicated in this list.

It is intended that through the work carried out in IEA EBC Annex 75, accurate, understandable information, guidelines, tools, and recommendations are provided to support decision-makers from the public and private sectors in making better decisions and choosing the best options that apply to their specific needs.

2.2 Objectives of the success stories

The objective of the success stories is to gather best-practice examples of district renovation in different countries. This includes a detailed description of the renovation goal and concept, drivers and barriers, technical highlights, innovative approaches, information about the district's energy use before and after the intervention, and costs. A detailed description of the whole decision and implementation process is included, with special emphasis on the challenges from a technical, economic, financial, and management point of view that have been encountered during the process. Furthermore, the success factors, main bottlenecks, and lessons learned are included as take-away messages that can be drawn from the success story and considered and implemented in future interventions.

The collected success stories are presented and subsequently analysed in the following chapter.

3. Success stories

3.1 Renovation Strubergasse, Salzburg (Austria)

Country: **Austria**

Name of city/municipality: **City of Salzburg**

Title of case study: **Renovation Strubergasse**

Period of the renovation: **2008 – 2018** (it includes concept phase, planning phase, building phase and resettlement phase)

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Link(s) to further project related information/publications, etc.:
https://www.stadt-salzburg.at/internet/websites/smartcity/smartcity/wohngebaeude/struber-gasse_452403/quartierserneuerung_461475/sanierung_strubergasse_452405.htm
https://nachhaltigwirtschaften.at/resources/hdz_pdf/berichte/endbericht_1443a_stadtum-bau_lehen_subprojekt_6a_anhang_06.pdf

Schematic figure or aerial overview

Figure 2. Schematic/aerial view of Strubergasse renovation area. Source: Google Maps, adapted by SIR, 2022.

New buildings/high-performance renovation of building owner GSWB
Thermal renovation of building owner City of Salzburg

Introduction and description of the situation before the renovation

The city of Salzburg owns 26 residential buildings in the district of Lehen between the Ignaz-Harrer-Straße in the north and the railway line in the south. The residential buildings in the area were built between 1950 and 1965. The formerly common small apartments were hard to rent. The buildings had no central heating. The apartments were still heated to about 50% with stove heating based on coal or wood. In some cases, single gas boilers were installed. Some objects were faced with massive problems of mould.

Already implemented renovation measures were scarce: in some dwellings, windows were exchanged. In one object, the façade was insulated, and the roofs were partially renovated. The heat loss to the outside was, therefore, considerably high.

Figure 3. Photographs of the conservation state of the buildings before rehabilitation. Source: SIR, 2009.

The acoustic protection was a problem within the houses and against the outside, as the living and sleeping rooms were partly situated on the heavily trafficked roads (Rudolf-Biebl-Straße and Ignaz-Harrer-Straße).

A further issue was the accessibility of the buildings. Even if elevators were retrofitted, the residents had to overcome the mezzanine from the elevator to the apartments.

Generous open spaces were given between the buildings but hardly any car parking areas. Many residents parked on the public roads.

In the adjacent district "Stadtwerk Lehen", many projects were implemented between 2008 and 2015, which, on long-term, led to an appreciation of this central district: In the northern part, 287 subsidized rental apartments, a kindergarten, the new city gallery, and a dorm, in the southern part offices, laboratories, and seminar rooms. Here, the largest thermal solar system of Salzburg with 2,048 m² thermal collectors and a 200,000-liter buffer storage was built.

Description of the renovation goal

The general objective of the renovation with partially new constructions was to create a sustainable and long-lasting residential complex with high sociocultural, functional, ecological, and economic quality.

In detail, the renovation goals were:

- Increasing the living quality and adapting the buildings to a contemporary standard of living
- Quality improvement and increase in the value of the building stock
- Improving the quality of open space in the district
- Ensuring permanent rentability
- Reducing energy costs and carbon emissions
- Improving the image and its effect as identification for the inhabitants and the district

As part of the modernization, a balanced mix of apartments should be achieved. The complex has 482 residential units with a focus on 2- and 3-room apartments. Due to the favourable location and the unused areas in the attic, it made sense to carry out an extension. Due to the high demand for housing, apartments for four and more people should be newly created. The concept included the possibility of creating approximately 70 apartment units in this way.

These renovation goals were achieved. However, there are no quantitative values of consumption and cost reductions.

Description of the renovation concept

The following measures were implemented in the buildings which are owned by the City of Salzburg:

- Thermal renovation: façade insulation, new windows, basement, and attic ceiling insulation.
- Balconies: Each apartment was equipped with a balcony during the renovation.
- District heating connection to the existing network of the Salzburg AG. The neighbouring city district "Stadtwerk Lehen" micro-grid has been extended into the area around the Strubergasse so that the heat from the solar system (especially in summer) can be used.
- Since the old apartments were not connected to a modern central heating system, supply lines were laid to each apartment. Each tenant had the opportunity to continue to operate his old heating system or to connect to the district heating system of the city of Salzburg.

Thermal renovation

For the thermal renovation of the buildings, radical measures were proposed. Each building component, which is renovated, should achieve the highest possible energy standard to achieve acceptable energy consumption also in 40 to 50 years without major renewals.

Different renovation packages were elaborated on and evaluated:

- Renovation package 1: optimized building envelope according to already intended standard.
- Renovation package 2: "factor 10" renovation: improved standard with high profitability using passive house components and mechanical ventilation systems with heat recovery.
- Renovation package 3: passive house standard for all new buildings and also for the additions of stories.

Table 3 shows a comparison of the U-values, insulation thickness and envelope's airtightness of all three renovation packages and the existing buildings (on average).

Table 3. U-values in W/m^2K, insulation thickness in cm, and airtightness at 50 Pa in h^{-1} before and after renovation.

component	existing buildings	renovation package 1		renovation package 2		renovation package 3	
	U-value [W/m²K]	insulation thickness [cm]	U-value [W/m²K]	insulation thickness [cm]	U-value [W/m²K]	insulation thickness [cm]	U-value [W/m²K]
exterior wall	1.015	16	0.180	20	0.138	25	0.114
ceiling to cellar	1.111	12	0.231	20	0.151	25	0.124
ceiling to attic	0.812	20	0.143	25	0.119	30	0.101
roof	1.127	27	0.154	30	0.131	35	0.113
windows			0.90		0.85		0.80
ventilation	free	mechanical exhaust air		mech. supply/exhaust air with heat recovery		mech. supply/exhaust air with heat recovery	
envelope's air-tightness (50 Pa)	3 - 6 h^{-1}	1.0 h^{-1}		0.6 h^{-1}		0.6 h^{-1}	

The results of the PHPP calculation for the different renovation packages and the existing situation can be found in **Figure 4**:

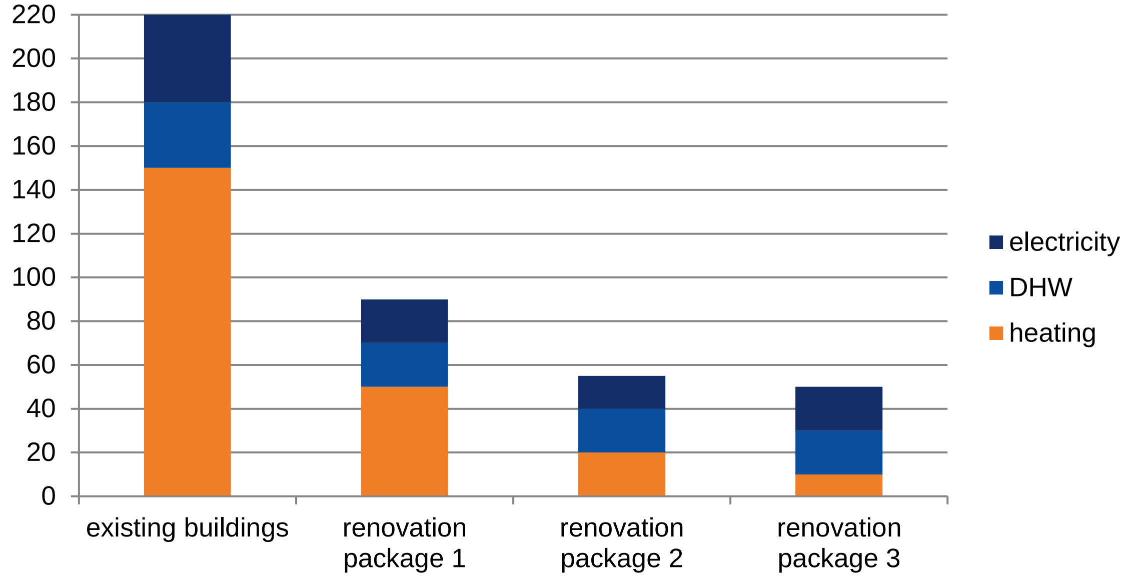

Figure 4. Calculated energy demand of the existing buildings and the three renovation packages in kWh/m^{2}a.

The renovation concept of the whole area included buildings with renovation package 1 (standard renovation), factor 10 renovation, and new buildings in passive house standard (referred to as renovation package 3). The attics will be built as new residential floors in the passive house standard.

During the planning phase, the goal was also to evaluate the possibility of producing electricity on-site by photovoltaic modules. One of the findings was that the highest electric yield could be achieved on the roof areas if different roof shapes were created. The yield of a large-scale PV is higher than the demand so that electricity could be obtained for mobility on the balance sheet.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	45,000	45,000
Population in the area:	-	1,400	1,600
Number of buildings in the area	-	26	23
Heated floor area of all buildings	m²	15,500	36,000
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	-	-
Multi-family homes (MFH) - up to three stories and/or 8 flats		-	-
Apartment blocks (AB) - more than 8 flats		95	95
Schools		-	-
Office buildings		-	-
Production hall, industrial building		-	-
Other (ground floor area spaces)		5	5
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	-	-
Medium consumers: AB, schools, etc. – 80-800 MWh/a		100	100
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		-	-
Property situation of buildings:			
Private (but: limited profit organization)	% of heated floor area	50	50
Public		50	50
Property situation of energy supply system (district heating):			
Private (but: city as a shareholder)	% of heated floor area	100	100
Public		-	-

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	93-150	27-35
Domestic hot water demand (calculated)	kWh/m²a	included in the heating demand	
Cooling demand (calculated)	kWh/m²a	-	-
Electricity demand (calculated)	kWh/m²a		
Heating consumption (measured)	kWh/m²a		
Domestic hot water consumption (calculated)	kWh/m²a	included in the heating consumption	
Cooling consumption (measured)	kWh/m²a	-	-
Electricity consumption (measured)	kWh/m²a		
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	50	0
***Decentralised* biomass boilers**		-	-
***Decentralised* heat pumps**		-	-
Centralised (district heating)		0	75
Other *(please specify) coal, wood ovens*		50	0
Renewable energy generation on-site:		0	25
Solar thermal collector area	m²	0	2,048 (connected to the microgrid of "Stadtwerk Lehen"
Photovoltaics	kW_p	0	0
Other (please specify)	kW	0	0

Financial issues:

Parameter	unit	before renovation	after renovation
Total costs of the whole renovation and construction project	Euro	-	59,520,000
Thereof costs of the renovation	Euro	-	7,800,000
- **building envelope renovation costs**	Euro/m²	-	-
- **heating/cooling supply costs**	Euro/m²	-	-
- **renewable energy production costs**	Euro/m²	-	-
LCC available	yes/no	No	no

Description of the technical highlight(s) and innovative approach(es)

Non-technical Aspects:

Gentle neighbourhood redevelopment through successful relocation management.

The acceptance and understanding of the existing residents and efficient settlement management. Over five years (2011-2016), 337 households were resettled in the settlement. Thus, satisfactory housing solutions, including relocation assistance, were found for almost all residents. For the most part, a free professional relocation service was used for the tenants. Otherwise, relocation aid was paid out. Fears could be overcome in long personal conversations involving tenants in the preparation and implementation of the renovation and including a tenants' advisory board for the renovation period. In this way, it was possible to offer new or renovated apartments to the residents who were to move, mostly in their familiar surroundings. An evaluation after the completion of the project has shown that there is a flexible response to complex problems. Challenges are impending redemption demands or delays during the project. On the other hand, only targeted information work by all those involved can help inform the relevant residents about rental price developments in urban and subsidized rented housing, thereby conveying realistic ideas. Methodically, on-site meetings, information letters, and personal contacts were selected. Resettlement also requires a clear implementation plan with time reserves in order not to come under pressure in case of difficulties. It is also essential to inform the affected citizens immediately of the decision to resettle and to have the responsible staff and politicians accompany and support the entire process.

Decision and design process

General/organizational issues:

Stakeholders involved

Non-profit building association GSWB and Bausparerheim.

City of Salzburg Municipal Department 3/03.

Main steps

The main steps of the process for the successful implementation of the project were as follow (Table 4).

Table 4. Timeline and main project milestones.

June 2008	Concerto contract for EU funding project to finance construction measures in Salzburg Lehen	
Summer 2008	First talks with the mayor of the city of Salzburg	
Spring 2009	Evaluation of the existing situation (photo: SIR, 2009)	
September 2009	The founding of the working group “Rehabilitation of Strubergassensiedlung”	

October 2009	Start of construction of Stadtwerk Lehen housing unit	
December 2009	Commissioning of the master plan study by Arch. Schulze-Darup from Nuremberg	
February 2010	Workshop on the framework parameters and definition of objectives	
April 2010	Presentation of the study to the responsible people in the city administration and politics	
Autumn 2010	Residents’ information and survey	
January 2011	The decision of the municipal council to refurbish 14 multi-family houses and to demolish and rebuild 12 residential buildings (photo: SIR, 2011)	
February 2011	Start of the information and the resettlement of the residents in stages	
November 2011	Handover and settlement of the flats in the “Stadtwerk Lehen”	
December 2011	Establishment of the steering group to coordinate the various project stages and construction measures (photo: SIR, 2011)	
Spring 2012 – Summer 2013	Renovation of residential buildings in the Strubergasse (façade insulation and new windows, insulation of top floor ceiling, new balconies, connection to the district heating system) (photo: SIR, 2012)	
Summer 2012	Architectural competition for part A of the newly constructed buildings (photo: GSWB, 2012)	

Autumn 2012	Architectural competition for parts B and F (photo: GSWB, 2012)	
April 2013	Start of the demolition of part A (photo: SIR, 2013)	
June 2013	Starting the construction of part A of the new buildings	
Spring 2014	Start of the demolition of 3 buildings of part B	
February 2014	The decision of the municipal council on the concept to create open space and also on the budget for the project	
June 2014	Ground-breaking ceremony for part B (photo: SIR, 2014)	
	Starting the construction of part B of the new buildings	
September 2015	Handover of 111 new subsidized rental apartments in building A (photo: GSWB, 2015)	
December 2015	Handover of 108 new subsidized rental apartments in building B	
Autumn 2015	Beginning of the demolition of three buildings of part F (photo: SIR, 2015)	
January 2016	Starting the new construction of part B	
December 2016	Handover of 65 new subsidized rental apart-ments of part F	

March 2017	Starting the construction of the new open space (photo: SIR, 2017)	
May 2017	Starting the new construction of part I	
June 2017	Completion of open space	
September 2017	Settlement festival for the inhabitants	
October 2017	Handover of 23 rental apartments in section G	
Autumn 2018	Handover of 43 rental apartments of part I	

Resources available before the project

There is no information available.

Drivers and barriers (opponents)

Main drivers: Undoubtedly, the "Green Solar City" project, supported by the EU's CONCERTO funding programme, was the driving force behind the renovation offensive and kick-started the process that was difficult in the beginning due to the political differences at the time.

Main opponents: Political differences occurred because of the social aspect: "Would a renovation be considered a gentrification process?" Media exposure had negative impacts, and voices against the project were formulated (partly within politics, partly from inhabitants).

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision-maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	City of Salzburg Municipal Department MA 05	Decision-maker	Renovation of existing housing stock
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	Non-profit building association GSWB and Bausparerheim	Influencer	Construction of new housing as their business model
District-related actors (Community/occupants organizations, etc.)	Rosemarie Fuchshofer "StadtLandBerg"	Influencer	Social science support of process
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	Salzburg AG	Technical advisor	Supplier of energy services; supplier district heating
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Schulze Darup & Partner, Nürnberg Housing Office City of Salzburg Architect Aicher	Technical advisor Influencer Technical advisor	Development of framework plan Keeping Social dimension, "gentle" refurbishment Open space concept
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	SIR – Salzburger Institut für Raumordnung und Wohnen	Advisor and project developer; Scientific Partner	Improve the quality of the district

Design approach:

The design approach followed was the "Open and Green Space Concept".

Technical issues:

There is no information available.

Financing issues:

Costs and financing concept

For buildings from the post-war period, it is essential to check to what extent demolition and new construction represent an economically viable solution. In the development phase of this success story, very detailed estimations of the investment costs were made. **Table 5** shows an excerpt of the energy-related investment costs and the additional investment of the individual building components of renovation packages 2 and 3 (compared to renovation package 1) and the building services.

Table 5. Investment costs of different renovation scenarios.

	renovation package 1		renovation package 2 additional investment		renovation package 3 additional investment	
	[EUR]	[EUR / m²]	[EUR]	[EUR / m²]	[EUR]	[EUR / m²]
exterior wall	121,565	79.45	7,497	4.90	8,899	5.82
exterior wall to soil	1,954	1.28	118	0.08	118	0.08
top floor ceiling	32,719	21.38	2,809	1.84	2,929	1.91
basement ceiling	24,038	15.71	4,651	3.04	2,835	1.85
interior wall to un-heated	6,545	4.28	691	0.45	810	0.53
interior doors to un-heated	7,128	4.66	0	0.00	3,300	2.16
windows	98,206	64.19	6,799	4.44	15,109	9.87
exterior doors	5,856	3.83	0	0.00	2,768	1.81
thermal bridges	4,103	2.68	0	0.00	3,025	1.98
air tightness	5,049	3.30	400	0.26	200	0.13
ventilation	48,960	32.00	53,550	35.00	0	0.00
heating	159,970	104.56	-23,178	-15.15	-9,383	-6.13

Remarks: the mentioned Euro amounts are the gross values; Euro per m² refer to the m² of each building component.

For cost-effectiveness calculations, it is essential to consider the foreseeable overall life cycle of the buildings. "Cash Cows" in the housing industry are always buildings that were created sustainably at the time and can continue to be rented to a high standard even after the loan obligations expire. The same is the goal of renovation projects: to implement a sustainable master plan with a long-term economic viability assessment.

Policy framework conditions:

The support of the project "Green Solar City" by the EU's CONCERTO funding programme was the drive of the renovation and gave the impetus to initiate the process that was difficult in the beginning due to the political differences at the time.

Lessons learned/interesting findings

The renovation of 286 apartments and the demolition and new construction of another 350 apartments, including the implementation of a new, high-quality open space, shows a possible way to improvements of the housing quality for other existing city districts.

However, this requires a clear political decision and an integrative process of project development and project execution. In this integrative process, it is absolutely necessary to include also the tenants and the residents´ service points.

The goal must be the creation of an added value for both the residents and the society, and to significantly improve the living quality, the infrastructure including mobility, and the quality of its open spaces.

This example shows that the resettlement of the residents is indeed labour-intensive and tedious. But when applying an intelligent professional approach, as done in this example, even that is not a real problem.

In the city of Salzburg, several buildings would have to be upgraded in the following years to be ready for the future requirements of the housing market. This success story has shown how this is possible and should encourage stakeholders also to tackle larger projects.

3.2 Kildeparken, Aalborg (Denmark)

Country: **Denmark**

Name of city/municipality: **Aalborg**

Title of case study: **Kildeparken**

Period of the renovation: **2014 – 2020**

Author name(s): Jørgen Rose and Kirsten Engelund Thomsen
Author email(s): jro@sbi.aau.dk and ket@sbi.aau.dk

Link(s) to further project related information / publications, etc.:

Project homepage: www.kildeparken2020.dk (in Danish)

Schematic figure or aerial overview

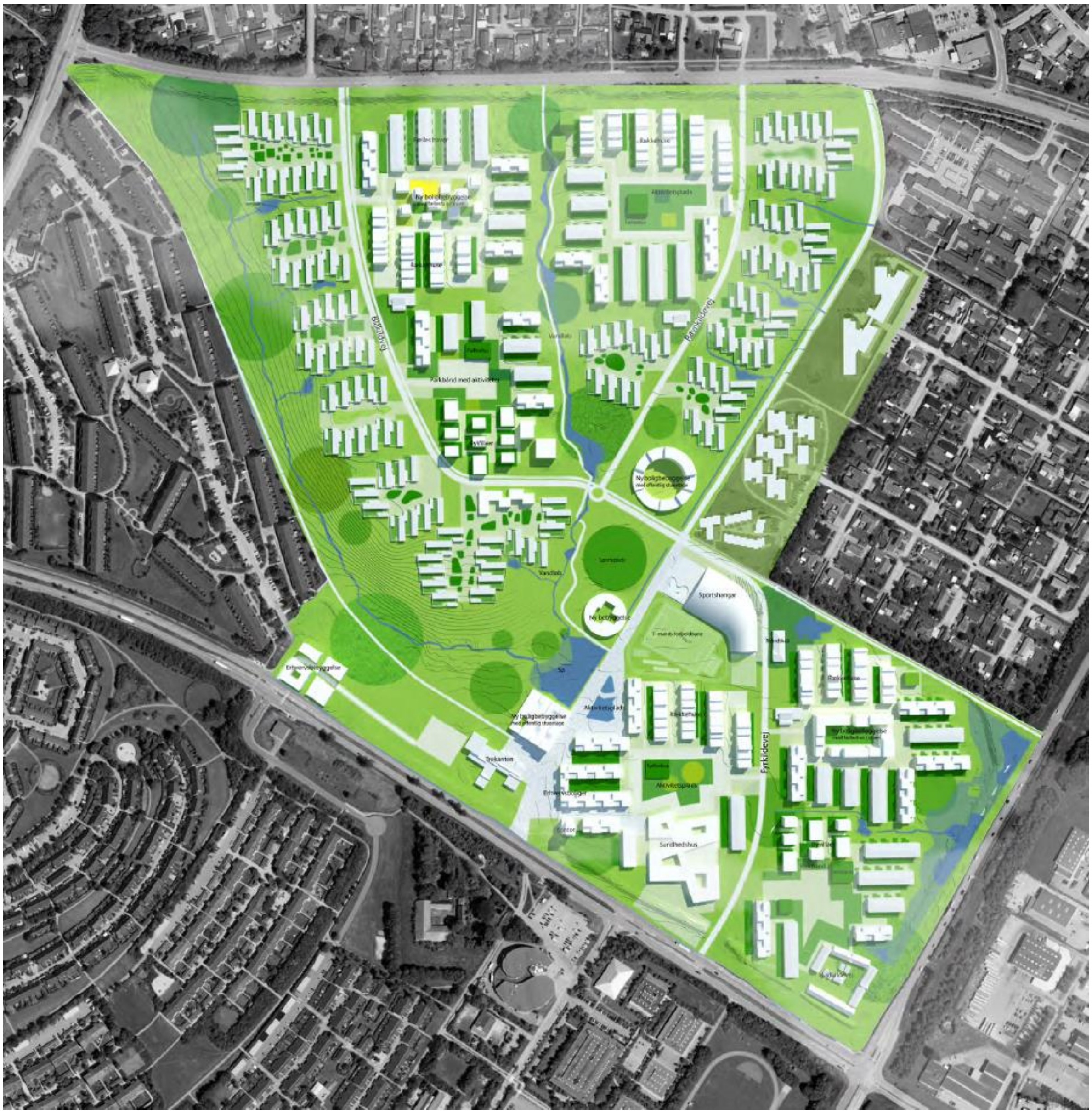

Figure 5. Schematic/aerial view of Kildeparken after renovation. Source: “Kildeparken. Foreløbig helhedsplan” from www.kildeparken2020.dk

Table 6. Main characteristics of the intervention.

	Before		After	
Number of dwellings, total	942	[-]	1,228	[-]
- **Apartment blocks**	792	[-]	594	[-]
- **Detached houses**	150	[-]	183	[-]
- **Tower blocks**	0	[-]	149	[-]
- **Terraced houses**	0	[-]	186	[-]
- **Roof apartments**	0	[-]	67	[-]
- **Other**	0	[-]	49	[-]
Heated floor area, total	96,446	[m^2]	119,886	[m^2]
- **Renovated**	96,446	[m^2]	97,274	[m^2]
- **New construction**	0	[m^2]	22,612	[m^2]

Introduction and description of the situation before the renovation

Kildeparken is a built-up area from the 1970s in Eastern Aalborg that consists of three clusters of buildings: Blåkildevej, Fyrkildevej, and Ravnkildevej. Before the renovation Kildeparken consisted of 792 apartment blocks and 150 detached houses (see Figure 5). One of the key features of the renovation was to transform some of the apartment blocks into different types of dwellings, i.e. terraced houses (Figure 6), and add roof apartments to some of the blocks. This makes the whole area less monotone and more attractive while offering a wider range of types of dwellings that may increase the diversity of inhabitants. The new buildings, i.e. the tower blocks, have different numbers of stories to create variation in the skyline.

Figure 6. Apartment block (left) and detached house (right) before renovation. Source: http://www.kildeparken2020.dk/

Kildeparken used to be on the so-called "Ghetto-list", meaning a neighbourhood struggling with problems like the high unemployment rate, high crime rate, etc. Therefore, the overarching aim of the renovation was to transform Kildeparken into an attractive and sustainable district and an integral and exciting part of Aalborg City.

Initially, Housing Association Himmerland's purpose was to develop a cooperation model for an energy partnership with Aalborg Municipality and Aalborg District Heating. The purpose of the energy partnership was to create synergy between energy optimization at the building and energy system levels towards the ideas behind "Smart Grid" systems. The energy partnership should point to concrete energy solutions so that Kildeparken would comply with the Building Regulation 2020 (BR20) standards after the renovation, while at the same time contributing to the sustainable conversion of the entire Aalborg East.

Unfortunately, it was not possible to establish a binding energy partnership with the energy supply and municipality despite several workshops and positive results of cooperation. Both Aalborg Municipality and Aalborg District Heating have contributed with relevant knowledge, and Aalborg District Heating promoted the renovation of the district heating pipes in Kildeparken as a result of the dialogue. However, a truly committed energy partnership was not achieved in which the parties cooperate, analyse, and decide common actions for the overall optimisation of the energy system in Aalborg East.

Description of the renovation goal

As mentioned, the renovation's overarching aim was to transform Kildeparken into an attractive and sustainable district and an integral and exciting part of Aalborg City.

Regarding energy, the goal of the renovation was to achieve an energy label corresponding to Renovation Class 2 according to the Danish building Regulations (BR18). This results in a primary energy consumption of approximately 71 kWh/m^2. It could be argued that this is not a very ambitious target. However, detailed calculations were performed showing that if the housing association had taken one step further, i.e. Renovation Class 1 (primary energy consumption of approximately 53 kWh/m^2), the distribution losses in the district heating network would account for more than 50% even if the temperature is lowered to 50 °C (temperature is typically 70-80 °C in Danish district heating systems). Therefore, the conclusion was to settle for Renovation Class 2 and focus on the distribution system instead.

Figure 7. Block of flats that has been converted into terraced houses. Source: http://www.kildeparken2020.dk/

The primary focus was on insulating the building envelope, i.e. heating and ventilation installations are replaced, but not significantly improved. However, analyses showed that further reducing the energy consumption (i.e., renovation class 1) was possible if the combined exhaust/natural ventilation was replaced by mechanical ventilation with heat recovery. This will be a possibility if further energy reductions are needed in the future.

Figure 8. Vision for Ravnkildevej. Source: D/K2 Building Consultants.

Description of the renovation concept

Before the renovation, Kildeparken consisted of 150 detached houses and 792 apartments in two-story apartment buildings. A number of new types of dwellings were added to diversify the area and make it more attractive to both existing and new residents.

The 33 detached houses, the so-called atrium houses, have been split into two dwellings, transforming them into smaller double houses. The apartment buildings were transformed in several different ways. Some buildings were extended with new roof apartments (67 apartments will be added), some of the smaller apartments were turned into youth apartments (37 apartments) and offices (12 apartments), and finally, some apartments were joined to form two-storey terraced houses (186 houses). The three neighbourhoods also have six new tower blocks with 149 apartments. The tower blocks have different heights to create a diverse and interesting skyline.

The new buildings (naturally) comply with the present Danish Building Regulations (BR18), meaning that the primary energy demand for heating, domestic hot water, and electricity for building operations is less than 30 kWh/m^2. The existing buildings were renovated to reach 70 kWh/m^2, which corresponds to approximately 50% of the energy use before renovation. Table 7 lists the U-values before/after the renovation.

Table 7. U-values in W/m^{2}K before and after renovation.

Terraced houses and apartments	U-value before	U-value after
Slab on the ground (wood/tiles)	0.28 / 0.50	0.28 / 0.50
Slab above basement (wood/tiles)	0.46 / 1.50	0.46 / 1.50
Façade (wall/balcony)	0.69	0.12 / 0.18
Gable	0.68	0.20
Roof, apartments	0.20	0.13
Roof, terraced houses (1st floor/2nd floor)	0.20	0.11 / 0.20
Windows	2.60	0.70 – 1.00
Detached houses		
Slab on the ground (wood/tiles)	0.31	0.09 / 0.12
Heavy wall, brick-brick / brick-light façade	0.44	0.16 / 0.17
Light wall	0.42	0.17
Roof	0.19	0.12
Windows	2.60	0.70 – 1.00

Ventilation with heat recovery was not installed in the existing buildings but can be added later, whereby the buildings will improve one level in the energy labelling system (A2010, renovation class 1). For now, demand-controlled exhaust ventilation is used in combination with natural ventilation.

The district heating supply to Kildeparken was not energy efficient, so the local system was renovated. The sustainable future scenario for the energy system in North Jutland is low-temperature district heating and renewable energy. Therefore, all radiators were replaced with high-capacity versions so that they can supply adequate heating when the district heating temperature is lowered.

No renewable energy was installed. The thought is that renewable energy should be supplied through the district heating network to avoid sub-optimisation.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	540,000	540,000
Population in the area:	-	2,450	2,950
Number of buildings in the area	-	942	1,228
Heated floor area of all buildings	m²	96,446	119,886
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	15.9	30.1
Multi-family homes (MFH) - up to three stories and/or 8 flats	% of heated floor area of all buildings	84.1	56.8
Apartment blocks (AB) - more than 8 flats	% of heated floor area of all buildings	0	12.1
Schools	% of heated floor area of all buildings	0	0
Office buildings	% of heated floor area of all buildings	0	1.0
Production hall, industrial building	% of heated floor area of all buildings	0	0
Other (ground floor area spaces)	% of heated floor area of all buildings	0	0
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	100	100
Medium consumers: AB, schools, etc. – 80-800 MWh/a	% of annual heat demand	0	0
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a	% of annual heat demand	0	0
Property situation of buildings:			
Private	% of heated floor area	0	0
Public	% of heated floor area	100	100
Property situation of energy supply system (district heating):			
Private	% of heated floor area	0	0
Public	% of heated floor area	100	100

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Energy use (primary energy)			
Apartment blocks	kWh/m²a	140	70
Detached houses	kWh/m²a	140	70
Tower blocks	kWh/m²a	-	30
Terraced houses	kWh/m²a	-	70
Roof apartments	kWh/m²a	-	30
Heating demand (calculated)	kWh/m²a	Not available	Not available
Domestic hot water demand (calculated)	kWh/m²a	Not available	Not available
Cooling demand (calculated)	kWh/m²a	Not available	Not available
Electricity demand (calculated)	kWh/m²a	Not available	Not available
Heating consumption (measured)	kWh/m²a	133 [1]	68 [2]
Domestic hot water consumption (measured)	kWh/m²a	52 [1]	23 [2]
Cooling consumption (measured)	kWh/m²a	0	0
Electricity consumption (measured)	kWh/m²a	Not available	Not available
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	-	-
***Decentralised* biomass boilers**	% of heated floor area	-	-
***Decentralised* heat pumps**	% of heated floor area	-	-
Centralised (district heating)	% of heated floor area	100	100
other *(please specify)*		-	-
renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	kW_p	0	0
Other (please specify)	kW	0	0

[1] Measured average consumption for all buildings.
[2] Measured average consumption for first buildings renovated.

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	-	Not known
- **building envelope renovation costs**	Euro/m²	-	Not known
- **heating/cooling supply costs**	Euro/m²	-	Not known
- **renewable energy production costs**	Euro/m²	-	0.00
LCC available	yes/no		no

Description of the technical highlights and innovative approaches

The overarching goal for the housing association was to develop a collaboration model for an energy partnership between housing organizations, municipalities, and an energy company. The purpose of the energy partnership was to create synergy between energy optimization at the building level and at the energy system level towards the ideas behind "Smart Grid" systems. The energy partnership should have also pointed to concrete energy solutions so that Kildeparken as a residential area could achieve compliance with BR20 regulations while contributing to an overall sustainable conversion of Aalborg East.

When Himmerland and the Danish Building Research Institute formulated the original pilot project in 2012, the goal was to establish an energy partnership with the municipality and district heating company and achieve BR20 requirements in the renovation of the Kildeparken under the heading "Smart Grid 2020". At the end of the pilot project in 2016, no committing partnership was established with the district heating company, Kildeparken was renovated to a lower standard, and the Smart Grid perspective was dimmed. The reasons for these changes are explained throughout this study and show an example of how focus and goals can change and shift during a project's lifetime.

The partnership was not a total success, but it helped make complex issues more tangible and created concrete positive results in the renovation case. Himmerland Housing Association and partners have:

- analysed questions about the development of the energy system and the role of the buildings in a future sustainable energy system
- analysed the balance between energy efficiency targets in buildings and the energy system in Aalborg East, in order to identify an appropriate renovation goal in balance with the energy system
- formulated a holistic energy renovation strategy for Kildeparken based on analysis and collection of knowledge about all sub-elements of an energy renovation
- inspired Himmerland's work to strengthen its role as a city developer in Aalborg East and create synergy between the renovation of Kildeparken and the sustainable transition of the entire Aalborg East
- given operational input to Himmerland's work on formulating a new sustainability policy in the organization in dialogue with the resident's democracy
- provided sparring to Himmerland's analysis of the energy-saving potential in the housing association's building stock that has formulated a roadmap for realizing this savings potential in the period up to 2030

The original goal for Kildeparken of achieving the BR20 standard was not fulfilled and instead, the buildings have achieved renovation class 2 as explained earlier. From a holistic perspective, this was the optimal solution since losses in the district heating system should match losses at the building level first, i.e. the district heating system should supply lower-temperature heating with fewer system losses. Therefore, the goal of finding an energy renovation level in reasonable balance with the heating system was successful.

Decision and design process

Knowledge partnership / Stakeholder involvement

As already described, the goal for the housing association was to develop a collaboration model for an energy partnership between the housing association, municipality, and energy company. The purpose of this energy partnership would have been to involve all the different stakeholders to ensure synergy between energy optimization at the building level and the energy system level. The thought was that the energy partnership would thereby benefit all the stakeholders.

More than energy

Himmerland Housing Association does not just focus on energy savings. They want to achieve three overarching sustainability goals:

- Social sustainability: Himmerland creates quality of life and space for everyone
- Environmental sustainability: Himmerland is at the forefront of the sustainable transition of the built environment
- Economic sustainability: Himmerland creates contemporary housing with a fine balance between price and quality

These goals have been defined further in the company sustainability policy.

Sustainability policy

Himmerland Housing Association has formulated a new sustainability policy as a result of the knowledge partnership and work on the "smart solutions" in Aalborg East. The foundation of the sustainability policy is a strategy for energy renovation, where the total energy consumption in 2030 - heating and building-related electricity – is reduced by 30% of the measured consumption in 2014. The year 2030 was chosen to harmonize goals with the national goals regarding energy consumption and carbon emissions.

The goal will be achieved by the following measures:

- energy savings are regularly carried out in the daily operation with measures that have a payback time of 5 years or less
- most of the housing organization's dwellings are renovated within the period
- measures are implemented that affect the residents' energy behaviour in a positive direction
- energy initiatives are largely implemented in cooperation/partnership with the municipality of Aalborg and the energy companies
- annual evaluation of the development and a following revision of strategy and continuous development of "smart solutions", that can lead to the ultimate goal being achieved
- energy initiatives are assessed based on Himmerland's sustainability policy, where they basically must have a positive or neutral effect in relation to a broad definition of sustainability

The content of the policy is formulated and developed further in the knowledge partnership, but also in workshops with employees in the housing association and dialogue with the occupant democracies.

Figure 9. Picture from the master plan Kildeparken 2020. Source: Himmerland Housing Association.

Himmerland's sustainability policy covers all three branches of the broad sustainability concept. Therefore, an initiative that aims to improve the energy efficiency of a dwelling must, at the same time, be socially and economically balanced.

The sustainability policy includes visions, strategic benchmarks, and a project catalogue. All concrete measures must be assessed based on the three branches of the policy: social sustainability, environmental sustainability, and economic sustainability.

Screening process

As already described, it is an important element in Himmerland sustainability policy that the measured building-related energy consumption in the total housing stock is reduced by 30% from the baseline in 2014 until 2030. Therefore, the housing association has thoroughly screened all their buildings to establish the individual savings potential of the different types of dwellings. The initial step was to determine the baseline, i.e., the total energy consumption, to determine the total necessary savings to achieve an overall 30% savings. Table 8 shows the total savings required to achieve the goal, i.e., 12,312 MWh primary energy.

Table 8. Measured total energy consumption for Himmerland Housing Associations' complete building portfolio and necessary reduction to achieve the overarching goal.

Area (m^2)	Measured heating consumption (kWh/m^2)	Measured electricity consumption (kWh/m^2)	Corrected total energy consumption (kWh/m^2)	Savings (%)	Savings (MWh)
Baseline 2014					
460,758	108.6	8.3	86.7		
Goal 2030					
460,758	74.9	6.2	60.7	30.0	12,312

The corrected total energy consumption (in Table 8) has been corrected for heating degree-days and heating and electricity are multiplied by the primary energy factors (i.e., 0.6 for district heating and 1.8 for electricity according to BR15).

Table 9 shows an example of a specific building type (prefabricated concrete buildings erected from 1965-1980 – see Figure 10). These types of buildings constitute 28.3% of the housing association's total building portfolio and a large part of Kildeparken.

Figure 10. Typical prefabricated concrete building. Source: http://www.kildeparken2020.dk/

Table 9. Measured total energy consumption for Himmerland Housing Association’s prefabricated concrete buildings and necessary reduction to achieve the overarching goal.

Area (m^2)	Measured heating consumption (kWh/m^2)	Measured electricity consumption (kWh/m^2)	Corrected total energy consumption (kWh/m^2)	Savings (%)	Savings (MWh)
Baseline 2014					
460,758	140.2	6.4	104.1		
Goal 2030					
460,758	65.0	4.0	50.1	51.9	7,046

As shown in Table 9, these types of buildings have a large saving potential of approx. 52%.

Further analysis

In addition to the energy savings screening process, Himmerland has initiated several analyses to determine the best possible way to move forward. The analyses cover a wide range of aspects, including the possibilities of:

- islanding as an alternative to integrating into the existing energy system
- including renewable energy systems as part of the renovation
- moving towards low-temperature district heating

In addition to this, the renovation of Kildeparken naturally covers a wide range of non-energy related measures e.g. traffic, mobility, roads, landscaping, rainwater use, climate change adaptation, etc.

The renovation of Kildeparken is divided into three separate projects corresponding to the three clusters of buildings, Blåkildevej, Fyrkildevej, and Ravnkildevej. This means that three different consortiums will deliver different solutions to the total renovation, making Kildeparken a more diverse and interesting area.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Aalborg Municipality		Integration of Kildeparken in Aalborg East
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	Himmerland Housing Association	Owner (decision maker)	Improved dwellings and surroundings, increase the quality of life for tenants
District-related actors (Community/occupants organizations, etc.)	Tenants' democracy	Tenants (influencers)	Improved dwellings and surroundings at a reasonable increase in rent
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	Aalborg District Heating	Energy supplier (delivery)	Integration of Kildeparken in the existing energy supply network
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Three consortiums. See list below	Architects and consultants, landscape, traffic, etc. (technical advisors)	No special motivation
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	Aalborg University, Danish Building Research Institute, COWI, Kuben Management	Advisors, consultants, etc. (technical advisors)	No special motivation

Three different consortiums were chosen to perform the renovation of the three neighbourhoods (Fyrkildevej, Blaakildevej, and Ravnkildevej):

Fyrkildevej:

Architect: Aarhus Arkitekterne A/S
Architect: Arkitekterne Bjørk & Maigård ApS
Consultant: Brix & Kamp Rådgivende Ingeniører A/S

Blaakildevej:

Architect: KPF Arkitekter A/S (now ERIK Arkitekter A/S)
Landscape architect: Preben Skaarup
Consultant: Viggo Madsen A/S
Traffic consultant: Via Trafik Rådgivning A/S

Ravnkildevej:

Architect/Consultant: Kærsgaard & Andersen A/S
Architect: EFFEKT Arkitekter ApS
Urban development/Consultant: SLA A/S

Financing issues:

Information not available.

Lessons learned/interesting findings

Balancing energy efficiency targets in buildings with the energy system

It is a central energy policy goal that Denmark's energy supply will be fossil-free in 2050. Housing Association Himmerland's first question was, therefore: is it smart to seek to integrate the building renovation into the existing energy structure, or can we get closer to the goal by choosing an independent supply system in the end? For example, should the housing organization set up a wind turbine combined with other renewable energy sources in an attempt to become completely self-sufficient and disconnected from the local energy system?

The answer is “no”. The analysis made for Denmark shows that it is not socio-economic rational to have "island operations" (self-sufficiency based on renewable energy) everywhere. Doing this leads to an over-investment in infrastructure. Energy systems must be connected, and local VE production must be integrated into the existing energy system. For Aalborg East, which is located in an efficient district heating area, the premise is that the long-term 2050 scenario is a low-temperature district heating solution plus supplementary renewable energy sources. To work positively together with a future energy supply system (based on 100% renewable energy by 2050), energy-saving measures in buildings should reduce the energy requirement in these buildings by 50% on average in the period 2030 - 2050.

Therefore, Kildeparken should not be disconnected from the energy system with its own renewable energy sources but integrated into the existing district heating system.

The district heating supply to Kildeparken was not energy efficient as a starting point (in 2013). Only two "plugs" were in the area, and the housing association handled the remaining distribution. As a consequence of the dialogue in the energy partnership, the modernization of the district heating network in Kildeparken was advanced, and the system is today renovated.

The sustainable future scenario for the energy system in North Jutland is low-temperature district heating and renewable energy. Therefore, as part of the refurbishment of Kildeparken, Himmerland has chosen to install radiators with a capacity that considers a future low-temperature model. The district heating system in Aalborg East cannot immediately be converted into a low-temperature solution, i.e. parts of the system are dependent on high temperature. These issues are expected to be addressed in a future trial project. The project will investigate how smaller local areas can be converted to low-temperature areas using mixing loops when moving from the large system to the individual areas. Unfortunately, Himmerland's original ambition to establish a binding partnership with the Aalborg District Heating Association for joint analysis and development of the housing role in a more integrated energy system has not been realised. One explanation may be that the central investments must take place in the district heating system (low-temperature VE future). The primary role of general housing in such a transition is to reduce total energy consumption by 50% by 2050.

References

The information given in this case study description is based on two primary sources:

1. "Kildeparken. Foreløbig helhedsplan" from www.kildeparken2020.dk
2. Engberg, L. A. and Buch, S., "Bæredygtighed og Smarte Løsninger i Aalborg Øst – Himmerland Boligforenings Erfaringer med Bæredygtighed i Praksis", SBi 2016:28, Danish Building Research Institute, Aalborg University, 2016.

3.3 Quartiere Giardino, Modena (Italy)

This success story is not an example of best practice in terms of cost-effective implementation of building renovation and renewables. It was implemented in the 1970s and only focused on the energy system while no measure related to building renovation has been performed. Nevertheless, it may be relevant to other similar interventions.

Country: **Italy**

Name of city/municipality: **Modena**

Title of case study: **Quartiere Giardino in Modena**

Period of the renovation: **1970 - nowadays**

Author name(s): L. Teso, T. Dalla Mora, F. Peron, P. Romagnoni
Author email(s): tdallamora@iuav.it
Link(s) to further project related information / publications, etc.:

Schematic figure or aerial overview

Figure 11. Location of Villaggio Giardino (red square) in Modena. Source: edited by the authors, based on "Google Image" by Google n.d.

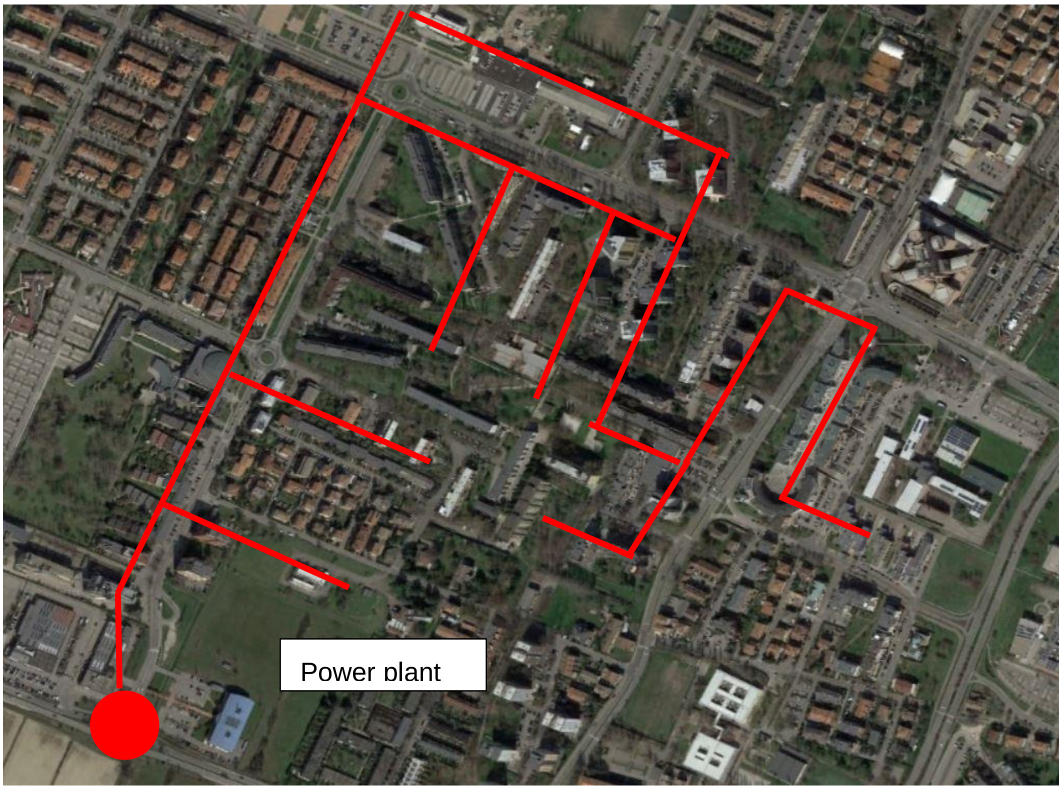

Figure 12. Extension of the district heating network in the considered area. Source: edited by the authors, based on "Google Image" by Google n.d.

Introduction and description of the situation before the renovation

The area called "Villaggio Giardino" (garden Village in English) is a part of the south district of Modena. The housing complexes in the area are immersed in a vast green area, as designed in the urban plan, starting from a nearby park and extending south. Some buildings of the "village", in particular those of the northern sector, are built by the IACP (public housing association), while private individuals build others under a contracted building scheme. The residential blocks are arranged freely in the lots in groups of bodies perpendicular to each other. The linear block is the most commonly used typological scheme, with considerable long plans and limited height. In some parts of the Village, this scheme is interrupted by higher buildings.

The apartment complexes in the area were built between 1950 and 1970 due to a high request for housing across Italy. At this time, the most used construction system for residential buildings was masonry walls; the stratigraphies of the façade in the linear typology reflect this trend. From the exterior side, these walls are composed of external plaster, two masonry structures with an air layer in between, and internal plaster. For this kind of building, the heating demand is satisfied by employing individual boilers fired up mostly using natural gas. Tower buildings, on the other hand, present a reinforced concrete structure with masonry infill walls without external plaster. In this case, the heating demand is satisfied with a central boiler that also uses natural gas. In both cases, the cooling supply is granted by the installation of single-unit air conditioning systems, but not all apartments are equipped with this technology.

In the considered example, all buildings are apartments, the property is mixed between the municipality and private owners for a total heated floor area of about 147,000 m^2.

Description of the renovation goal

In the 1970s the administration of the city of Modena wanted to modernize the housing stock and give the city's urban context a higher value. For that reason, the local administrator decided to build a district heating network to minimize energy consumption and harmful emissions from using individual heating devices in the apartments and maximize the energy savings a district network can offer. The basic idea of this project was to connect to the heating network residential buildings specifically built by the municipality to help families that could not afford private accommodation.

Moreover, since the district is immersed in a green area and open spaces already have good quality and livability, the administrators aimed to increase the quality of living even for less fortunate families and create an attractive environment for private investors as well.

The city administration stated that the project's main objective was to maximise the use of a single central system in place of private heating devices to achieve useful energy savings for the entire city. The project was developed in urban areas where this change in the heating system would significantly reduce energy consumption and harmful emissions, optimise energy use, and have a smaller impact on families' income.

Description of the renovation concept

The buildings in "Villaggio Giardino", owned by both municipality and private entities, were improved through the following measures:

- Construction of a district heating network and connection to the existing buildings. The network is still powered by a cogeneration plant consisting of 3 gas engines producing 3,660 thermal MW and 3,600 electrical MW. The municipality is planning the construction of a waste incinerator to connect to the district, but the works are not yet started.

- Since the old apartments were still running on single heating devices, these systems were changed by connecting the buildings to the network and switching from individual systems to a modern central heating system. Supply lines were laid to each apartment complex.

The city administrators didn't plan any action concerning retrofit measures for the thermal renovation of the municipality-owned buildings. The situation is similar for privately owned buildings: no plan for envelope renovation was considered during the work or the laying of the district heating network.

Table 10 shows the U-values of the two typologies of existing buildings (on average).

Table 10. U-values in W/m^{2}K and type of ventilation before the renovation.

Component	U-value [W/m²K]	
	Line buildings	Tower buildings
exterior wall	1.76	1.10
ceiling to cellar	2.48	1.56
ceiling to attic	1.80	1.80
roof	1.79	1.46
windows	2.8	2.8
ventilation	Natural	Natural

In **Figure 13**, it is possible to see the increase in the volume reached by the district heating network starting from the year 2000 and the thermal energy delivered for heating and domestic hot water. The decrease in the energy supplied can be explained by an increase in the renovation rate of the Italian building stock regarding envelope insulation and heating systems improvement.

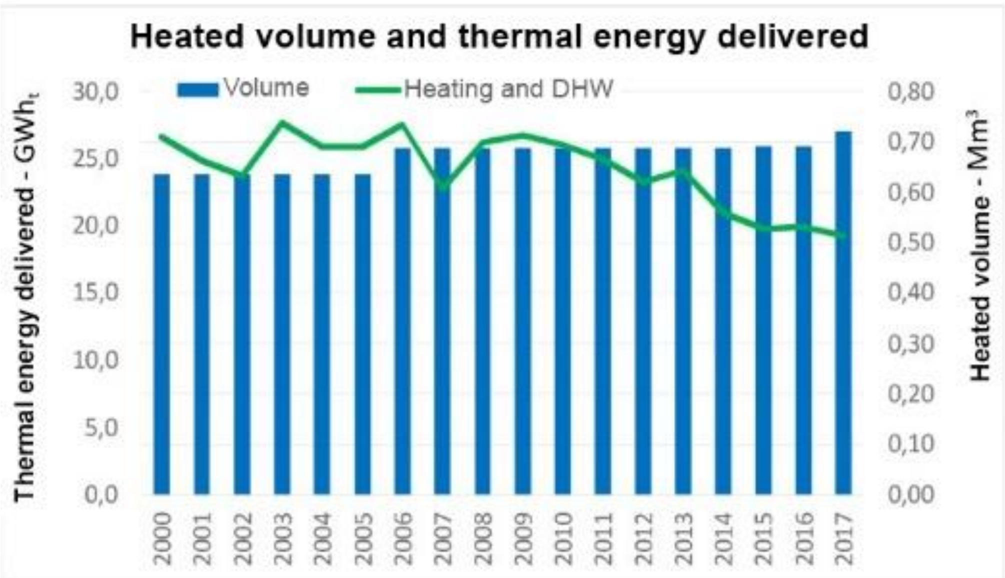

Figure 13. Thermal energy supplied to users in GWht for heating and DHW (green line) and volume of housing heated by DH in Mm^3 (blue columns) from the years 2000 to 2017. Source: edited by the authors, based on "Annuario il Riscaldamento Urbano 2018" report by AIRU.

The next two graphs (Figure 14) depict the situation before and after the construction of the district heating network (TLR=teleriscaldmento, Italian word for district heating network) in terms of fossil energy consumption and carbon emissions.

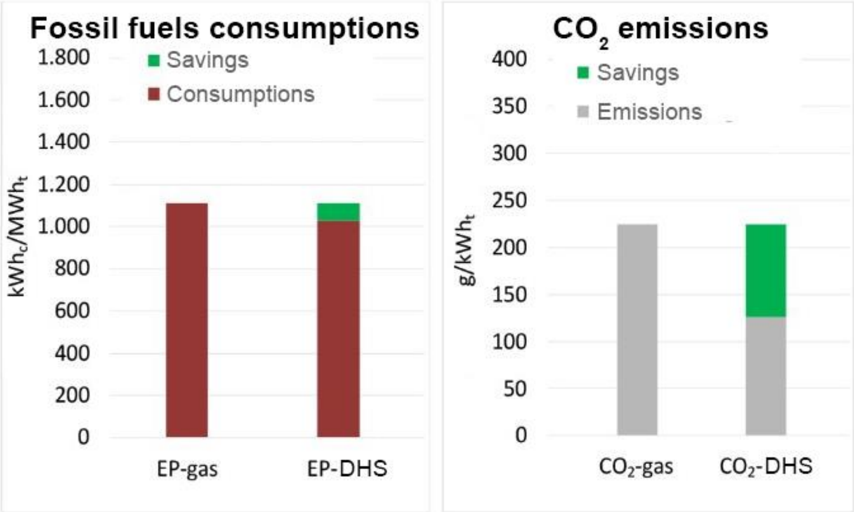

Figure 14. Left: comparison in fossil fuel consumption (brown column) before and after the installation of the DH system (in the second column the green part represents the savings in fossil energy consumption due to the switching from individual systems to a district heating system). Right: comparison in carbon emissions (grey column) before and after the installation of the DH system (in the second column the green part represents the savings in carbon emissions due to the switching from individual systems to a district heating system). Source: edited by the authors, based on "Annuario il Riscaldamento Urbano 2018" report by AIRU.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	-	-
Population in the area:	-	10,000 (1,500 users)	10,000 (1,500 users)
Number of buildings in the area	-	2,586 apartments	2,586 apartments
Heated floor area of all buildings	m²	147,000 c.a.	147,000 c.a.

Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	-	77%
Multi-family homes (MFH) - up to three stories and/or 8 flats		-	
Apartment blocks (AB) - more than 8 flats		-	
Schools		-	23%
Office buildings		-	
Production hall, industrial building		-	-
Other (ground floor area spaces)		-	-

Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	unknown	unknown
Medium consumers: AB, schools, etc. – 80-800 MWh/a		unknown	unknown
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		unknown	unknown

Property situation of buildings:			
Private	% of heated floor area	~50	~50
Public		~50	~50

Property situation of energy supply system (district heating):			
Private	% of heated floor area	100	0
Public		0	100

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	-	-
Domestic hot water demand (calculated)	kWh/m²a	-	-
Cooling demand (calculated)	kWh/m²a	-	-
Electricity demand (calculated)	kWh/m²a	-	-
Heating consumption (measured)	kWh/m²a	Unknown	21.3MW/11,430MWh/a
Domestic hot water consumption (calculated)	kWh/m²a	included in the heating consumption	included in the heating consumption
Cooling consumption (measured)	kWh/m²a	-	-
Electricity consumption (measured)	kWh/m²a	-	-
(Thermal) energy supply technologies:			
Decentralised **oil or gas boilers**	% of heated floor area	100	0
Decentralised **biomass boilers**	% of heated floor area	-	-
Decentralised **heat pumps**	% of heated floor area	-	-
Centralised (district heating)	% of heated floor area	0	100
Other *(please specify)*		-	-
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	kW_p	0	0
Other (please specify)	kW	0	0

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	€ 2,000,000 for network renovation and cogeneration plant	
- **building envelope renovation costs**	Euro/m²	-	-
- **heating/cooling supply costs**	Euro/m²	-	-
- **renewable energy production costs**	Euro/m²	-	-
LCC available	yes/no	no	no

Description of the technical highlight(s) and innovative approach(es)

The main highlight in the experience of the district heating of Modena is the innovation that was brought into the Italian energy sector in the 1970s. It is the first example of such a technology implemented in the country and has always been watched as an example.

Once the system was built by the municipality, it was handed over from the administration to a company with the technological resources and right know-how for the expansion and optimization of the network: the owner of the district system is still the municipality, but the use of the network is very cheap for the company making possible for them to keep the prices low for their clients and, at the same time, making a profit with the selling of the energy to the connected households.

This particular type of partnership between public entities and private companies is nowadays commonly used for important public works. In the case of Villaggio Giardino's district heating, the partnership is working since 1970, meaning that is a feasible solution for district renovation works.

Decision and design process

General/organizational issues:

The main highlight in the experience of the district heating of Modena is the approach that led to the creation of the heating network. The process started from the willingness of the city municipality to give a better quality of life for the people living in social accommodation. This decision was made following the consideration that a district heating network could help reduce the energy needed for the heating and the production of DHW, thus helping needy people and, at the same time, reducing the utilization of individual systems for heating, reducing hazardous emissions. With these two main reasons, a series of other considerations came in support of the construction of the network, such as the risk reduction for gas leaking and explosions, avoidance of costs for the users linked to chimneys, maintenance and periodic control on the heating device, the ease in installing new parts in the event of reconversion to different primary energy source, among others.

The intervention was performed to meet the sustainability goals planned by Modena municipality. The city wanted to start a renovation process starting from municipal-owned buildings to set an example and to produce and distribute heating and domestic hot water to users with the least possible carbon and pollutant emissions.

Stakeholders involved

The stakeholders that made the intervention possible were mainly two: the administrators of Modena, who in 1970 decided to build a DH and entrust the management to AMCM (a municipal utility for public services, the second stakeholder), later bought by Hera group and the AMCM itself.

Main steps

Since the project was supported by the municipality with the use of public funds, one of the most important steps was the initial decision to build this district heating system to improve the living condition of the people in the area and be an example to be replicated by private owners. After that step, the use of technical know-how for the implementation of the project and, in the end, entrusting a dedicated agency to run the network.

Resources available before the project

Before the project, buildings were served by individual boilers. The only resources available were public funds reserved by the municipality for renovation works of the housing stock owned by the municipality. Other than merely economic resources, knowing how to implement such a process was in the hands of the company that the municipality used for this kind of renovation.

Drivers and barriers (opponents)

One of the most critical drivers for this project was the initial interest shown by the municipality in investing in such a system. The entire investment was carried out with the use of public money. Only after the works ended was the system given to an external society to administrate it and expand it during its life. Some barriers were encountered by the residents of the area since these measures were top-down decisions taken without a participatory planning stage.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Municipality	Decision maker	Savings, carbon reduction, quality of living improvement
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	Municipal housing association	Influencer	Savings, standards improvement
District-related actors (Community/occupants organizations, etc.)	Households occupants (not included in the process)	Influencer	Savings, standards improvement
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	ESCO	Decision maker/delivery	Profit, experience, fame
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	ESCO	Technical advisor	
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	Dedicated agency	Technical advisor	

Design approach:

The installed systems are capable of satisfying the heating needs of the whole connected area. Even if the energy is produced with non-renewable energy sources (natural gas), there are energy savings and reductions in carbon emissions. This is possible thanks to optimal work done during the design phases: the working teams carried out the project for the detailed design of the piping systems and the dimensioning of the three engines, to answer the community's needs.

Technical issues:

The main challenges related to the project's technical implementation were related to the pipe lying in an already consolidated environment and the difficulties in finding the right place for the power plant.

Financing issues:

To guarantee the growth of the households connected to the district heating and to ensure a unified and stable strategy, the municipality decided to stop the incentives for the old boiler substitution in the area where the district heating network was already in place. The private company that manages the network is interested in an economic return on the investment, so households pay a price a little higher than the price for energy production, but it offers discounts of up to 25% for the connection of the buildings to the network. The society that manages the DH system guarantees annual savings between 5 and 10% compared to individual heating systems.

Management issues:

There was no particular challenging situation while dealing with project management.

Policy framework conditions:

The municipality was driving the process. One of the most important aspects was the initial interest shown by the municipality in investing in such a system. The entire investment was carried out with the use of public money. Only after the works ended was the system given to an external society to administrate it and expand it during its life.

Lessons learned/interesting findings

With district heating, it is possible to eliminate the costs for the construction of the flues and the purchase and maintenance costs of the boiler and its revision, verification, and cleaning. The district heating service is proposed to users with central heating and new buildings or renovations. The current legislation makes the district heating a convenient solution since the energy is sold at the production price and incentives for personal boilers are no longer granted. Given the absence of combustion, installation, and maintenance interventions are simplified and for the end users, district heating is cheaper than the other available energy vectors. The increase in oil prices in recent years makes district heating and independence from fossil energy imports very interesting economically.

From this experience, we can see an increase in the comfort perceived by the inhabitants in their houses and a parallel increase in the quality of life in municipal housing thanks to good project planning and better management of heating and DHW needs.

The municipality of Modena sets a good example of the whole planning process, including the decision and support of the investments that had to be carried out to realise a district network. Moreover, since a private company is now managing the district heating, it is in their interest to satisfy the customers to increase the connections to the network and not create a situation that may cause losses to the company. In this way, the municipality does not need to focus on managing the network, the inhabitants improve their living conditions, and the private company is earning money that they reinvest in the network for its maintenance and expansion.

3.4 Sangallo, ALER-Varese (Italy)

Country: **Italy**

Name of city/municipality: **Varese**

Title of case study: **Sangallo, ALER-Varese**

Period of the renovation: **2015, 1 year**

Author name(s): Giuliano Dall'Ò, Simone Ferrari, Federica Zagarella
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Link(s) to further project related information / publications, etc.:https://www.alervarese.com/home/patrimonio-interventi/nuove-costruzioni-recuperi-demolizioni.html (in Italian)

Schematic figure or aerial overview

The area of intervention is shown in **Figure 15** and **Figure 16**.

Figure 15. Map of Quartiere Sangallo district with the renovated buildings highlighted. Source: ALER- Varese.

Figure 16. Satellite view of Quartiere Sangallo district with the renovated buildings highlighted. Source: ALER-Varese.

Table 11. Main features of the study area.

	Quartiere Sangallo	Renovated buildings
Buildings heated area [m²]	23,257.96	3,661.32
Number of building units	235	48
Buildings use category	Residential	
Buildings' owner	ALER Varese – Como – Monza Brianza – Busto Arsizio	

Introduction and description of the situation before the renovation

Quartiere Sangallo is a social housing district in the city of Varese (north Italy) owned by ALER (i.e. Lombardy Company for Residential Buildings) - Varese (i.e. for the territorial sectors of Varese, Como, Monza-Brianza, and Busto Arsizio). It consists of 24 residential buildings, including detached houses, multi-family homes, apartment blocks, and towers, while a building has a commercial ground floor.

Buildings have been built between the end of the 1960s and early 1970s and, as usual in that period, have a reinforced concrete bearing structure. All of them are over a basement (garage), except for building Bb, which is over pilotis (piers).

Buildings' envelope

Buildings have poor-quality envelopes, featured by high thermal transmittance values. Also, several thermal bridges are revealed, mainly in the structure nodes and windows. Buildings are characterized by: uninsulated external walls made of hollow bricks and air cavities, floors made of concrete slabs with clay bricks, single-glazed windows with wooden frames, and uninsulated wooden shutter boxes.

Systems

Regarding the space heating energy supply, 23 buildings are connected to a district heating (DH) network, which is fed by 3 recently installed heat generators (total capacity 3.9 MW), each one made of 2 condensing gas-boilers, while one building (i.e. Dg) has an individual heat generator on the roof. Due to the local orography, the DH network is split into 2 branches having 2 plate heat exchangers (1.8 and 1.5 MW, respectively) linking the primary with the secondary distribution networks. System regulation is accomplished through a climatic compensation sensor within the thermal power plant. Within buildings, the distribution system comprises uninsulated vertical raiser pipes, while the emission system comprises cast iron radiators.

Regarding the Domestic Hot Water (DHW) energy supply, individual electric boilers are installed in all buildings.

Figure 17. Left: Satellite view of the thermal power plant. Right: Thermal power plant. Source: ALER- Varese.

Description of the renovation goal

The project aims are the reduction of energy consumption and, subsequently, of the related carbon emissions, through measures for increasing the regulation and distribution efficiencies of the heating system and, in particular, focusing on major energy renovation of 3 buildings (i.e. Ba, Bb and Bc) concerning the opaque and glazed envelope, the DHW system and the integration of renewables.

Description of the renovation concept

Major renovation of buildings Ba, Bb, Bc

Building envelope thermal insulation

- External walls - through both cavity insufflation with glass wool flocks and external insulation with high-density glass wool panels, also useful to correct the thermal bridges;
- Walls facing unheated staircases – glass wool panels;
- Floors in contact with the outside (i.e. pilotis, only in Building Bb) - high-density glass wool panels;
- Floors in contact with unheated underground spaces (i.e. garages) - high-density glass wool panels;
- Walkable floors below the pitched roofs - polystyrene panels;
- Not-walkable floors below the pitched roofs – glass wool panels;
- Floors of the terraces - polystyrene panels;
- Replacement of windows with PVC frame double-glazed ones;
- Shutter boxes (finally, not done);
- Correction of thermal bridges of window sills with insulating covering.

Table 12. Thermal transmittance values of envelope elements before and after the energy renovation.

BEFORE RENOVATION		AFTER RENOVATION	
Element	**U [W/m²K]**	**Element**	**U [W/m²K]**
Opaque vertical envelope			
External wall 39 cm	1.273	External wall 39 + 6.6 cm	0.121
External wall 29 cm	1.261	External wall 29 + 6.6 cm	0.188
External wall below windows 23 cm	1.400	External wall below windows 23 + 6.6 cm	0.401
Wall against staircase 25 cm	2.548	Wall against staircase 25 + 4 cm	0.772
Floors			
External floor 30 cm	1.354	External floor 30 + 14 cm	0.199
Floor over garage 30 cm	1.152	Floor over garage 30 + 11 cm	0.262
Walkable floor below roof 35 cm	1.097	Walkable floor below roof 35 + 15 cm	0.279
Floor below roof 35 cm	1.097	Floor below roof 35 + 10 cm	0.279
Floor of the terrace 26 cm	1.146	Floor of the terrace 26 + 15 cm	0.281
Windows			
Single glazed – wooden frame (windows 130x140 cm)	4.693	Double glazed – PVC frame (windows 130x140 cm)	1.654
Single glazed – wooden frame (windows 140x140 cm)	4.728	Double glazed – PVC frame (windows 140x140 cm)	1.651
Single glazed – wooden frame (windows 70x250 cm)	4.440	Double glazed – PVC frame (windows 70x250 cm)	1.665
Single glazed – wooden frame (windows 140x250 cm)	4.928	Double glazed – PVC frame (windows 140x250 cm)	1.611

Buildings systems

- Replacement of the individual electric boilers with the installation of two DHW tanks (2000 litres) per building, having a double coil (DH connected during winter, HP connected during summer);
- Installation of one air-to-water heat pump per building (PHeating = 31.8 kW - PInput = 9.1 kW - COP = 3.51) for DHW production in summertime;
- Installation of grid-connected PV systems (polycrystalline panels) on each building roof (per each building: P = 16.2 kWp and estimated production = 16,800 kWh/year).

Renovation measures on all buildings

- Installation of thermostatic valves on radiators;
- Installation of a hydraulic separator with mixing valves controlled by a climatic sensor within each building substation.

Renovation measures on the centralised thermal plant

- Replacement of the climatic control unit with a highly efficient one and removal of mixing valves on primary distribution networks (now present in each building substation, therefore redundant).

Description of the non-technical aspects, e.g. stakeholder involvement, communication, etc.

The project has been funded through a call by the local public body Regione Lombardia on energy efficiency in buildings, foreseeing that the interested buildings would have to be upgraded at least to the energy class B according to the local energy labelling. The overall budget has been covered by one-third from the public body, while the buildings' owner "ALER- Varese" assigned the remaining two-thirds to an ESCO (i.e. CNP, 20 years Project Financing).

The association of tenants (i.e. Sunia) has been involved in discussing the project. The early-stage design of the project was attributed to the Politecnico di Milano, while the final stages and realization to the CNP.

Apart from being mentioned on the ALER-Varese webpage, the project has not been disseminated yet.

Project Fact Box (I.a)

General information:

Quartiere Sangallo

Parameter	unit	before renovation	after renovation
Covered area:	m²	7,542	7,542
Population in the area:	Apt	235	235
Number of buildings in the area	-	24	24
Heated floor area of all buildings	m²	23,258	23,258
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	-	-
Multi-family homes (MFH) - up to three storeys and/or 8 flats		29	29
Apartment blocks (AB) - more than 8 flats		71	71
Schools		-	-
Office buildings		-	-
Production hall, industrial building		-	-
Other (please specify)		-	-
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	29	29
Medium consumers: AB, schools, etc. – 80-800 MWh/a		71	71
Large consumers: industrial consum-ers, hospitals, etc. > 800 MWh/a		-	-
Property situation of buildings:			
Private	% of heated floor area	-	-
Public		100	100
Property situation of energy supply system (district heating):			
Private	% of heated floor area	-	-
Public		100	100

Project Fact Box (I.b)

General information:

Renovated Buildings (Ba, Bb, Bc)

Parameter	unit	before renovation	after renovation
Covered area	m²	1,066	1,066
Population in the area	apt	48	48
Number of buildings in the area	-	3	3
Heated floor area of all buildings	m²	3,661	3,661

Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	-	-
Multi-family homes (MFH) - up to three stories and/or 8 flats		-	-
Apartment blocks (AB) - more than 8 flats		100	100
Schools		-	-
Office buildings		-	-
Production hall, industrial building		-	-
Other (please specify)		-	-

Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	-	-
Medium consumers: AB, schools, etc. – 80-800 MWh/a		100	100
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		-	-

Property situation of buildings:			
Private	% of heated floor area	-	-
Public		100	100
Property situation of energy supply system (district heating):			
Private	% of heated floor area	-	-
Public		100	100

Project Fact Box (II)

Specific information on energy demand and supply:

Renovated Buildings (Ba, Bb, Bc)

Parameter	unit	before renovation	after renovation
Primary energy for space heating (calculated)	kWh/m²a	219	50
DHW primary energy (calculated)	kWh/m²a	54	22
cooling demand (calculated)	kWh/m²a	-	-
electricity demand (calculated)	kWh/m²a	-	-
heating consumption (measured)	kWh/m²a	197	-
domestic hot water consumption (calculated)	kWh/m²a	22 electricity	14 gas 3 electricity
cooling consumption (measured)	kWh/m²a	-	-
electricity consumption (measured)	kWh/m²a	-	-
(Thermal) energy supply technologies:			
***decentralised* oil or gas boilers**	% of heated floor area	-	-
***decentralised* biomass boilers**	% of heated floor area	-	-
***decentralised* heat pumps**	% of heated floor area	-	-
centralised (district heating)	% of heated floor area	100	100
***decentralised* electric boilers for DHW**	% of heated floor area	100	0
***centralised at building level* heat pumps *+ centralised (district heating)* for DHW**	% of heated floor area	0	100
renewable energy generation on-site:			
photovoltaics area	m²	0	303
photovoltaics	kW_p	0	49
other (please specify)	kW	0	0

Financial issues:

Parameter	unit	before renovation	after renovation (including 10% VAT)
Total investment costs of the renovation	Euro/m²	-	334
- **building envelope renovation costs**	Euro/m²	-	250
- **heating/cooling supply costs**	Euro/m²	-	60
- **renewable energy production costs**	Euro/m²	-	25
LCC available	yes/no	no	no

Description of the technical highlight(s) and innovative approach(es)

DHW system

- replacement of the individual electric boilers with the installation of two DHW tanks (2000 litres) per building having a double coil (DH connected during winter, HP connected during summer);
- installation of one air-to-water heat pump per building (PHeating = 31.8 kW - PInput = 9.1 kW - COP = 3.51) for producing DHW in summer period.

The DHW system includes these components, installed in the building's basement:

- circulating pump;
- water softener system and Legionella bacteria control system;
- energy meters for both the heat pumps and the DH side.

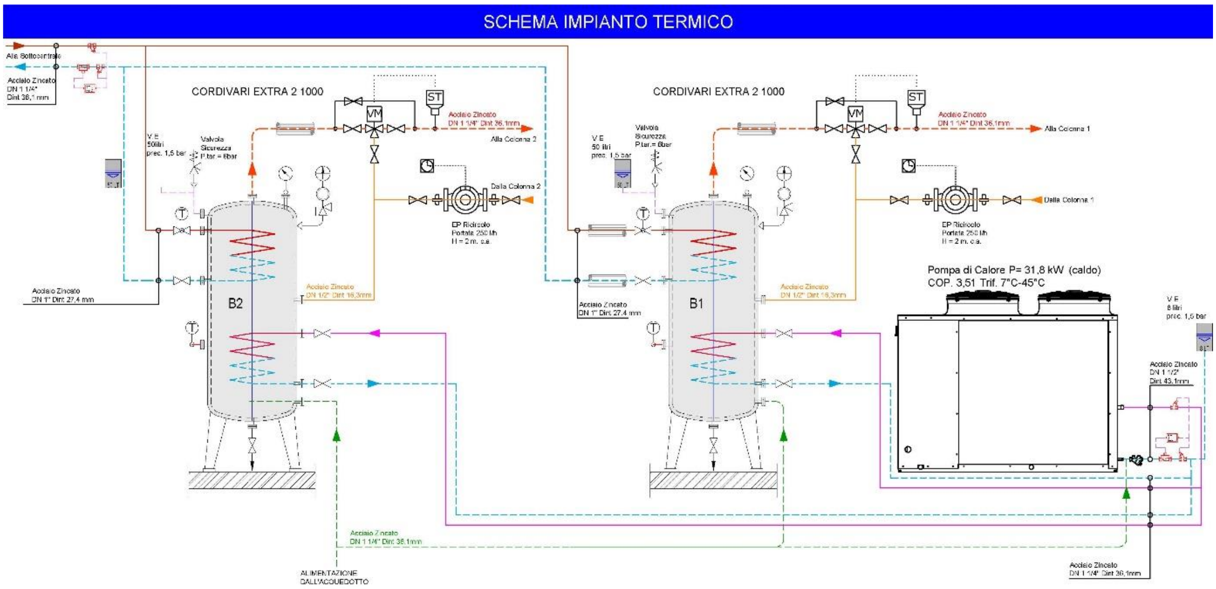


Figure 18. DHW system scheme. Source: ALER- Varese.

Decision and design process

General/organizational issues:

The project was initiated taking advantage of a public call on energy efficiency, to reduce the energy consumption and related emissions of existing social housing buildings, typically featured by poor energy quality.

Stakeholders involved

- Policy actors: Regione Lombardia (as public financier);
- Users/investors: ALER-Varese (as the owner of the built area), CNP (ESCO co-financing the project);
- District-related actors (Community/occupants organizations, etc.): Sunia (association of tenants)
- Energy Network Solution Suppliers: CNP
- Renovation Solution Suppliers: Politecnico di Milano (in charge of early stage design), CNP (in charge of final stages design and realization)

Main steps

The main step for the successful implementation of the district heating was to involve the CNP-ESCO.

Resources available before the project

There were no resources available before the project.

Drivers and barriers (opponents)

The main drivers have been ALER-Varese, aiming at renovating its low-performing building stock, and Regione Lombardia, awarding the call and financing the project for 1/3 of the total costs.
The main barrier was the unavailability of funds from the owner.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Regione Lombardia	Public Financier	Call for boosting energy efficiency in public buildings
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	ALER	Decision maker	Energy renovation of the owned building stock
	CNP	ESCO Co-Financier	Business
District-related actors (Community/occupants organizations, etc.)	Sunia (association of tenants)	Influencer	Protect tenants' needs
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	CNP	ESCO	
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Politecnico di Milano	Technical advisors	Early-stage design
	CNP	Technical advisors	Final stages design + realization
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)			

Design approach:

The project has aimed to reduce the buildings' energy demand, achieve the class B of the local energy labelling, and subsequently reduce the related carbon emissions.

Decision steps

- Public call from Regione Lombardia
- Early-stage design from Politecnico di Milano
- Presented projects evaluation
- Presented projects' ranking and announcement of the assignee
- Assignation of funds
- Involvement of an ESCO and evaluation of its proposal for the final stages of design
- Assignment of work to CNP-ESCO
- Renovation of buildings

Main challenge

The main challenge has been the achievement of the energy class B starting from the initial G one, as required by the call.

Technical issues:

Major technical challenges/constraints regarding system design/implementation

During the renovation, a higher wall cavity thickness than expected has been founded. Because of the additional costs related to the larger cavity insulation, it has been decided not to insulate the shutter boxes as initially foreseen. The PV system grid-connected is not working yet because of bureaucracy-related problems.

Financing issues:

The whole renovation project has been financed for 1/3 by a public body (i.e. Regione Lombardia) and 2/3 in Project Financing by a private ESCO (i.e. CNP).

Subsidies or other financial incentives

Apart from 1/3 of the public funding, there were no other subsidies or financial incentives.

Main challenges/constraints regarding financing

The main challenge has been retrieving the financier for the 2/3 of costs, solved with the involvement of CNP.

Business models

Project Financing.

Management issues:

The main project management challenges have regarded dealing with the complex Italian bureaucracy and regulations in terms of public building renovation.

Policy framework conditions:

Regulations that stimulated/hindered the process

The project has been carried out respecting current EPBD national (and regional) implementation requirements.

Police instruments that moved the district into action

The policy instrument that moved the district into action can be considered a “carrot policy”.

Lessons learned/interesting findings

Major success factors

The 1/3 public body (i.e. Regione Lombardia) funding call and the private ESCO (i.e. CNP) investing for the remaining 2/3 in Project Financing.

Major bottlenecks

The barrier was the unavailability of funds from the owner, solved with the involvement of an ESCO. As it has been explained, during the renovation a higher wall cavity thickness than expected was founded. Because of the additional costs related to the larger cavity insulation, it was decided not to insulate the shutter boxes as initially foreseen. The PV system grid-connected is not working yet because of bureaucracy-related problems (still unsolved).

Aspects to be transferred from this intervention

The ALER – Varese intends to achieve continuous improvement of its owned buildings’ energy performance according to the specification ISO 50001 “Energy management systems – Requirements with guidance for use”. Besides, considering the issue of low income of the building tenants, the project has had the additional goal to reduce the related fuel poverty condition.

3.5 Valdastico (Italy)

This success story is only focused on the energy system, no measure related to building renovation has been performed, but it may be relevant to other similar interventions.

Country: **Italy**

Name of city/municipality: **Valdastico**

Title of case study: **Valdastico district**

Period of the renovation: **2014**

Author name(s): L. Teso, T. Dalla Mora, F. Peron, P. Romagnoni
Author email(s): tdallamora@iuav.it
Link(s) to further project related information / publications, etc.:

Schematic figure or aerial overview

The Municipality of Valdastico is located in the Province of Vicenza, in the northeast of Italy, and it represents a typical small community of mountain area (1,300 inhabitants at 405 m above sea level).

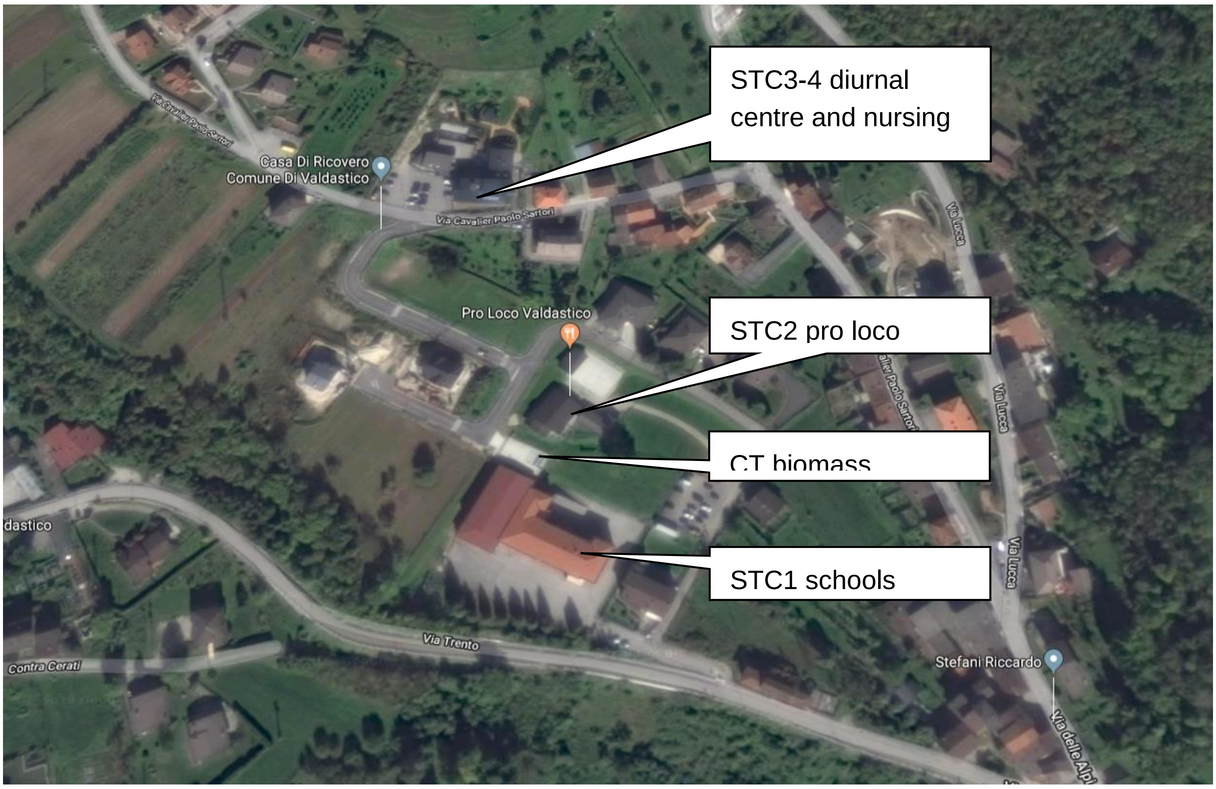


Figure 19. Satellite view of Valdastico district with highlights on the interested buildings. Source: edited by the authors, based on "Google Image" by Google n.d.

The district heating net consists of a thermal power system, powered by **biomass** of agro-forestry origin (wood chips), to **produce thermal energy for the heating and domestic hot water** production of 4 public buildings by the Municipality of Valdastico:

- Middle and elementary schools;
- Head office of the Valdastico Pro Loco;
- Nursing home "Casa Nostra";
- Nursing home "Casa Nostra" (diurnal centre).

Table 13. Main features of the researched area.

	Valdastico Renovated buildings
Buildings heated area [m²]	4,000
Number of building units	4
Buildings use category	School - Nursing home
Buildings' owner	Valdastico Municipality

Introduction and description of the situation before the renovation

Before the renovation, the buildings were heated by gas boilers.

Table 14 shows how energy use was focused on winter months, while in summer was very limited and practically attributed only to the nursing houses, which are responsible for a great part of energy use (almost 60%).

Table 14. Main data about the situation before the intervention, focusing on heated volume and yearly energy use by the interested buildings, concerning consumption data for 2012/2013.

	Users	heated volume	useful power exchanger	2012/13 annual gas consumption (before renovation)		
				yearly consumption	winter (H+DHW)	summer (DHW)
		[m^3]	[kW]	[Sm^3]	[Sm^3]	[Sm^3]
1	**Middle and elementary schools**	8,080	300	20,156	18,396	3,010
2	**Head office of the Valdastico Pro Loco**	660	35	1,750	1,000	500
3	**Nursing home “Casa Nostra”**	3,300	170	27,179	19,184	3,655
4	**Nursing home “Casa Nostra” (diurnal centre)**	830	35	7,022	5,383	1,639
	Total	12,870	540	56,107	43,963	7,804

Description of the renovation goal

The general goal was to create a sustainable complex for public users. The new biomass district heating plant aims to cover 100% of the thermal demand through renewable sources.

Utilities are connected to the biomass power plant using a specific district heating network, seized to provide energy to other public buildings in the future.

Specifically, renovation goals were to:

- Reduce energy costs and carbon emissions;
- Use renewable sources for energy use;
- Increase the living quality and adapt the buildings to a contemporary standard of living;
- Improve the image so that there is a good effect and it works as identification for the inhabitants and the district.

Description of the renovation concept

Buildings' systems

The renovation project concerns only the system. The technical choice fell on the following aspects:

- Central biomass heating plant (wood chips) centralised to fully meet the thermal needs of users;
- Solar heating system to supplement the summer domestic hot water needs of the nursing home users;
- Maintenance of existing boilers, after appropriate requalification and regulatory adaptation, as an emergency system in case they are needed.

The management of the system can be carried out remotely to minimize the operating costs of the entire system and guarantee a higher quality of service and a real-time response in case of breakdown.

The substations were made to not substantially modify the heat distribution circuits to the users, thus maintaining the current distribution and adapting it to the operation envisaged with district heating.

Middle and Elementary School

By maintaining the existing boiler as a backup, the following improvements were carried out, together with the installation work of the DHN substation:

- Switching from an open vessel to a closed vessel system, with a consequent reduction in the dirt and corrosion of the plants;
- Integration and replacement of the safety devices currently present on the gas boiler to allow operation, in case of emergency, as an alternative to the district heating exchanger, by a simple manual interception of the exchanger circuit;
- Installation of a new primary circulation pump to allow the operation of the system with the district heating exchanger.

Pro-Loco head office

For the Pro-Loco, due to the recent construction of the boiler and the systems, only a minimum intervention for interfacing has been provided. The connection between the exchanger and the existing gas boiler is achieved through manual ball shut-off valves.

Nursing home

The gas boiler for heating was kept, while, for the production of domestic hot water, the boiler with gas burner was replaced due to the not regulatory compliance.

In this substation, the following improvement measures were carried out:

- Integration and replacement of the safety devices currently present on the gas boiler to allow operation as an alternative to the district heating exchanger;
- Installation of a solar thermal system on the roof and a boiler for the production of domestic hot water supplied by solar heating or, in case of necessity, by district heating. The boiler will be equipped with a thermostatic mixer;
- Dismantling of the gas cylinder that does not comply with current regulations.

Nursing home – diurnal centre

Also, in this case, given the recent construction of the boiler and the systems, only the minimum interventions required for interfacing have been foreseen.The connection between the exchanger and the existing gas boiler is achieved through manual ball shut-off valves.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	8,000	8,000
Population in the area:	-	300	300
Number of buildings in the area	-	4	4
Heated floor area of all buildings	m²	4,000	4,000
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	0	0
Multi-family homes (MFH) - up to three stories and/or 8 flats		0	0
Schools		63	63
Office buildings		5	5
Nursing home		25.5	25.5
Nursing home (diurnal centre)		6.5	6.5
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	0	0
Medium consumers: AB, schools, etc. – 80-800 MWh/a office + school		39	42
Large consumers: industrial consum-ers, hospitals, etc. > 800 MWh/a 2 nursing home		61	58
Property situation of buildings:			
Private	% of heated floor area	0	0
Public		100	100
Property situation of energy supply system (district heating):			
Private	% of heated floor area	-	0
Public		-	100

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/a	-	-
Domestic hot water demand (calculated)	kWh/m²a	included in the heating demand	included in the heating demand
Cooling demand (calculated)	kWh/a	-	-
Electricity demand (calculated)	kWh/a	-	-
Heating + electricity demand (calculated)	kWh/m²a	124	148
heating consumption (measured)	kWh/a	-	-
domestic hot water consumption (calculated)	kWh/m²a	included in the heating consumption	included in the heating consumption
cooling consumption (measured)	kWh/a	-	-
electricity consumption (measured)	kWh/a	-	-
Heating + electricity consumption (measured)	kWh/m²a	140	200
Energy vector used		52,000 m³ gas	174,000 kg of Biomass (wood chips)
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	100	In emergency case
***Decentralised* biomass boilers**		-	-
***Decentralised* heat pumps**		-	-
Centralised (district heating)		0	100
Other *(please specify)*		-	-
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	13.8 m²
Photovoltaics	kW_p	0	0
Other (please specify)	kW	0	0

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro	-	670,000 (€ 332,828 by Region Veneto fund)
- **building renovation costs**	Euro	-	-
- **heating/cooling supply costs**	Euro	38,000	20,000
- **renewable energy production costs**	Euro	-	-
LCC available	yes/no	no	no

Description of the technical highlights and innovative approaches

Biomass plant - characteristics of the system

The installed biomass boiler has a rated power of 550 kW, with screw feed mobile grate technology, and can burn chips with water content up to 40%.

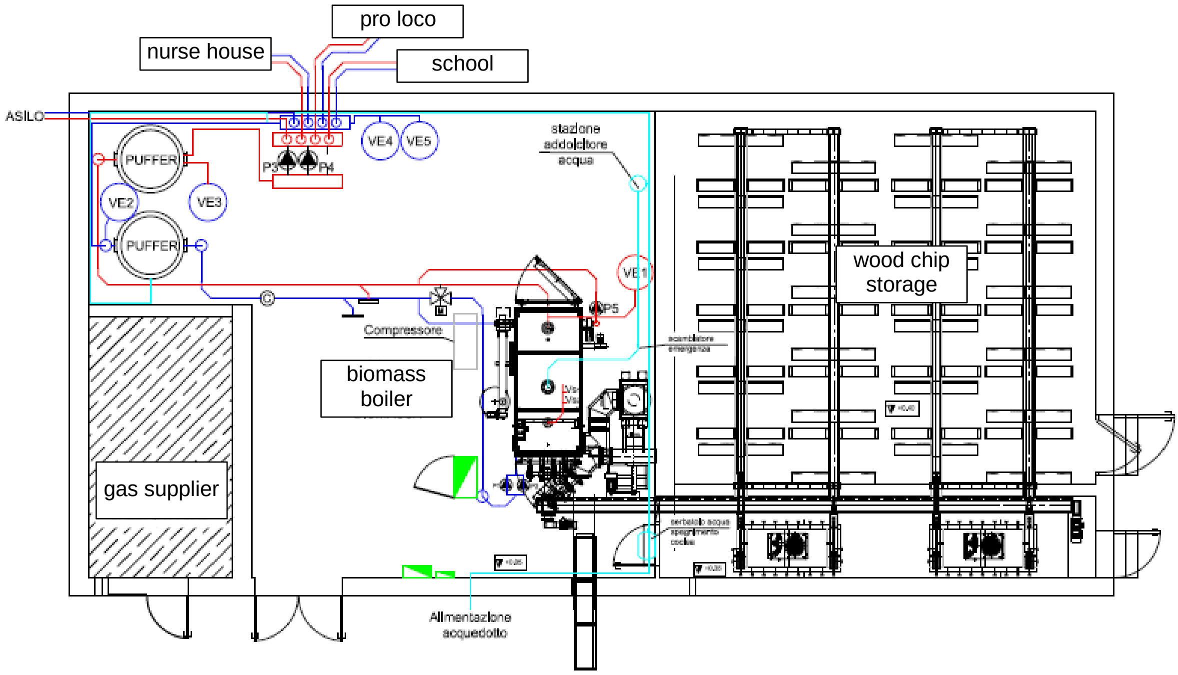


Figure 20. Layout of the thermal plant. Source: technical drawing from as built project, by Comune di Valdastico.

It is equipped with inverter control of the fans for air combustion and smoke exhaust. The local deposit has a useful volume of 290 m³ and is equipped with 4 rakes with 2 pistons for handling the wood chips. The boiler is equipped with a management programmable logic controller (PLC) that automatically regulates its operation, as is the discharge of the ash into special containers.

The thermal energy produced is accumulated in two "puffers" of 3,000 litres each and from these taken and distributed to the users through 2 inverter pumps.

Table 15. Technical data biomass plant.

Brand and model	UNICONFORT – BIOTEC G50
Nominal useful power	550 kW
Nominal hearth power	640 kW
Nominal yield at 100% power	86%
Water content	2,040 litres
Operating pressure	4 bar
Operating temperature	85 °C
Wood-chips charecteristics	Max 40% water content, P45
Local wood-chip storage	290 m³
Thermal storage tanks	2 x 3,000 litres

Biomass plant - wood chips fuel

The biomass boiler uses wood chips as fuel. The combustible material's quality is strategically important for controlling polluting emissions and for the effective performance of the boiler and its duration in time.

Table 16. Characteristics of the wood chips.

Type	100% fir
Origin	Veneto and Trentino Alto Adige Region
Size	< P 45
Water content	< 30%
Calorific value	> 3.4 kWh/kg
Ash content	< 1%
Certifications	certified supplier PEFC

This choice allows to optimize the combustion characteristics of the boiler, the number of fuel recharges, and the need for maintenance of the system.

The selection of wood chips is essential to achieve the objectives of effective emission reduction without increasing local pollution by guaranteeing the quality and the traceability of the supplied fuel.

The analysis of the local wood chip market makes it possible to state that, given the high availability of high-quality chip chippings in the immediate vicinity, it is believed that the supply of wood chips is sustainable from an environmental, technical, and economic point of view in the medium to long term.

As for the treatment of fumes, in addition to the normal emissions regulations, a multi-cyclone dust collector (a kind of pulveriser) is planned to further reduce dust emissions, especially during boiler start-up and shut-down phases.

Thermal solar system - characteristics of the system

To supplement the biomass plant, a solar thermal system was installed at the nursing home, to increase the use of local renewable sources. Six solar panels and a thermal storage tank with a capacity of 1,000 litres have been installed.

Since the user is a nursing home, the use of domestic hot water is well distributed throughout the day and there are no significant monthly or weekly changes, also based on consumption trends.

Table 17. Technical data of the solar thermal system.

Net capturing surface	13.8 m^2
Tilt angle	25°
Orientation	25° West
Annual irradiation in the panels plane	1,286 kWh/m^2 year
Average annual return	60%
Average annual thermal energy production	10,650 kWh/m^2 year

Primary energy savings	14,200 kWh/m² year
Useful life solar system	20 years
Coverage of DHW requirements in summer	56% of the requirements

In an emergency it is possible to use the pre-existing gas boilers, thus ensuring continuity of service to all users.

The heat exchangers are equipped with a control unit with a two-way power modulation valve, which allows them to regulate the temperature and power supplied to the user in order to use the actual needs.

Table 18. Technical data district heating network.

Overall length of the network	600 m
Brand and model	BRUGG – Calpex
Material	Polyethylene PE-Xa pre-insulated
Main line diameter	110 mm ø int. - 162 mm ø est.
Transportable thermal power	1,000 kW
Average temperature difference expected	< 20 W/m
Number of users that can be intercepted in the thermal power plant	3 (active) + 1 (prepared)

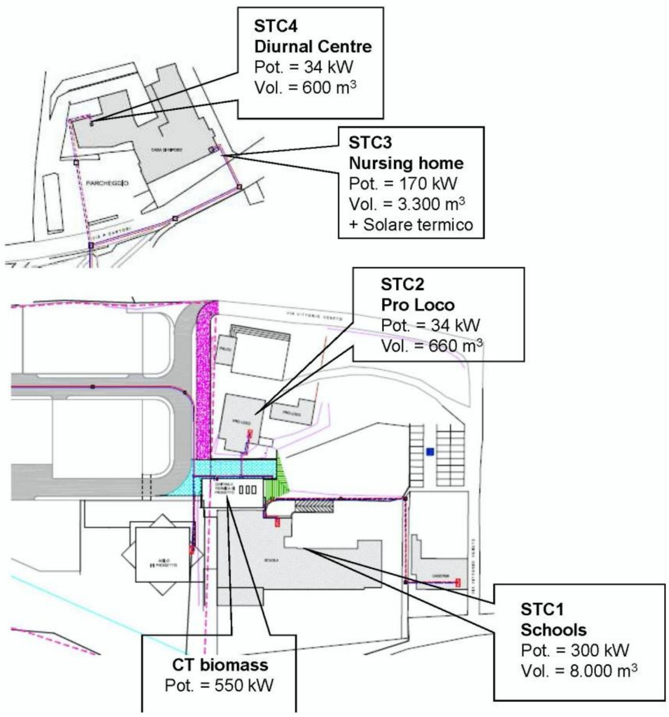


Figure 21. The district heating net includes 5 buildings: a CT thermal central station and 4 STC substations. For each building, a label describes the name of the station, the use, the installed power Pot, and the volume Vol. Source: technical drawing from as built project, by Comune di Valdastico.

Decision and design process

General/organizational issues:

Valdastico municipal administration planned the intervention according to sustainability goals to reduce the energy use and cost of fossil fuels and the relative carbon emissions.

Stakeholders involved

The stakeholders involved were the following:

- Policy actors: municipality;
- Users: housing association and school administration;
- Design and consultant company: Studio Centro Sicurezza Ambiente, in charge of design and realization stages;

Main steps

The main steps were: the availability of public funds to apply the intervention; the total adhesion to this project by the three municipal administrations during the whole process; and the installation works. Moreover, the installation works have been possible without resettling the hosts in the nurse houses and without interfering in the school activities.

Resources available before the project

Before the renovation, the buildings were heated by gas boilers. There were no resources available before the project.

Drivers and barriers (opponents)

The main driver is the municipality and the large availability of wood chips in the neighbouring environmental context, which allows an eco-compatible use of the district heating system with a drastic reduction of the pollutants emitted.

The main barrier regards the unavailability of funds for the administration to face the project and an unexpected consequence after the intervention because the strong noise from the central disturbs the neighbouring inhabitants.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Municipality	Decision maker	Savings, carbon reduction, quality of living improvement
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	Regione Veneto	Financier	Call for boosting energy efficiency in public buildings
District-related actors (Community/occupants organizations, etc.)	Occupants' organization of schools and nursing home	Influencer	Savings, standards improvement
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	Unknown	Decision maker/delivery	Profit, experience, fame
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Studio Centro Sicurezza Ambiente	Consultant and design company, technical advisor	Profit, experience, management of design + realization stages;
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)			

Design approach:

The new biomass district heating plant aims to cover 100% of the thermal demand through renewable sources.

Decision steps

The steps implemented were as follows:

- Public call from Regione Veneto
- Early stage design by Studio Centro Sicurezza Ambiente
- Presented projects evaluation
- Presented projects' ranking and announcement of the assignee
- Assignation of funds by Regione Veneto
- Evaluation of proposals for final stages of design
- Assignment of works and project management
- Intervention

Main challenges in the design phase

The main challenge was evaluating the most effective technical solution in terms of plants to reduce energy costs; in addition, the administration was obliged to seek external technical support to present a valid project for the call of Region Veneto in terms of requirements and timing.

Technical issues:

The challenges in this phase concern positioning the biomass plant and the solar heating system, and the net design for connecting the more distant public buildings. During this phase, the problem was keeping and adapting the existing boilers as an emergency system. Another challenge concerns organizing the intervention schedule during the summertime to not interfere with school activities.

Financing issues:

The renovation was financed by public money. The region funded the project through the funds by the ministerial plan for energy production from renewable sources and energy efficiency. Conto Termico, a particular incentive plan to produce thermal energy from renewable sources for small plants, achievable after the intervention, was available. The main challenge for municipal administration has been to find and to finance the cost non-covered by funds, a very difficult step for a small city of 1,300 inhabitants.

There was no business model applied.

Management issues:

No relevant management aspects are known.

Policy framework conditions:

There were no special policy frameworks. The project has been carried out respecting current EPBD national implementation requirements, in particular for energy efficiency measures and thermal energy production from renewable sources for small plants.

Policy instruments

"Carrots-policy" was the policy instrument that moved the district into action.

Lessons learned/interesting findings

Major success factors

First of all, the achievement of public funds, without which the project would not have been funded for a small city such as Valdastico.

From the technical point of view, the new biomass district heating plant aims to cover 100% of the thermal demand through renewable sources; most of the summer energy demand (limited to the use of domestic hot water in the nursing home) is covered by solar thermal panels. This also improves the efficiency of the use of biomass, since in summer the biomass boiler has lower yields (due to the greater ignition and shutdowns) and the dispersions along the network become significant; the use of fossil sources (natural gas) is limited to the case where both systems are not able to meet the energy needs.

The analysis of the local wood-chip market makes it possible to state that, given the high availability of high-quality chip chippings in the immediate neighbourhood, the supply of wood chips is sustainable from an environmental, technical, and economic point of view in the medium to long term.

Major bottlenecks

Some difficulties during the process were:

- the choice of an effective technical solution in terms of the plant to reduce energy use and costs by connecting distant public buildings, with different use;
- the cost of changing the existing plants implied an expense for the disposal of the old plants, so the decision was to keep and adapt the existing boilers as an emergency system;
- the municipal technical offices were not equipped with technical personnel competent in plant engineering topics, so the administration was obliged to seek external technical support to present a valid project for the call of Region Veneto in terms of requirements and timing.

Major lessons learned

The availability of public funds and a national incentive plan are crucial to help and involve small communities to reduce the energy consumption and related carbon emissions of public buildings.

Aspects to be transferred from this project

The reduction of fossil use is possible by the realization of a small net connecting public buildings; moreover, the availability of national funds and incentives cover a great part of the investment, given the possibility also to a small community to improve the living quality in terms of energy use and environmental impact reduction and also to reduce the public costs for energy bills.

From a technical point of view, the transition to biomass as an energy source is an efficient and sustainable solution for mountain communities, especially nearby woodland areas.

3.6 Santa Marta Campus, University Iuav of Venice (Italy)

This success story is only focused on the energy system, no measure related to building renovation has been performed. However, it is an energy system intervention at a district scale in a unique context that may be relevant to other similar interventions.

Country: **Italy**

Name of city/municipality: **Venice**

Title of success story: **University Iuav of Venice – Santa Marta Campus**

Period of the renovation: **2017**

Author name(s): L. Teso, T. Dalla Mora, F. Peron, P. Romagnoni
Author email(s): tdallamora@Iuav.it
Link(s) to further project related information / publications, etc.:

Schematic figure or aerial overview

Figure 22. Location of Santa Marta Campus in Venice (highlighted in red). Source: University IUAV of Venice.

In the university campus of Santa Marta, in Venice, all buildings are schools except a caretaker's house. The property is from the University Iuav of Venice, comprising a total volume of about 104,000 m^3 and about 17,500 m^2 of heated floor area (source: edited by the authors, based on "Google Image" by Google n.d.).

Introduction and description of the situation before the renovation

Santa Marta campus is located in the southwest part of the island of Venice, within the Dorsoduro district; it is a predominantly popular and residential area and is characterised by the presence of the maritime merchant station, where some warehouses were located.

The university campus of Santa Marta is the main centre of the Iuav offices and consists of buildings mainly dedicated to educational activities. There are several buildings:

- ex-Cotonificio Olcese;
- ex-Magazzino Ligabue n. 5, owned by Ca' Foscari University;
- ex-Magazzino Ligabue n. 6 and 7;
- ex-Convent Terese.

The ex-Cotonificio Olcese building was inaugurated in 1883 as a cotton spinning and production company set up in Venice. Partially destroyed by a fire in 1916, the cotton mill was rebuilt. Remained operative until 1960, then it was abandoned for thirty years before its restoration in the 1990s by Iuav.

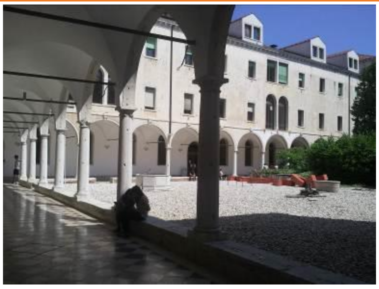
The Magazzini Ligabue were port warehouses built in the 1920s. It grew as a port with storage warehouses at an industrial scale. Warehouses 5, 6, and 7 were restructured in late 2000 by Iuav Studi Progetti ISP and Iuav.

The ex-Cotonificio and Magazzini buildings present the typical brick pre-industrial structure, like other industrial or manufacturing buildings of the time in the area.

The Convent of Santa Teresa was built in the second half of the 17th century. The building complex develops around a single large cloister characterized by its arched porticos. Iuav restored the former convent in the late 1990s and the first 2000s, with the architectural renovation and adaptation operations necessary to host the new teaching and research activities. However, the interventions respected the formal structural features of the building, typical of a 17th-century convent.

Before the renovation, the buildings were served mainly by natural gas boilers and heat pumps, as described below:

Table 19. Characteristics of the heating stations and energy vectors for each university buildings before the intervention. Source: University IUAV of Venice.

Building	Existing generator	Energy vector
 **Ex Cotonificio Olcese**	The central heating station includes 3 generators. Generator: RIELLO TAU-N 450 Bruciatore: RIELLO RS 50/M Nominal thermal capacity (Qmax): 450 kW Rated power (Pn max): 445.2 kW (80°-60°C) Efficiency: 98.9% (Pn max) 107% (Pn min 30%)	Natural gas
 **Ex- Convent Terese**	Generator: RIELLO TAU-N 350 Bruciatore: RIELLO RS/M MZ Nominal thermal capacity (Qmax): 349 kW Rated power (Pn max): 346.7 kW (80°-60°C) Efficiency: 99.3% (Pn max) 107.3% (Pn min 30%)	Natural gas
 **Magazzini 6 (and 5)**	Generator n. 1 Model: Generator BALTUR Multiblock 90 Nominal thermal capacity (Qmax): 21-84 kW Generator n. 2 Model: Generator BALTUR Multiblock 145 Nominal thermal capacity (Qmax): 21-84 kW Generator n. 3 Model: Generator BALTUR Multiblock 180 Nominal thermal capacity (Qmax): 21-168 kW	Natural gas
 **Magazzino 7**	Generator in heat pump n. 1: model HITACHI RAS-20FSG cold rated output 23.6 kW heat rated output 22.7 kW Generator in heat pump n. 2: model HITACHI RAS-8FSG cold rated output 8.9 kW heat rated output 8.4 kW	Electricity

There is no use or generation of renewable energy on-site, but the characteristics and orientation of the roof in the Ex-Cotonificio are potentially usable for installing a photovoltaic system.

Description of the renovation goal

The university administration is operating in the continuous maintenance of the university buildings and, since the 1990s, has implemented various measures of redevelopment and restructuring that mainly concern the structure and the envelope.

In the last years, Iuav planned to modernise its building stock and renew the system plant. The main result was the inauguration of the local district heating in the Santa Marta Campus in November 2017 to minimize energy consumption and carbon emissions derived from the use of heating and maximize energy savings. In fact, it represents a pilot role in technological innovation because it is the first realization of a district heating network in the historical Venetian context and the Venetian public buildings.
The aims of Iuav are linked to the institutional policy to increase the university's environmental sustainability and realize a research and experimentation opportunity.

The goals of reducing the energy use and cost for heating and cooling have been possible with the technical-financial partnership of ENGIE Servizi SpA and the exploitation of the government economic-financial opportunities that include the Kyoto revolving fund for the environmental value and the obligation to reinvest 10% of the expected energy expenditure charged to the contractor to an Integrated Energy Services contract (called CONSIP SIE2).

The intervention consists of two measures:

- a trigeneration plant with natural gas composed of a cogeneration group to produce 238 kW of electricity and 363 kW of thermal energy and of an absorption group of 255 kW refrigerators supplied by a thermal waste of the cogenerator and used for summer cooling of the buildings;
- a hot water district heating based on 90 °C supply temperature that serves the 5 neighbouring buildings developing over a distance of 1.3 km.

The intervention amounts to approximately 1,100,000 €, about 50% financed by the Kyoto Fund and the remainder from the recovery of the mandatory investment shares provided for and according to the SIE2 contract.

Description of the renovation concept

The intervention consists of two measures: a trigeneration plant (combined cooling, heat, and power plant) with natural gas and a hot water district heating to serve 5 school buildings.

The equipment is located on the Ex Cotonificio roof, near the refrigeration units and the thermal plant. The plant is quite compact and prefabricated in ISO containers. It contains all the mechanical and electrical equipment necessary for its operation. Both of them include heat recovery units, while refrigerated ones are performed using an absorber housed in a neighbouring container with the relative evaporative tower nearby.

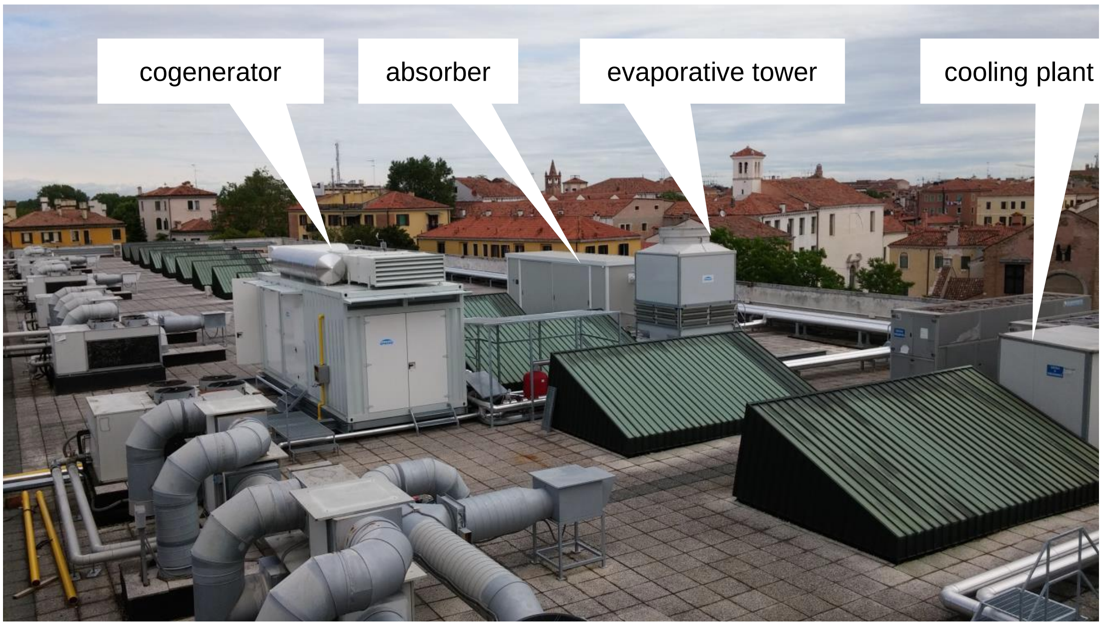


Figure 23. External view of the roof with actual localization of the trigeneration plant on the roof of the Ex Cotonificio. Source: University IUAV of Venice.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	11,000 m²	11,000 m²
Population in the area:	-	4,000	4,000
Number of buildings in the area	-	5	5
Heated floor area of all buildings	m²	17,500 m²	17,500 m²

Building mix in the area:			
Single-family homes (SFH)		-	-
Multi-family homes (MFH) - up to three stories and/or 8 flats		-	-
Apartment blocks (AB) - more than 8 flats	% of heated floor area of all buildings	-	-
Schools Educational space		90	90
Office buildings Office space		10	10
Production hall, industrial building		-	-
Other (please specify)		-	-

Consumer mix in the area:			
Small consumers: SFH + MFH – < 8- MWh/a		-	-
Medium consumers: AB, schools, etc. – 80-800 MWh/a	% of annual Heat demand	100	100
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		-	-

Property situation of buildings:			
Private	% of heated floor area	-	-
Public		100	100

Property situation of energy supply system (district heating):			
Private	% of heated floor area	-	-
Public		100	100

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation (2017)	after renovation (2018)
Heating demand (calculated)	kWh/m²a	-	-
Domestic hot water demand (calculated)	kWh/m²a	-	-
Cooling demand (calculated)	kWh/m²a	-	-
Electricity demand (calculated)	kWh/m²a	-	-
Heating consumption (measured)	kWh/m²a	96.57	160.01
Domestic hot water consumption (calculated)	kWh/m²a	included in the heating consumption	included in the heating consumption
Cooling consumption (measured)	kWh/m²a	-	-
Electricity consumption (measured)	kWh/m²a	97.13	82.67
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	80	-
***Decentralised* biomass boilers**		-	-
***Decentralised* heat pumps**		20	-
Centralised (district heating)		-	100
Other *(please specify)*		-	-
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	kW_p	0	0
Other (please specify)	kW	0	0

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	-	-
- **building renovation costs**	Euro/m²	-	-
- **heating/cooling supply costs**	Euro/m²	-	86.67
- **renewable energy production costs**	Euro/m²	-	-
LCC available	yes/no	No	No

Description of the technical highlight(s) and innovative approach(es)

The system plant represents the first example implemented on a university campus in Italy and also the first public building in Venice. The innovative approach consists of the combination of a trigeneration plant with a district heating network, applied to school and historic buildings that are listed by Superintendence. The project is considered a best practice because the system can produce renewable energy in an urban context where the installation and the requirements are severely binding.

The district heating network consists of a delivery pipe, which carries hot water at a maximum temperature of 90 °C, and a return pipe, which conveys water to an average temperature of 60 °C. The dimensional characteristics of the network are characterized by a development equal to 1,056 m of divided double pipes.

Table 20. Description of the installed power on the 5 users.

Users	Power installed Heating (kW)	Power installed DHW (kW)
Ex Cotonificio	**150**	**50**
Ex Convento Terese	**400**	**50**
Casetta Asi	**35**	**35**
Magazzino 6	**100**	**50**
Magazzino 7	**100**	**50**
Total installed	**785**	**235**

Technical features of the machines

The tri-generator system is characterized by 238 kWe electrical power, 363 kWt thermal power, 256 kW cooling power, but most important is the reduction of environmental emissions, because the plant guarantees an emissions reduction of 340 Ton carbon compared to previous years.

The choice of the cogeneration engine was considerably influenced by the need to obtain the tax benefits on purchasing natural gas intended for the functioning of the boilers. To achieve this, according to law 10 of 09/01/1991, art.11, it is necessary that:

- the installed electric power for cogeneration is equal to at least 10% of the thermal power supplied to the user;
- the electricity produced is at least 10% of the total thermal energy supplied to the system.

The choice of the absorber size is based on the available thermal power (approximately 363 kWt)

Cogeneration group MAN natural gas engine

The co-generator identified for the installation is a MAN E 2842 E 312 powered by natural gas, with heat recovery from the engine block and the fumes in the water, optimised for heat recovery interlocked to the absorption group. It is characterized by the following main data:

- Nominal electrical power: 238 kWe
- Nominal cogenerated thermal power: 363 kWt
- Nominal thermal power input: 667 kWt

- Emissions: CO <600 mg / Nmc, NOx <450 mg / Nmc (referred to as 5% oxygen).

Absorber

The system will be coupled with an absorption chiller powered by hot water, for indoor installation, brand SMART HWC 350-255 VS.

Decision and design process

General/organizational issues:

The intervention was performed to meet the sustainability goals planned by Iuav. The university aims to renovate the university buildings to reduce energy use (and consequently energy bills) and carbon and other pollutant emissions.

Stakeholders involved

In 2017, the Iuav administrators planned a district heating network with the technical support of ENGIE group.

Main steps

The main step of the process for its successful implementation has been the inclusion of the Kyoto revolving fund to incur the economic investment.

Resources available before the project

Before the project, the buildings were served by individual boilers at the end user. The energy carrier before the project consisted of fuels harmful to the environment. There were no resources available before the project.

Drivers and barriers (opponents)

The main driver is the university administration and ENGIE and the main barrier has been the feasibility of the intervention in such an historical context with cultural heritage requirements to observe.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	University Iuav board	Decision maker	Energy savings, carbon reduction, quality of living improvement
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	University Iuav board and management	Influencer	Savings, standards improvement
District-related actors (Community/occupants organizations, etc.)	University Iuav community (researchers, students)	Influencer, researcher	Pilot Case study, monitoring study, dissemination of results,
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	ENGIE group (ESCO)	Decision maker/delivery	Profit, experience, fame
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	ENGIE group (ESCO)	Technical advisor	Profit, experience, fame
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	ENGIE technical team and university research team	Technical advisor, influencer	Reply to the experience and repeat the project

Design approach:

The design target was the minimization of energy costs, maintenance costs and emission reduction.

Decision steps

The main steps are as follows: discussion between Iuav and ENGIE, design delivery for Superintendence review and then delivery to Environmental and Economic Ministries, fund approval, construction, and realization.

Main challenges in the design phase

The calculation of energy profile, schedule, and energy need; moreover, the definition of the feasibility estimate and the economic convenience by ENGIE.

Technical issues:

Major technical challenges have been the implementation time of intervention during summertime (when didactic activities are stopped) and the construction site for installing the pipe grid under the public pavement, with compliance with the requirements fixed by the Cultural Heritage Venetian Superintendence.

Financing issues:

The project was partly funded by public money (Kyoto fund) and private money, meaning the main role of ENGIE group as an Energy Service Company (ESCO).

Subsidies or other financial incentives

The main subsidies are linked to the inclusion of the Kyoto revolving fund (50%) and the obligation to reinvest 10% of the energy expenditure charged to the contractor as per the contract (CONSIP SIE2).

The choice of the cogeneration engine was considerably influenced by the need to obtain tax benefits on the purchase of natural gas intended for the functioning of the boilers.

Main challenges/constraints regarding financing

In terms of financing, the main challenge was to meet the requirements set by the Environmental and Economic Ministries (REF, MISE call) to access the Kyoto fund and submit the request for funding per the terms of the call and benchmarks.

Business models

Energy Service Company model.

Management issues:

The biggest challenge regards the bureaucratic and contractual aspects, namely the preparation of the contract and the procurement arrangement given that the project involves public administration. In addition, there were some issues with the management and the availability of consumption data and maintenance information for the university during the duration of the contract.

Policy framework conditions:

The key policy actors were the Environmental and Economic Ministries.

Regulations that stimulated/hindered the process

The project has been carried out respecting current national requirements for energy efficiency measures and thermal energy production from renewable sources.

Police instruments that moved the district into action

Carrots policy: 50% subsides by Kyoto fund, no tax for natural gas purchase;

Lessons learned/interesting findings

The main result consists of the reduction of operation and maintenance costs by the reduction of energy costs and the scale resizing of heat central with the possibility of reinvesting savings also in the conservation of buildings, so giving a benefit for the whole context in terms of buildings and energy system.

The realization demonstrates the feasibility of interventions traditionally considered with high landscape impact even in historical-cultural contexts and in full respect of the requirements and the restriction given by the Cultural Heritage Venetian Superintendence.

The project represents also a unique testbed realized in Italy on a university campus in terms of environmental context and scientific nature of the subject, as the demonstration for repeating the experience in another similar context.

Finally, this project represents a responsible response to the demands of sustainability, image improvement, the satisfaction of the end users, and use of the case study for institutional university teaching.

3.7 District Heating City of Turin (Italy)

This success story is not a best practice example in terms of cost-effective implementation of building renovation and renewables. However, it is an energy system intervention at a district scale in a unique context that may be relevant to other similar interventions.

Country: **Italy**

Name of city/municipality: **Turin**

Title of case study: **District Heating City of Turin**

Period of the renovation: **1982 - nowadays**

Author name(s): L. Teso, T. Dalla Mora, F. Peron, P. Romagnoni
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Link(s) to further project related information / publications, etc.:

Schematic figure or aerial overview

Turin's integrated cogeneration and district heating system is fed with the heat produced by the 3 modern combined cycle plants operating in cogeneration mode at the Moncalieri and Torino Nord stations. The needs for supplementary power are covered by the thermal power plants of Moncalieri, Torino Nord, BIT, Mirafiori Nord, and the Polytechnic.

The system is capable of **heating a volume of 60 Mm^3, covering 55% of the heat demand** in the buildings of Turin through a complex network of over 500 km, making Turin the city with the largest district heating system in Italy.

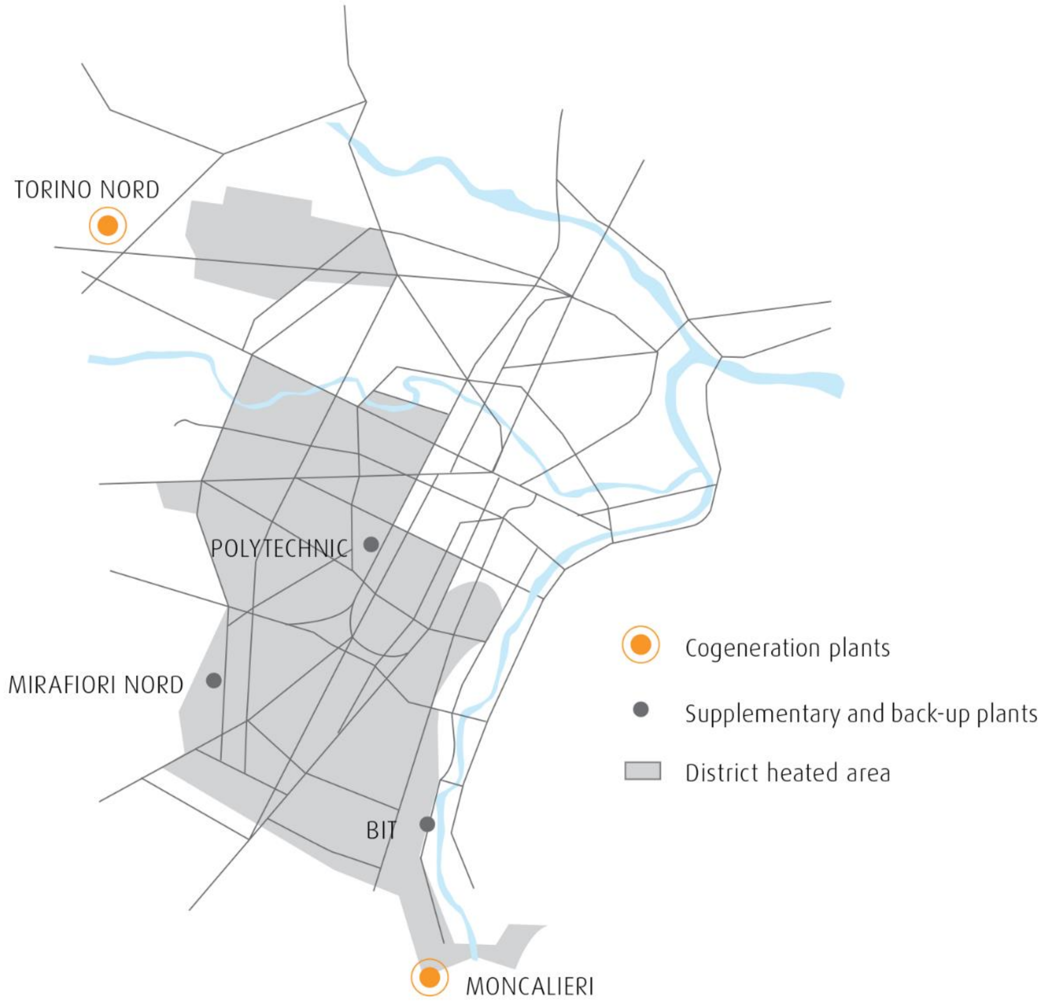

Figure 24. Scheme of Turin District Heating Network, showing the two main stations and the supplementary sub-stations for the heated area. Source: Iren Energia S.p.A.

Introduction and description of the situation before the renovation

Systems

Before the district heating change, the Turin residential buildings had individual heating systems. Each one was heated by individual or condominium boilers with fossil fuels, especially natural gas.

Some of the oldest buildings in the city of Turin were fed with ecoden, a fuel oil that since 2017 can no longer be used, as the Region considers it very polluting.

The first cogeneration system was installed in 1982 at “Vallette”, which was characterized by a heating power of 22 MW and supplied 3 million m^3. Since 2011, it is not anymore in use.

Air quality condition

The most critical pollutants in this area are nitrogen oxides, ozone, and airborne PM10 powders.

In particular, for nitrogen oxides, in the last years, the average annual concentration limit value (40 μg/m3) has been exceeded in all monitoring stations closest to the intervention area, as well as the hourly value of 200 $\mu g/m^3$ has been exceeded more than 18 times.

On the other hand, carbon monoxide is no longer a critical pollutant, since its concentrations in the atmosphere have been significantly reduced in recent decades, reaching values well below the limits prescribed by law.

Description of the renovation goal

The project aims are the containment of emissions into the atmosphere, thanks to the progressive elimination of hundreds of condominium boilers that allows obtaining a reduction in emissions of 134 tons per year of nitrogen oxides, 400 tons per year of sulphur oxides, and 17 tons of harmful powders. In terms of energy, an annual **saving of 95,000 toe** (equivalent tons of oil) is achieved, in addition to the 180,000 toe years already saved thanks to the Moncalieri cogeneration plant.

The most important environmental benefit regards its potential impact, in terms of improving the air quality in the urban area, following the expansion of district heating services. The district heating service in the Turin area can be extended to the city's northern sector, with an increase in the volume of buildings served, equal to 15 million m^3.

Additional benefits include the closure of the current system, “Vallette” and the reconversion of the areas due to the demolition of the power plant which makes it possible to form a continuous green belt to protect the district.

Description of the renovation concept

The main data of the Turin district heating network is summarized in **Table 21**.

Table 21. Main characteristics of Turin district heating network.

Heated volume	60 million m^3
District heating users	560,000 inhabitants
Total thermal energy delivered	2,000 GWh/y
Network extension (double pipes)	500 km
Energy saving	100,000 tep/year
CO_2 avoided emissions	300,000 ton/year
NO_x avoided emissions	134 ton/year
SO_2 avoided emissions	400 ton/year
Fine powders avoided emissions	17 ton/year
Reuse of meteoric water	yes
Condensate recovery produced by the combustion air cooling	22,000 m^3/year

The heating system is composed of two major power plants:

1- Moncalieri: it has been built in 1990 and the renovation measures, performed in 2006, consist of:

- replacement of the old existing power plant with a new combined-cycle cogeneration unit (2nd GT), upgrading existing capacity from 141MW to 400MW and thermal capacity of 260 MW;
- Installing a second combined-cycle cogeneration unit (3rd GT) using the latest technologies for simultaneous electricity and heat production.

2- Torino Nord: works started in 2011 and the project peculiarities of the intervention are:

- installation of 24 "very-low-Nox" BURNERS powered by natural gas;
- Adjustable input controls (IGV) for modulating the airflow;
- 2 combustion modes (Premix from 0 to 100% load; Pylot to stabilize the flame).

The most significant parts of the system are:

- the combined-cycle thermoelectric unit (gas turbine and steam turbine) with a gross power of about 400 MW fuelled by methane;
- the 3 integration and reserve steam generators, with a total thermal capacity of 340 MW;
- the heat storage system comprises 6 tanks with a total useful capacity of 5000 m^3.

Project Fact Box (I)

General information:

Parameter	unit	before renovation (1988)	after renovation (2017)
Urban scale of area:	m²	-	-
Population in the area:	Inhabit.	960,000	902,137
Number of buildings in the area		-	62,643
Heated floor area of all buildings	m²	7,350,000	19,800,000
Heated volume	m³	164 Mm³	60 Mm³
Building mix in the area:			
Residential	% of heated floor area of all buildings	62%	/
Schools, office buildings		35%	/
Production hall, industrial building		3%	/
Building mix in the area:			
Residential	% of total energy use of all buildings	*0.55*	*0.55*
Schools		*89.5*	*89.5*
Office buildings		*7.7*	*7.7*
Public Illumination		*0.34*	*0.34*
Transport		*1.51*	*1.51*
Other buildings		*0.4*	*0.4*
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	10	10
Medium consumers: AB, schools, etc. – 80-800 MWh/a		90	90
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		0	0
Property situation of buildings:			
Private	% of heated floor area	-	-
Public		-	-
Property situation of energy supply system (district heating):			
Private	% of heated floor area	100	0
Public		0	100

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation (1988)	after renovation (2017)
Heating demand (calculated)	GWh/a	-	2,000
Domestic hot water demand (calculated)	kWh/m²a	-	-
Cooling demand (calculated)	kWh/m²a	-	-
Electricity demand (calculated)	kWh/m²a	-	-
Heating consumption (measured)	kWh/m²a	-	-
Domestic hot water consumption (calculated)	kWh/m²a	-	-
Cooling consumption (measured)	kWh/a	3,656,648	3,961,362
Electricity consumption (measured)	kWh/a	11,667,430	10,266,918

(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	100	0
***Decentralised* biomass boilers**		-	-
***Decentralised* heat pumps**		-	-
Centralised (district heating)		-	100
Other *(please specify)*		-	-

Renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	GWh	0	371.5
Other (eolic)	GWh	0	0.1

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro	ca. 2 billion for power plants and networks	
- **building renovation costs**	Euro	-	/
- **heating/cooling supply costs**	Euro	-	/
- **renewable energy production costs**	Euro	-	/
LCC available	yes/no	no	no

Description of the technical highlight(s) and innovative approach(es)

The most recent power station of the whole system is located in North Turin, as it is following described:

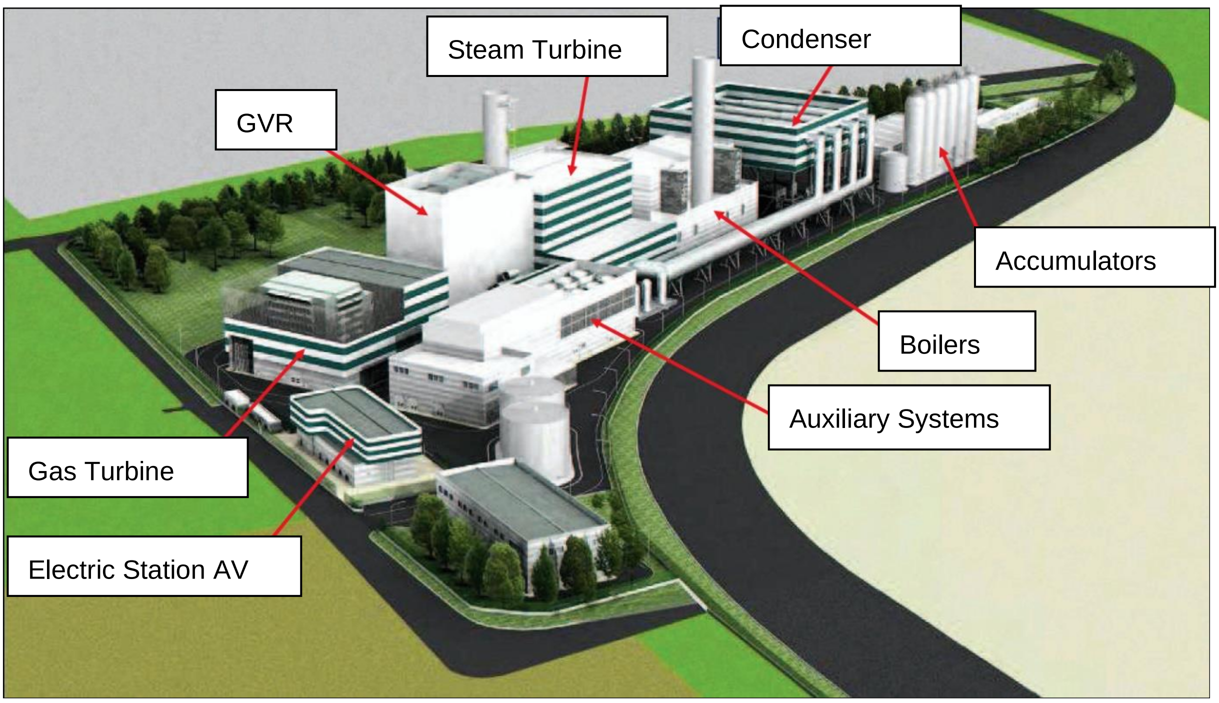

Figure 25. Schema of the new power station. Source: edited by the authors, based on Iren Energia S.p.A. report.

The cogeneration system, which has a combined-cycle group of about 400 MW and three integration and reserve steam generators with a total thermal capacity of 340 MW, is equipped with a **modern control room** with the most modern technological solutions available in the sector. Located on the first floor of the main building, there is a main console and a backup with 24-hour operation.

The plant is composed of the following production groups:

- 1 Combined cycle thermoelectric group in cogeneration structure;
- 3 integration boilers and district heating reserve;
- 1 Auxiliary boiler;
- 1 modern control room.

The combined cycle fuelled by gas is the most efficient of this type, offering considerable advantages over traditional ones through a high efficiency (55-58%), a reduced environmental impact, and a low-cost production of energy. The combined-cycle thermoelectric power system in the cogeneration structure of the power system consists of the following equipment:

- a gas turbine with an electrical power of about 250 MW, powered by natural gas, with an air-cooled electric generator equipped with "very low NOx" burners;
- a recovery steam generator with a chimney, equipped with a system to reduce emissions into the atmosphere;
- a condensation steam turbine, composed of three sections of electrical power of about 140 MW with an air-cooled electric generator, with low-pressure steam extraction for the production of superheated water for district heating;
- a condensation system for the steam and air turbine with an air heater;
- heat exchanger system for district heating, with a capacity of 220 MWt, which uses the low-pressure steam tapped by the steam turbine.

Table 22. Energy production of Turin district heating network.

Electric power	390 MW (electric attitude)
	335 MW (cogeneration attitude)
District heating thermal power	220 MW
Electrical efficiency	56%
Thermal efficiency cogeneration	83%

Decision and design process

General/organizational issues:

The intervention was performed to meet the request of the inhabitants of Turin. The use of a power plant makes it possible to produce and distribute hot water and electricity to users, and there is a progressive decrease in the pollutants emitted by individual boilers using non-renewable energy sources.

Stakeholders

A total of 66 subjects were involved:

- 28 companies
- 5 research centres
- 23 institutions
- 10 non-profit associations

More than 350 participants. From the city of Turin:

- 77 persons
- 55 persons directly involved in the workgroups

Main steps

The whole intervention was possible thanks to a deep knowledge of Turin's urban development, which has brought a successful overall planning of the district heating system and allowed to build the first integrated cogeneration. Since then, it has been observed a well-run and controlled improvement over the years.

Resources available before the project

There were no resources available before the project.

Drivers and barriers (opponents)

The main driver was the wish of the municipality; opponents are not known.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	[a] Municipality [b] FSU (Finanziaria Sviluppo Utilities)	[a] Decision maker [b] Financier	[a] Savings, carbon reduction, quality of living improvement [b] Business
Users/investors (individual owners, housing association, building managers, asset managers, project developers)			
District-related actors (Community/occupants organizations, etc.)	Territorial committees	influencer	Savings, standards improvement
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	IREN Energia AES Torino	Decision maker	Sustainable development and energy renovation. Profit
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Politecnico di Torino Università di Torino	Technical advisor	To contribute with own scientific know-how to improve the system
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	-	Technical advisor	

Design approach applied:

The design approach followed was an iterative process in which several alternatives were studied, and multiple expansions have followed over the years.

This study investigated the operation of heat storage in district heating systems management. It is shown that the installation of heat storage optimizes the efficiency of the district heating system, reducing the need for heat produced by backup boilers during peak demand and increasing CHP generation. In this way, primary energy savings are obtained.

These systems can store heat at night when demand is minimal, and use it during the early hours of the morning when demand is at its highest. During the daytime, they can also perform further charge and discharge cycles. Still, these intermediate operation cycles have low relevance because they do not affect the proportion covered by cogeneration. For these reasons, the simulation modelled the behaviour at night-time and during the early hours of the morning that involve the most significant amount of energy.

Technical issues:

Since the Turin DH network was the first example in Italy of a city-scale intervention, there were a lot of difficulties regarding the planning and the work for the implementation of the project. The major challenges for the project were the use of new technologies and the continuous planning of expansions in the network.

Financing issues:

The society that started the project found economic limitations because of its public nature and, in some cases, the impossibility of expanding the network.

Nowadays, to guarantee the growth of IREN and ensure a unified and stable strategy, the majority shareholders – FSU (Finanziaria Sviluppo Utilities, equally controlled by the municipalities of Turin and Genoa) and the ed Enia agreement municipalities. The articles of association limit the share held by private individuals to a maximum of 5%.

Management issues:

There were no particular challenges in the management of the project, but as said before, during the first years, the society that started the project found economic limitations because of its public nature and in some cases, the impossibility of expanding the network, caused by lack of adequate laws dealing with a new type of heating system.

Policy framework conditions:

The Industrial Union of Turin, Iren Mercato S.p.A., and Iren Energia S.p.A. have signed a framework agreement to promote district heating as an efficient, economical, and sustainable energy solution for the energy upgrading of the buildings of the Metropolitan City of Turin. The agreement is part of the broader development of the Group's integrated district heating systems, in line with the 2019-2023 Business Plan and with the company strategy that leverages historical strengths such as the link with customers and relations with territories of reference and develops a distinctive value proposition based on the integration of the offer, digital channels, and customer centrality.

Lessons learned/interesting findings

Major success factors

Organizing and realizing an accurate agenda related to the improvement of environmental performance, monitoring, and measuring data, supervision and strict deadlines for each area are essential elements for the successful implementation of such an intervention. Furthermore, it has been possible to reach a value of 98% of energy introduced in the network thanks to the heat storage system settled into the power station and along the network.

The disadvantages of a district heating network may be the large economic cost to be incurred and the invasiveness of the laying of underground pipes.

Major bottlenecks

Since there is a very wide distribution network, the number of users lacking electricity and heating supply would be considerable in case of damage even at one point.

Major lessons learned

During the system planning of this district heating, it has been given great importance to reduce as much as possible the emission of pollution in the environment as well as to maximize the energy production to reach a wider range of users.

Aspect to be transferred

The planning methodology used in this case has led Turin to be the city with the largest district heating system in Italy and one of the largest in Europe.

3.8 Rainha Dona Leonor neighbourhood, Porto (Portugal)

Country: **Portugal**

Name of city/municipality: **Porto**

Title of case study: **Rainha Dona Leonor, Porto**

Period of the renovation: **2009-2014**

Author name(s): Manuela Almeida, Ricardo Barbosa
Author email(s): malmeida@civil.uminho.pt
Link(s) to further project related information / publications, etc.:
https://www.covenantofmayors.eu/IMG/pdf/Porto.pdf
http://iea-annex56.org/Groups/GroupItemID6/13.PT.pdf
http://www.ilobo.pt/ines_lobo_arquitectos_lda/01023_Rainha_D._Leonor_Social_Housing_Quarter.html

Schematic figure or aerial overview

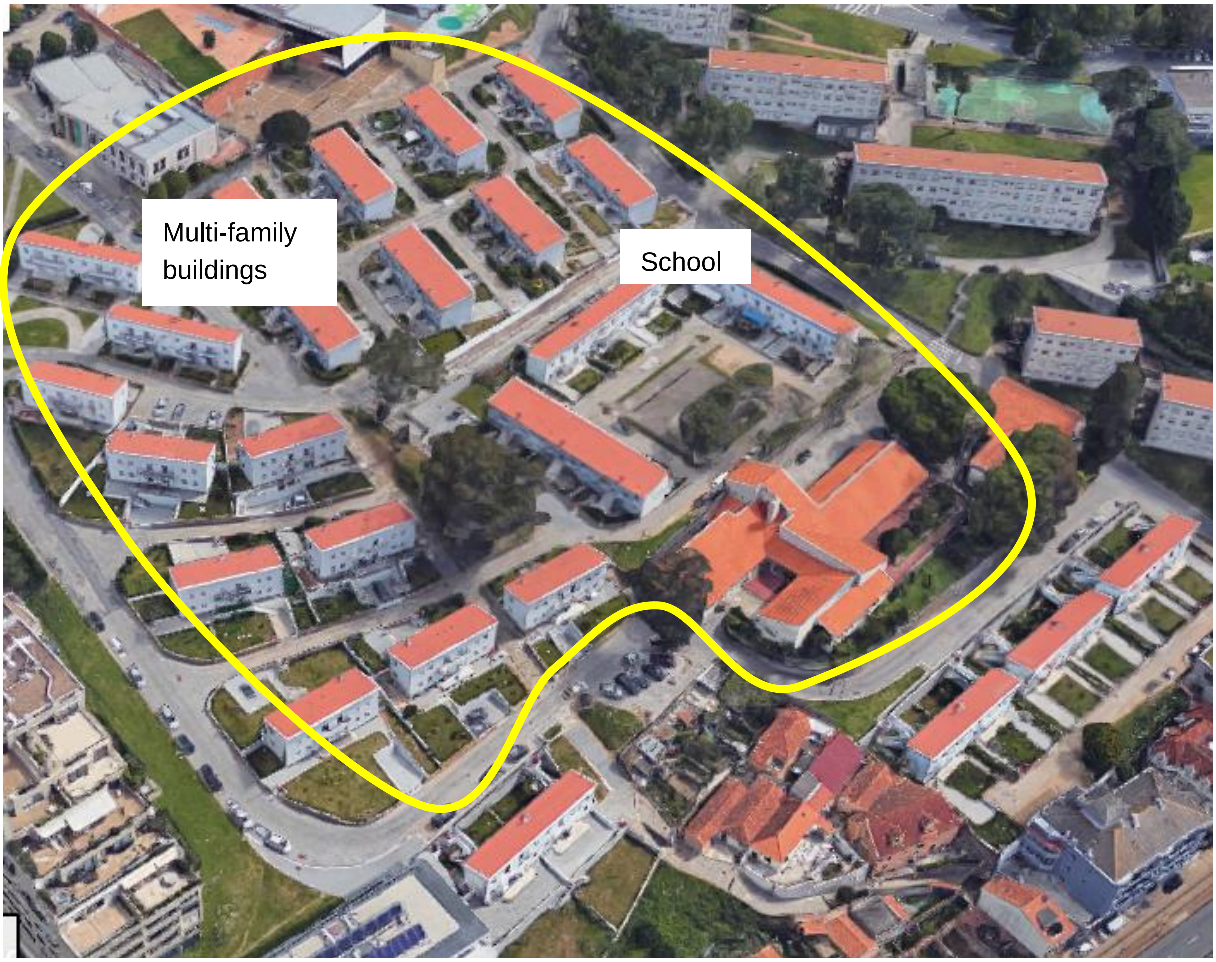

Figure 26. Schematic view of Rainha Dona Leonor neighbourhood. Source: “Google Maps”.

Introduction and description of the situation before the renovation

Rainha Dona Leonor neighbourhood consists of 150 multifamily dwellings originally built in 1953. The buildings, with a concrete structure, non-insulated envelope with brick walls, lightweight slabs, and single-glazed wood frame windows, had never been upgraded, which led to a profound state of degradation of the neighbourhood. Additionally, several buildings had elements added illegally, such as small exterior storage units and other changes to the original façades.

During the planning phase of the renovation intervention, the municipality had to decide whether to deeply renovate or demolish the buildings. The decision to renovate was made in 2009 and the plans included reducing the total number of dwellings from 150 to 90. The objective was to increase the average area of the housing units. About 5,000 m^2 of the gross heated area was renovated, and the renovation works were completed in 2014.

At the time of the renovation intervention, the neighbourhood was a social housing complex composed of eighteen two-story buildings and three apartment blocks. As part of the overall neighbourhood intervention (and the financing operation of the renovation), the three apartment blocks were demolished and replaced by new buildings (including a private non-social housing residential building).

Initially, energy efficiency was not central to the renovation intervention, which aimed to improve the dwellings' liveability and restore consistency and homogeneity to the buildings and exterior spaces.
There was not any heating or cooling system installed. Occupants used individual electric heaters or portable fan coils in their houses. Individual electric heaters with storage tanks supplied the domestic hot water.

Figure 27. Building before and after the intervention. Photos: University of Minho team.

Description of the renovation goal

The main driver for the renovation works was to improve the deep state of physical degradation of the buildings. Additional drivers included recovering the neighbourhood's image, maintaining the original architectural and urban features, increasing the dwellings area, and adjusting it to the actual living standards. There were also concerns regarding the maintenance of the neighbourhood's architectural image and characteristics.

The main concern of the renovation decision was not related to the reduction of energy needs. However, due to the depth of the renovation intervention, it had to comply with the thermal requirements imposed by national regulations. Therefore, the building envelope had to be significantly improved in terms of energy performance. Measures, such as exterior wall and roof insulation, as well as double-glazing windows, were taken as a way to address poor thermal comfort and thermal bridge issues, which were responsible for severe condensation problems. In addition, new heating and cooling systems were put into place, as well as renewable energy supply sources.

Description of the renovation concept

The renovation included improvements to the building envelope insulation. Exterior wall and roof insulation were added, as well as double-glazing windows. 60 mm thick expanded polystyrene (EPS) panels were used for the external walls. 50 mm extruded polystyrene (XPS) panels were used for the roof insulation. Windows were replaced by wooden frames and double glazing with 4 mm and 6 mm panes (Table 23). New energy-efficient heating and cooling systems were installed as a Multi-split air conditioning system with a coefficient of performance (COP) of 4.1 for heating and an energy efficiency ratio (EER) of 3.50 for cooling, on each flat, with a solar thermal system for domestic hot water (3 m^2 per flat).

Renovation measures reduced 12.9 tons of annual carbon emissions and a yearly primary energy savings of 286.54 kWh/m^2. In particular, the improvement of the building envelope and airtightness control allowed for an annual reduction in energy needs of 49.78 kWh/m^2a. The uptake of renewable energy by using solar thermal panels for domestic hot water (DHW) contributes 9.96 kWh/m^2 per year to the neighbourhood's energy needs reduction.

Even though rents were increased in Rainha Dona Leonor following the renovation, this could be offset by a decrease of about 70% in energy costs for the residents.

Table 23. Measures implemented in the renovation intervention regarding building envelope.

Element	U-Value (W/m^2°C) before renovation	U-Value (W/m^2°C) after renovation	Material used
Exterior Walls	1.38/1.69	0.45/0.48	60 mm EPS insulation
Windows	3.40	2.90	Double glazing with wood frame
Roof	2.62	0.64	50 mm XPS insulation

Domus Social is the main involved stakeholder, the municipal company whose purpose is to manage the municipal public housing stock (including social housing), maintenance and conservation of all real estate, equipment, and municipal infrastructures.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	19,700	19,700
Population in the area:	-	N. a.	N. a.
Number of buildings in the area	-	150	90
Heated floor area of all (renovated) buildings	m²	5,000	5,000
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings		
Multi-family homes (MFH) - up to three stories and/or 8 flats		95	95
Apartment blocks (AB) - more than 8 flats			
Schools		5	5
Office buildings			
Production hall, industrial building			
other (please specify)			
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	97	97
Medium consumers: AB, schools, etc. – 80-800 MWh/a		3	3
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		0	0
Property situation of buildings:			
Private	% of heated floor area		
Public		100	100
Property situation of energy supply system (district heating):			
Private	% of heated floor area	N. a.	N. a.
Public		N. a.	N. a.

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	**119**	**69**
Domestic hot water demand (calculated)	kWh/m²a	37	27
Cooling demand (calculated)	kWh/m²a	6.5	8
Electricity demand (calculated)	kWh/m²a	N. a.	N. a.
Heating consumption (measured)	kWh/m²a	N. a.	N. a.
Domestic hot water consumption (calculated)	kWh/m²a	413.75	127.21
Cooling consumption (measured)	kWh/m²a		
Electricity consumption (measured)	kWh/a	20,456	6,289
(Thermal) energy supply technologies:			
Decentralised **oil or gas boilers**	% of heated floor area	-	-
Decentralised **biomass boilers**		-	-
Decentralised **heat pumps**		-	-
Centralised (district heating)		-	-
Other*: electric heaters*		*100*	-
Other*: Multi-Split HVAC*		-	*100*
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	540
Photovoltaics	kW_p	0	0
Other (please specify)	kW	0	0

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	-	1'338
- **building envelope renovation costs**	Euro/m²	-	N. a.
- **heating/cooling supply costs**	Euro/m²	-	130
- **renewable energy production costs**	Euro/m²	-	57
LCC available	yes/no	no	no

Description of the technical highlight(s) and innovative approach(es)

The combination of building envelope measures with the chosen heating, cooling, and DHW systems led to considerable energy demand reductions, which are quite significant in the social housing context. The heating needs were reduced by 43%, evidencing the effectiveness of the measures implemented to improve the building envelope. The cooling system installed also improved the indoor living conditions during summer. The measures adopted in renovation led to an increase in housing rents. Still, this increase was offset by potential energy savings for heating, cooling, and DHW, which were reduced by 70%, enabling users to heat indoor spaces and keep the interior environment within healthy and comfortable temperatures at a significantly lower cost.

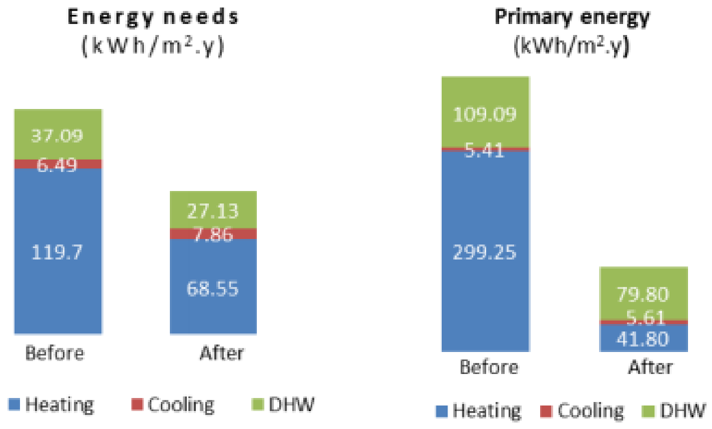

Figure 28. Energy needs for heating, cooling, and DHW before and after renovation and non-renewable primary energy use for heating, cooling, and DHW. Source: https://www.covenantofmayors.eu/IMG/pdf/Porto.pdf.

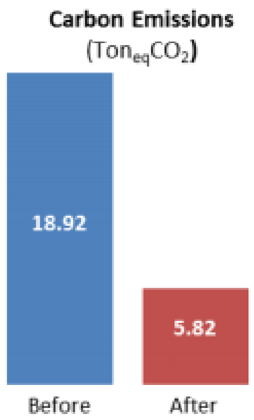

Figure 29. Carbon emissions before and after the building renovation related to the non-renewable primary energy use. Source: https://www.covenantofmayors.eu/IMG/pdf/Porto.pdf.

An innovative approach adopted in this project is related to financing the neighbourhood's overall intervention. Initially, the municipality intended to support the costs of renovating the two-floor buildings but found it very difficult. As a way to promote private investment, the municipality held a public tender to find a developer who would demolish the three apartment blocks and build “high-end social housing” buildings, as well as a private-owned residential building that would be put on the regular market. The financing model took advantage of the prime location (and economic value) of the neighbourhood land, which is close to the centre of the city of Porto and has generous Douro River views. The contract with the developer included several obligations dedicated to protecting the investment that had to be made in the social housing neighbourhood. For example, the developer could only start with the private-owned residential building construction after all the interventions regarding the social housing project were concluded. The approach (finalized in 2018) allowed the neighbourhood to be renovated and expanded by introducing new social housing (20 dwellings) that meets current energy and thermal requirements, keeping residents in the same location, and housing new residents at no cost for the municipality. The new four-story buildings have 70 new dwellings (from one-bedroom to four-bedroom apartments) (**Figure 30**).

Figure 30. View of the new buildings in Rainha Dona Leonor neighbourhood. Source: https://www.engenhariaeconstrucao.com/

Decision and design process

General/organizational issues:

The project was initiated to respond to a high level of deterioration of the buildings.

The main stakeholders involved in the building's renovation were:
Domus Social (municipality social housing company)
Inês Lobo Architects
AdEPorto - Agência de Energia do Porto (municipal energy agency)

The main stakeholders involved in the new construction were:
Domus Social (municipality social housing company)
AYTHYA – Investimentos Imobiliários, Lda (real estate development company).

Barriers to the project included:

- the need to comply with the norms: although energy renovation was not the focus of the intervention, the intervention had to comply with thermal requirements imposed by national regulations, which increased complexity;
- the preliminary lack of financing to complete the necessary renovation works;
- the discussion on whether the best solution was to renovate or demolish;
- the temporary transfer of tenants to other buildings because of the need to have the buildings vacant to carry out the renovation works.

Stakeholders' role and motivation

Main stakeholder	Specify which organization(s) was (were) involved	Role (Decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Domus Social (municipality social housing company)	Owner/Decision maker	High level of building deterioration
Users/ investors (individual owners, housing association, building managers, asset managers, project developers)	Domus Social (municipality social housing company) AYTHYA (real estate development company)	Owner/Decision maker Investor	a) improvements in the profound state of physical degradation of the buildings b) recover the neighbourhood's image maintaining architectural and urban original characteristics c)Increase the dwellings area, adjusting it to today's people's life patterns
District-related actors (Community/occupants organizations, etc.)	There weren't any of them involved	-	-
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	There weren't any of them involved	-	-
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Inês Lobo Architects AdEPorto - Agência de Energia do Porto (municipal energy agency)	Influencer/Technical advisor, delivery	
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	There weren't any of them involved	-	-

Design approach:

The main purposes of the intervention were to improve the indoor quality of the dwellings and simultaneously restore consistency and homogeneity of the neighbourhood, subtracting the illegally added elements and restoring the original building volumes.

The main targets were:

- to recover the neighbourhood's architectural image;
- to renovate the buildings due to their deep degradation state;
- to adapt the living areas to modern living standards since the original dwellings were very small;
- to improve indoor comfort;
- to renovate outdoor areas such as playgrounds and circulation areas.

The technologies included in the intervention were the following:

- exterior wall insulation;
- roof insulation;
- double glazing windows;
- daylighting improvement with bigger windows in the living room;
- energy-efficient heating and cooling systems;
- solar thermal system for DHW.

The measures concerning the building envelope were:

- wall: External insulation and wall renovation with 60mm of EPS covered with reinforced plaster;
- roof: Insulation with 50mm XPS panels;
- windows: Wooden frames + double glazing with 4mm and 6mm panes.

The measures concerning the building systems were:

- HVAC: Multi-split air conditioning system with a coefficient of performance (COP) of 4.1 for heating and energy ratio (EER) of 3.50 for cooling, on each flat;
- lighting: Improved daylighting with larger windows;
- renewables: 3 m2 of solar panels for DHW per flat;
- DHW: New electric heater with a storage tank.

The main challenges in the design phase consisted of the decision-making process regarding the intervention to be made. Demolition was also considered as an alternative to the renovation intervention.

Technical issues:

The major constraint regarding technical issues consisted of the lack of infrastructure that allowed for the implementation of heating and cooling equipment without affecting the aesthetic of the buildings.

Financing issues:

Private investors made the most significant investment in neighbourhood renovation interventions. The municipality designed and implemented a financing model that allowed a private investor to retain a part of the neighbourhood’s land and promote a new real estate development in exchange for being responsible for renovating and constructing a new social housing building. There were delays regarding the public tender and contracting that caused constraints to the initial planning for the neighbourhood renovation, especially due to the complexity of the financing operation.

Even though rents were reported to be higher after the renovation works, this rent increase is expected to be offset by a reduction of about 70% in energy costs for the residents of the renovated dwellings.

Management issues:

The main challenge regarding the project management consisted of moving the residents to other locations to carry out the renovation work.

Policy framework conditions:

Although there was no intention to perform an energy renovation at the beginning of the renovation process, it should be noticed that thermal regulations and energy standards requirements, and in particular the compliance with the Decree-Law 118/2013 requirements, were key to obtaining energy reductions.

Lessons learned/interesting findings

The technical measures implemented during the renovation allowed for significant energy savings and reductions in carbon emissions. The intervention also made it possible to achieve a higher quality in indoor comfort conditions, which is quite important in the context of social housing.

Identified bottlenecks include the preliminary lack of financing for completing the necessary renovation works and the need to move tenants to other buildings to carry out the renovation works.

Rents were increased due to the intervention, which has been contested by the residents, despite the expected savings in energy consumption.

In addition to the buildings´ renovation intervention, it was foreseen that a part of the neighbourhood would be demolished, and a privately-owned residential building would be constructed to finance additional social housing. This model was implemented and completed in 2018 by a private promoter that was chosen through an international public tender. Besides the obvious promotion of social inclusion, the model can be considered an innovative business model to finance new social housing and renovate existing neighbourhoods. However, it is dependent on several contextual conditions (e.g. attractiveness of the location or available space).

There is significant potential for transferability and replicability of the lessons learned in this project for other municipalities and governance structures, namely regarding the opportunity to combine social inclusion and improve energy efficiency measures.

3.9 Vila D'Este neighbourhood, Vila Nova de Gaia (Portugal)

Country: **Portugal**

Name of city/municipality: **Vila Nova de Gaia**

Title of case study: **Vila D' Este**

Period of the renovation: **2009-2015**

Author name(s): Manuela Almeida, Ricardo Barbosa
Author email(s): malmeida@civil.uminho.pt
Link(s) to further project related information / publications, etc.:
https://www.interregeurope.eu/policylearning/good-practices/item/677/vila-d-este-housing-refurbishment/
https://www.gaiurb-habitacao.pt/viladeste
http://www.cm-gaia.pt/fotos/editor2/a-nova-vila-deste.pdf

Schematic figure or aerial overview

Figure 31. Schematic view of Vila D'Este neighbourhood after renovation. Source: "Google Maps".

Introduction and description of the situation before the renovation

Vila D’Este is a densely populated neighbourhood, with approximately 17,000 inhabitants, located in Vilar de Andorinho, in the municipality of Vila Nova de Gaia, Portugal. The neighbourhood has a total of 109 buildings distributed over 18 blocks, with 2,085 dwellings and 76 commercial spaces. It was initially built between 1984 and 1986, through a funding program for Housing Developments. The neighbourhood is one of the most significant housing developments in the metropolitan area of Porto and the municipality of Vila Nova de Gaia and is served by an elementary school (built in 1999), a sport and public pool facilities (built in 2001).

From the urban perspective, it was a closed, degraded, and peripheral area, making it a challenge also in terms of social cohesion. The area was considered critical regarding social problems and the concentration of socially vulnerable minorities.

The buildings of Villa D'Este used a technique designated as "tunnel formwork", which is very common in social housing projects from the '80s of the XX century in Portugal. The stairwells are prefabricated and supported on ledges in the concrete walls of the adjacent "tunnels". The façades are of brick walls or blocks without insulation.

Before the renovation intervention, there was a general deterioration of the façade materials, mainly due to the absence of maintenance and repair measures. The anomalies consisted of low indoor thermal comfort, poor ventilation, the presence of water infiltration, and condensation, which have a negative impact on the durability of the building components and indoor air quality.

The renovation intervention represented a very high investment effort for the Vila Nova de Gaia municipality. As the ownership of buildings in the neighbourhood is divided between the municipality and the private owners, no financial return from the intervention was expected.

At the urban level, the lack of an effective planning process guiding the disconnected interventions made in the last decades was also identified as a problem that had to be dealt with in the scope of an overall neighbourhood intervention.

Description of the renovation goal

The renovation was integrated into a new strategic vision for the neighbourhood that included improving educational policies, sports, urbanism and public spaces, accessibility, and road systems.

The physical intervention in the buildings was triggered by the state of degradation and the need to meet current energy and indoor air quality requirements, as well as to renovate the entire neighbourhood from an architectural and aesthetic perspective.

Figure 32. Façade in Vila D'Este district before renovation (left) and after renovation (right). Source: Gaiurb, from: http://www.cm-gaia.pt/fotos/editor2/a-nova-vila-deste.pdf

Description of the renovation concept

The neighbourhood renovation was part of a dynamic action program created to involve all partners in the process. It was designed to ease the articulation between public and private organizations and to guarantee the success of the intervention, through complementarity and innovative solutions.

The neighbourhood renovation was carried out in two separate phases and using distinctive funding instruments. In both phases, the project was co-financed by the municipality and the EU structural funds. The first phase (2008) was financed through "ON.2 – North Regional Operational Programme (QREN)". The second phase (2011) was based on the "Cities Policy - Partnerships for Urban Regeneration" program.

The first phase concerned three different axes: Building Requalification, Public Space and Urban Environment Requalification, Social Inclusion, and Socio-Economic and Professional Valorisation. Physically, this intervention focused on 6 blocks of the neighbourhood, besides reorganising the road system and creating green areas and new walking zones. Socially, the intervention was followed by several actions dedicated to promoting the qualification of minorities living in the neighbourhood. In addition, several actions were created to promote better conditions for the young population to access the employment market.

The second phase in 2011 focused on two dimensions: Building Requalification and Social Inclusion and Socio-Economic and Professional Valorisation of the population. This phase intended to continue the work already initiated in the first phase and focused on the remaining 12 blocks.

At the building level, the renovation was primarily an extensive improvement of the building envelope. For that purpose, the municipality's energy agency – ENERGAIA – developed an energy analysis based on thermal regulations requirements and the Portuguese Thermal Performance Building Code in force.

The following measures and materials were implemented:

Roof

- Execution of metallic coating type "Roofzip[3]";
- Introduction of an 8 cm thick layer of rockwool insulation and windshield vapour barrier, heat transfer coefficients of 0.39 W/m2 ºC and 0.38 W/m2 ºC, for upward and downward airflow, respectively;
- Application of Aeolian[4] fans on top of the ventilation conducts of sanitary facilities.

[3] Waterproof metallic coating which is applied without the use of screws - www.roofzip.com.
[4] Fans driven by the action of wind.

Exterior Walls

- Application of a 5 cm thick layer of thermal insulation in external walls with expanded extruded polystyrene (ETICS), heat transfer coefficients of 0.59 W/m2 ºC;
- Installation of panels and flaps in GRC (Glass Fibre Reinforced Cement);
- Replacement of window areas in buildings' entrance doors, stairwells, and storerooms;
- Installation of shading elements in window areas.

The renovation included the installation of approximately 500 m^2 of solar panels.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m^2	170,000	170,000
Population in the area:	-	~17,000	~17,000
Number of buildings in the area	-	109	109
Heated floor area of all buildings	m^2	126,000	126,000
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings		
Multi-family homes (MFH) - up to three stories and/or 8 flats			
Apartment blocks (AB) - more than 8 flats		85	85
Schools		5	5
other: sales and cultural		5	5
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	85	85
Medium consumers: AB, schools, etc. – 80-800 MWh/a		15	15
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		-	-
Property situation of buildings:			
Private	% of heated floor area	N. a.	N. a.
Public		N. a.	N. a.
Property situation of energy supply system (district heating):			
Private	% of heated floor area	N. a.	N. a.
Public		N. a.	N. a.

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	84	57
Domestic hot water demand (calculated)	kWh/m²a	30	30
Cooling demand (calculated)	kWh/m²a	N. a.	N. a.
Electricity demand (calculated)	kWh/m²a	N. a.	N. a.
Heating consumption (measured)	kWh/m²a	N. a.	N. a.
Domestic hot water consumption (calculated)	kWh/m²a	N. a.	N. a.
Cooling consumption (measured)	kWh/m²a	N. a.	N. a.
Electricity consumption (measured)	kWh/m²a	N. a.	N. a.
(Thermal) energy supply technologies:		N. a.	N. a.
***Decentralised* oil or gas boilers**	% of heated floor area	-	-
***Decentralised* biomass boilers**		-	-
***Decentralised* heat pumps**		-	-
Centralised (district heating)		-	-
Other *(please specify)*		-	-
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	~500
Photovoltaics	kW_p	0	0
Other (please specify)	kW	0	0

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro	~12 000.000,00	
- **building envelope renovation costs**	Euro/m²	-	-
- **heating/cooling supply costs**	Euro/m²	-	-
- **renewable energy production costs**	Euro/m²	-	-
LCC available	yes/no	no	no

Description of the technical highlight(s) and innovative approach(es)

The combination of building envelope measures with the chosen systems led to considerable energy and carbon emissions reductions, which in the social housing context are quite significant. In terms of heating demand, a calculated reduction of 32% (27 kWh/m^2a) was achieved with the intervention. The Vila D´Este Housing renovation project improved the buildings´ energy performance, allowing a potential annual saving of 3,800 ton $carbon_{eq}$ and an estimated annual saving of 837,433.92 €/year, according to the information provided on the Interreg Europe website[5].

Decision and design process

General/organizational issues:

The intervention was initiated because of a strategic decision by the municipality to improve the liveability of the neighbourhood. The buildings in the neighbourhood presented a high level of deterioration. There were complaints through the residents' association of poor indoor conditions with high levels of thermal discomfort and extensive areas of mould.

The project was coordinated by the City of Gaia, and the following interested agents were involved:

- owners association;
- residents association;
- condominiums association;
- Junta de Freguesia de Vilar de Andorinho (Parish council of Vilar de Andorinho);
- Vilar de Andorinho Church;
- Gaiurb-Urbanismo e Habitação, EM (municipality social housing company);
- CONSTRUCT – Universidade do Porto (research centre from the University of Porto).

[5] https://www.interregeurope.eu/policylearning/good-practices/item/677/vila-d-este-housing-refurbishment/

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Gaiurb (municipality social housing company)	Owner/ Decision maker	Improved dwellings and surrounding conditions and increased quality of life of the residents
Users/ investors (individual owners, housing association, building managers, asset managers, project developers)	Owners association* Junta de freguesia de Vilar de Andorinho (Parish council of Vilar de Andorinho)	Influencers	Improved quality of life of the residents
District-related actors (Community/occupants organizations, etc.)	Residents association	Influencers	Improved quality of life of the residents
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	There weren't any of them involved	-	-
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	CONSTRUCT – University of Porto (Energy efficiency research centre) Municipality's energy agency (ENERGAIA)	Technical advisor	Participation in relevant research and implementation project
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	There weren't any of them involved	-	-

Design approach:

The renovation intervention was part of a broader plan of the municipality to improve the neighbourhood's image and the residents' quality of life. The project had two main objectives to be integrated: energy performance improvement and complete aesthetics reformulation of the neighbourhood.

The major challenges in the process were related to the relocation of families during the renovation works.

Technical issues:

No information available.

Financing issues:

The strategic intervention in Vila D´Este neighbourhood was financed by the municipality and through EU structural funds (Table 24). Although there are differences between the two phases, there was roughly 80% funding from the EU and 20% from the municipality for the operation.

Based on this investment and the energy savings achieved, the estimated payback time is of less than 12 years.

Table 24. Phases of the renovation process made in Vila D'Este district.

Phases	Phase I	Phase II
Year	2009	2013
EU structural funds	3,565,782.67	6,200,411.71
Gaiurb	1,091,139.70	1,247,632.80
Total Investment	**4,656,922.37**	**7,448,044.51**

Management issues:

No information available.

Policy framework conditions:

The obligation to comply with thermal regulations and energy standards, in particular, the requirements of Decree-Law 118/2013 was key to obtaining energy reductions.

Lessons learned/interesting findings

The implementation of the renovation of the neighbourhood constitutes a clear example of a successful intervention that can increase the quality of life of the residents, as well as address social inclusion and improve the sustainability of the built environment, with significant energy savings and carbon emissions reductions.

The project also demonstrates good practice regarding the implementation of national thermal regulations in line with the Energy Performance of Buildings Directive (EPBD) objectives and nZEB target and EU policy framework related to energy poverty concerns.

There is a significant potential for transferability and replicability of the lessons learned in this project for other municipalities and governance structures, namely regarding the opportunity provided by EU structural funds and the focus on the combination of social inclusion and improvement of energy efficiency (and renewable energy sources) measures.

3.10 Boavista neighbourhood, Lisboa (Portugal)

Country: **Portugal**

Name of city/municipality: **Lisbon**

Title of case study: **Boavista neighbourhood, Lisbon**

Period of the renovation: **From 03/2013 to 09/2013**

Author name(s): Manuela Almeida, Ricardo Barbosa
Author email(s): malmeida@civil.uminho.pt

Link(s) to further project related information / publications, etc.:
http://lisboaenova.org/wp/eco-bairro-boavista-ambiente/
http://www.cm-lisboa.pt/fileadmin/Noticias/ficheiros/Eco-District_Boavista__PT_.pdf

Schematic figure or aerial overview

Figure 33. Schematic view of the intervention areas after renovation. Source: ”CML” from: http://www.lisboaenova.org/images/stories/EcoBairroBoavista/Eco_Bairro_Boavista_fevereiro_2012_BOOKv5_print.pdf

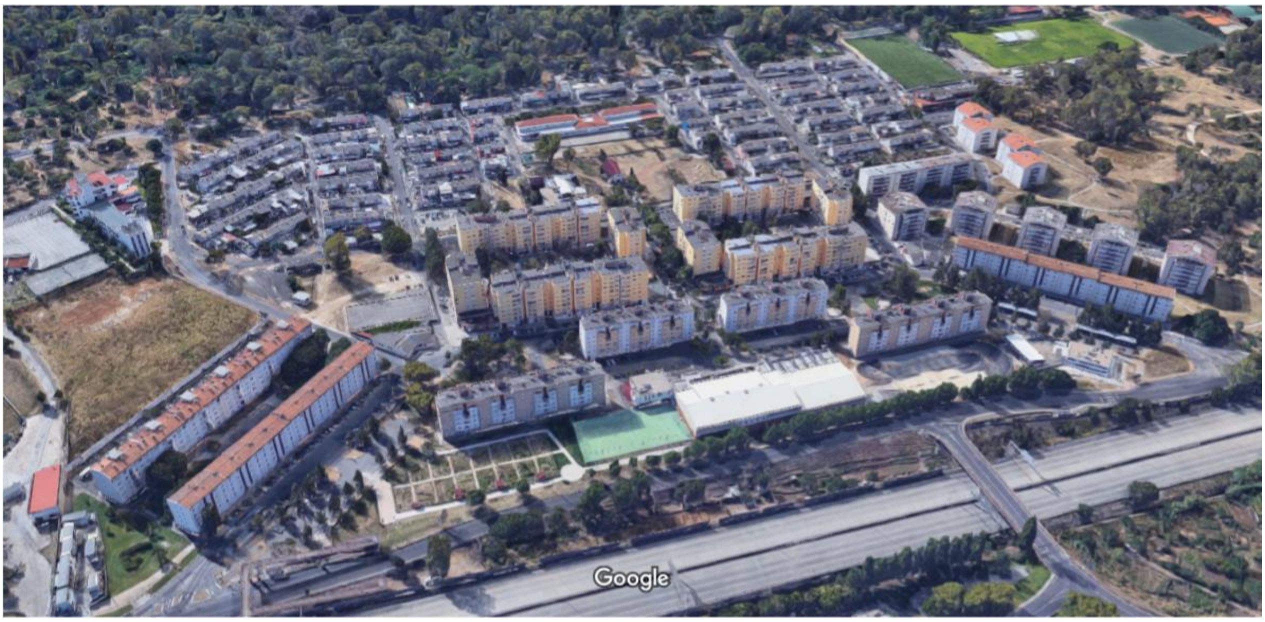

Figure 34. 3D aerial view after renovation - Boavista neighbourhood. Source: “Google Maps”.

Introduction and description of the situation before the renovation

Boavista neighbourhood is located on the western outskirts of Lisbon and is surrounded by the Forest Park of Monsanto. City authorities in the '60s of the XX century built this neighbourhood to relocate families with low resources who lived clandestinely in the city's central areas.

The area has undergone successive phases of rehousing, and its current population is estimated at 6,000 inhabitants, with a total of 1,559 housing units. The majority of the units are public-owned. The municipal company Gebalis manages this neighbourhood that mainly consists of two different areas, which were occupied in different rehousing periods: Single Family Houses, designated as "Alvenarias" (1960/1970) from the first phase, and Multifamily Buildings and Services (1980/1990) that were built in different phases. Table 25 shows some key characteristics of this neighbourhood.

Table 25. Key characteristics of Boavista neighbourhood. Source: Gebalis (www.gebalis.pt).

Rehousing phases	1st : 510 "Alvenarias" – 1960/1970 2nd: 4 lots built between 1976 and 1977 3rd: 9 lots built between 1981 and 1984 4th: PIMP[6] – 34 lots built between 1988 and 1996 5th: PER[7] – 14 lots built between 1997 and 1999
Socio-demographic characterisation	About 6,000 residents. The majority of the population is Caucasian. There are about 20 families of gipsy ethnicity and 30/35 families of African origin.
Employment and jobs	The population presents a generalized low level of education. There is a significant percentage of retired people and individuals with temporary jobs, mainly related to the building construction sector, hospitality, and housekeeping services.

Before the renovation, buildings presented a generalized state of advanced deterioration, including cracking of the plaster of the façades. From occupants' surveys realized by Gebalis, some of the most frequent complaints of the residents were the cold indoor climate, the humidity and mould, and the air infiltrations inside the houses, even in the most recent zones of the neighbourhood.

The Municipal Master Plan of Lisbon qualified this neighbourhood as a Priority Intervention District in 2011.

Description of the renovation goal

The intervention in the Boavista neighbourhood was realized under the "Eco-Bairro" initiative, which comprised not only questions regarding the existing built environment of the neighbourhood but also diverse, comprehensive initiatives to motivate ecological and energy-saving behaviours in the residents.

The two areas referred to in the Introduction and indicated in Figure 33 – "Alvenarias" and the "Multifamily buildings area" – had distinctive states of conservation, and the strategy followed in each one was quite different. The "Alvenarias" area was considered uninhabitable, so it was decided to replace the existing single-family houses with new constructions. This project was concluded in 2018 and it has a completely different process than the one followed in the rest of the neighbourhood. For this reason, this operation is not addressed in this document.

[6] PIMP – Programa de Intervenção a Médio Prazo (Mid-term Intervention Programme).
[7] PER – Programa Especial de Realojamento (Special Programme for Rehousing).

On the other hand, the multifamily buildings presented a high level of physical deterioration at the façades and signs of deterioration in indoor comfort conditions, including large areas of mould inside dwellings. Consequently, these buildings were renovated to improve their energy and thermal performance while considering the environmental performance of the materials used. For this purpose, thermal insulation (black cork agglomerate) was applied to the envelope of the buildings. At a later stage of the renovation process, the existing single-glazed and aluminium frame windows were replaced by PVC frame windows with double-glazing. In addition, solar thermal panels were implemented in the pool and sports complex.

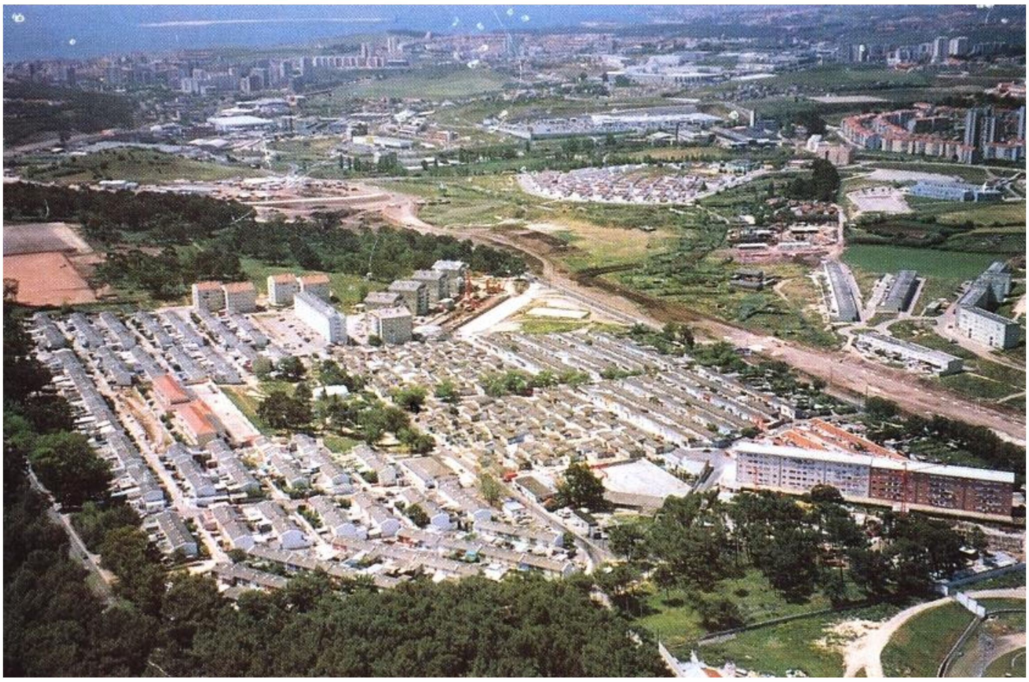

Figure 35. Schematic view of the Boavista neighbourhood before renovation. Source: "Blog Bairro da Boavista – Lisboa" from http://bairrodaboavista-lisboa.blogspot.com/p/fotografias.html

Description of the renovation concept

The Program of Action for the "Eco-Bairro" initiative had seven active fronts on its agenda:

- Renovation of multifamily residential buildings;
- Construction of new equipment in the neighbourhood as Eco-center and Eco-gardens;
- Installation of renewable solar thermal;
- "Net-Verde", wireless network of free access to the Internet in the neighbourhood;
- "PediBus", pedestrian circuit in the neighbourhood;
- Urban and architectural solution for "Alvenarias" zone;
- Communication actions, for example, through the creation of the Eco-Bairro website and social networks, sports and recreational activities, and Energy-Environmental awareness actions and monitoring.

Regarding residential building renovation, to answer the problems indicated in the previous section, support was requested from the Lisboa E-NOVA (Municipal Agency for Energy and Environment) and the National Civil Engineering Laboratory (LNEC). After a public tender, around 20,000 m^2 of an External Thermal Insulation Composite System (ETICS) using cork as an insulation material was applied. The selection criterion for the insulation material was related to its reduced environmental impact. In the second phase, about 3,000 windows covering 4,000 m^2 of the heated area were also replaced.

The energy demand was reduced by 28% only due to the application of ETICS. This is the measure with the highest impact in terms of energy needs reduction.

Regarding renewable energy sources, 118 m^2 of solar thermal panels were installed on the roof of the existing municipal pool of the neighbourhood, allowing for the pre-heating of the water used in the facilities. Monitoring of the installed system registered a thermal efficiency of 65%. In July and August, solar heat was responsible for 95% of the heating needs in the pool, whereas, in the following months, the value dropped to around 80%.

Lighting in the streets and the school serving the neighbourhood was changed to LED technology. Replacement in public lighting has generated a 70% reduction in electricity consumption. In the elementary school "Arquiteto Gonçalo Ribeiro Telles" there are savings of around 13.8 MWh/year, which corresponds roughly to about 55% reduction in the electricity consumption regarding lighting in the facilities.

Involved stakeholders included: the Recreational Association of Bairro da Boavista Residents; Lisbon Municipality, Lisboa E-Nova – Municipal Energy Agency and Gebalis - Municipal company that ensures an integrated management policy, which aims at the administration of the neighbourhoods, the quality of life of the resident population and the conservation of the municipal real estate in Lisbon.

Figure 36. Solar thermal system installed in the pool roof. Source: Lisboa E-Nova.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	55,000	55,000
Population in the area:	-	6,000	6,000
Number of buildings in the area	-	28	28
Heated floor area of all buildings	m²	80,000	80,000
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	-	-
Multi-family homes (MFH) - up to three stories and/or 8 flats			
Apartment blocks (AB) - more than 8 flats		80	80
Schools		5	5
Office buildings		-	-
Production hall, industrial building			
Other - commercial and cultural		10+5	10+5
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	80	80
Medium consumers: AB, schools, etc. – 80-800 MWh/a		20	20
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		0	0
Property situation of buildings:			
Private	% of heated floor area	10	10
Public		90	90
Property situation of energy supply system (district heating):			
Private	% of heated floor area	N. a.	N. a.
Public		N. a.	N. a.

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	60.5	48.2
Domestic hot water demand (calculated)	kWh/m²a	30	20
Cooling demand (calculated)	kWh/m²a	N. a.	N. a.
Electricity demand (calculated)	kWh/m²a	N. a.	N. a.
Heating consumption (measured)	kWh/m²a	N. a.	N. a.
Domestic hot water consumption (calculated)	kWh/m²a	included in the heating consumption	
Cooling consumption (measured)	kWh/m²a	N. a.	N. a.
Electricity consumption (measured)	kWh/m²a	N. a.	N. a.
(Thermal) energy supply technologies:		N. a.	N. a.
Decentralised **oil or gas boilers**	% of heated floor area		
Decentralised **biomass boilers**			
Decentralised **heat pumps**			
Centralised (district heating)			
Other *(please specify)*			
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	118
Photovoltaics	kW_p	0	0
Other (please specify)	kW	-	-

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	-	130
- **building envelope renovation costs**	Euro/m²	-	N. a.
- **heating/cooling supply costs**	Euro/m²	-	N. a.
- **renewable energy production costs**	Euro/m²	-	N. a.
LCC available	yes/no	no	no

Description of the technical highlight(s) and innovative approach(es)

The Boavista neighbourhood case is an interesting intervention because it is part of the "Eco-Bairro" initiative, which has wider objectives and intends to improve ecological behaviour and sustainability awareness in the neighbourhood residents. It is the first phase of a significant intervention area of 20 hectares, where approximately 6,000 people live. The intervention considered not only energy efficiency issues but also the health and thermal comfort of the users. The intervention also showed sustainability concerns regarding the materials used (materials with low embodied energy), like the use of cork as the insulation material in the ETICS. The intervention also combined energy efficiency measures with renewable energy sources.

Residents of the Boavista neighbourhood frequently complained about the cold indoor climate, humidity and mould, and air infiltrations. It was also evident the cracking of the buildings' façade mortar. As a solution, the application of experimental mortar based on lime and cork was proposed. The material was tested to guarantee the best application in an area of around 20.000 m^2 (Figure 37). In the second phase of the intervention, more than 3,000 windows were replaced by more energy-efficient windows.

Figure 37. Experimental test of the mortar in existing building in Boavista neighbourhood. Source: CM-Lisboa, from: http://www.cm-lisboa.pt/fileadmin/Noticias/ficheiros/Eco-District_Boavista__PT_.pdf

Decision and design process

General/organizational issues:

Besides the municipality, several stakeholders were involved:

- CML, Câmara Municipal de Lisboa (Lisbon municipality);
- EPAL, Empresa Portuguesa de Águas Livres as (national water distribution company);
- GEBALIS, Gestão de Bairros Municipais de Lisboa EEM (municipality social housing company);
- ISCTE, Instituto Superior de Ciências do Trabalho e da Empresa (educational institution for work sciences and business);
- SCML, Santa Casa da Misericórdia de Lisboa (social solidarity private institution);

- APF, Associação para o Planeamento da Família (family planning Association);
- ABAE, Associação Bandeira Azul da Europa (European Blue Flag Association);
- APA, Agencia Portuguesa do Ambiente (national environmental agency);
- CARRIS, Companhia Carris de Ferro de Lisboa (Lisbon public transport company);
- EDP, Distribuição Energia SA (national energy company);
- EPUL, Empresa Pública de Urbanização de Lisboa (urban planning municipal company);
- Agrupamento de Escolas Pedro de Santarém (local schools cluster);
- Lisboa E-NOVA, Agencia Municipal de Energia e Ambiente de Lisboa (municipal energy company);
- Fábrica da Igreja Paroquial de S. José do Bairro da Boavista (local church);
- VALORSUL, Valorização e Tratamento de Resíduos Sólidos da Área Metropolitana de Lisboa (Norte) (municipal waste management company);
- IHRU, Instituto de Habilitação e Reabilitação Urbana, IP (national housing and urban renovation company);
- PSP, Polícia de Segurança Pública (police);
- LNEC, Laboratório Nacional de Engenharia Civil (national laboratory of civil engineering);
- ARMABB, Associação Recreativa de Moradores e Amigos do Bairro da Boavista (Residents Association);
- Junta de Freguesia de Benfica (parish council);
- Centro de Saúde de Sete Rios (local healthcare centre)

The inclusion of Boavista neighbourhood into the letter BIP/ZIP (Neighbourhoods and Priority Intervention Areas in Lisbon), approved in 2011 by the municipal assembly, was an important institutional issue to support the project. Because of the comprehensive nature of the project, the involvement of a large number of project partners was considered essential for the success of all the associated actions. The role of the residents' association (ARMABB) must also be highlighted. The association was responsible for motivating residents to participate and facilitating all actions within the scope of the "Eco-Bairro" project.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	GEBALIS (municipality social housing company) CML (Lisbon Municipality)	Owner/ Decision-maker	Need for corrective maintenance and poor energy-environmental performance of the neighbourhood, resulting in building pathologies
Users/ investors (individual owners, housing association, building managers, asset managers, project developers)	ARMABB (Residents Association)	influencer	Need for corrective maintenance and poor indoor conditions
District-related actors (Community/occupants organizations, etc.)	ARMABB (residents association)	influencer	Poor interior conditions with high levels of thermal discomfort and the presence of mouldy areas Evidence of cracking of buildings' façade mortar
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	EDP - Energias de Portugal (national energy company)	Technical advisor/Partner	Social Responsibility /Research
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Lisboa E-NOVA (municipal energy agency) LNEC (National Laboratory of Civil Engineering)	Delivery/ technical advisor	Participation in a relevant research project
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	Santa Casa da Misericórdia (social solidarity private institution) CARRIS (Lisbon public transport company) VALORSUL (municipal waste management company)	Partner	Social Responsibility/ Participation in a relevant research project

Design approach:

The program ”Eco-Bairro Boavista Ambiente” had as principal objectives:

- intervention in the façades and gables using eco-insulated cladding and the replacement of existing windows;
- the use of the participatory methodology in urban and renovation architectural projects;
- to develop and apply concepts of energy efficiency and environmental behaviour and awareness under the programme “Eco-Bairro”.

Technical issues:

Technically, the most challenging issue was to find the most adequate material to be used as an external wall insulation material with the ability to improve the indoor comfort condition, humidity and mould problems and the air infiltration issues expressed by the households before the renovation, using sustainability criteria to support the decision.

Financing issues:

The “Eco-Bairro” project was financed within the framework of the “Política de Cidades – Parcerias para a Regeneração Urbana do QREN” (City Policy – Partnerships for the Urban Regeneration under QREN). The QREN – Quadro de Referência Estratégico Nacional – (National Strategic Reference Framework) was an instrument for the implementation of the common policy for economic and social cohesion amongst the European member states in the period 2007-2013. The availability of structural funding for this operation was key for the implementation of the project since the municipality did not have the resources necessary for the intervention.

Management issues:

No particular challenges were found regarding the management of the project.

Policy framework conditions:

The social housing management company Gebalis led the renovation process, and the intervention was conducted under a broad environmental programme, which can be framed as a kind of preaching policy. Using sustainability criteria in intervention in existing buildings can also be considered a demonstration for other social housing contexts. The obligation to comply with thermal regulations and energy standards, particularly the requirements of Decree-Law 118/2013 was essential to obtaining energy reductions.

Lessons learned/interesting findings

One of the major success factors of the neighbourhood intervention is its integration in a broader environmental program that aimed at raising energy and environmental awareness in the residents. There was a holistic perspective of the intervention, combining renewables and passive measures on the envelope while considering sustainability concerns regarding the choice of the insulation material, which should have low embodied energy. Significant energy and carbon savings were achieved from the technical measures implemented. Heating demand was reduced by 20% when considering building envelope measures alone.

There is significant potential for transferability and replicability of the lessons learned in this project for other municipalities and governance structures, namely regarding the opportunity provided for EU structural and cohesion funds and the focus on the combination of social inclusion and improvement of energy efficiency (and renewable energy sources) measures.

3.11 Coronación district, Vitoria-Gasteiz (Spain)

Country: **Spain**

Name of city/municipality: **Vitoria-Gasteiz**

Title of case study: **SmartEnCity Vitoria-Gasteiz**

Period of the renovation: **2016-2021**

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Link(s) to further project related information/publications, etc.:
https://smartencity.eu/about/lighthouse-cities/vitoria-gasteiz-spain/
www.visesa.euskadi.eus/coronacion
www.vitoria-gasteiz.org/wb021/was/contenidoAction.do?idi-
oma=es&uid=u559cff7e_151852964b0__7db7

Schematic figure or aerial overview

RESIDENTIAL buildings: 27 (312 dwellings)
Heated area > 22,700 m^2

+ GYM & SPA
  BINGO
  CIVIC CENTRE
  ASSOCIATIONS CENTRE
  CHURCH

TOTAL EQUIVALENT DWELLINGS: 655

PROPERTY:

- PRIVATE: dwellings, gym & spa, bingo and church
- PUBLIC: Civic Centre and Associations Centre (Municipal property)

Figure 38. Aerial view of Coronación district, Vitoria-Gasteiz (Spain). Source: VISESA, H2020 project “SmartEnCity” and Municipality of Vitoria-Gasteiz.

Figure 39. Detailed aerial view of the buildings that are part of the intervention. Source: VISESA, H2020 project “SmartEnCity” and Municipality of Vitoria-Gasteiz.

Figure 40. Apartment block before (left) and after renovation (right). Source: VISESA, H2020 project “SmartEnCity” and Municipality of Vitoria-Gasteiz.

Figure 41. Apartment blocks after renovation. Source: VISESA, H2020 project “SmartEnCity” and Municipality of Vitoria-Gasteiz.

Introduction and description of the situation before the renovation

Vitoria-Gasteiz is the capital of the Basque Country in the north of Spain, with 240,000 inhabitants. It is a Europe-leading municipality investing in green economy (Green Capital 2012).

Coronación district is located on the north-west edge of the old town of Vitoria-Gasteiz. The district was built to accommodate mainly migrants from rural areas of other parts of Spain who moved to the city during the 1950s and 1960s to work in the industry. Coronación can be considered the first neighbourhood of the first city ring built before 1980. The majority of the buildings were constructed during the 1960s and 1970s (85% of dwellings were built before 1970), presenting minor urban changes after that period.

After a thorough field study analysis developed by project partners concerning the intervention area, some relevant numbers and conclusions were extracted:

- In terms of building accessibility, 68% of the buildings have an elevator (vertical accessibility), and 49% of buildings have an accessible entrance (horizontal accessibility). However, just 40% of buildings are completely accessible (both horizontally and vertically). Thus, there is a large number of buildings where an intervention in the building entrance and/or the elevator may imply a significant accessibility improvement. Five buildings with accessibility problems accommodate more than 50% of elderly residents.
- Regarding building typologies and energy efficiency aspects, 51% of the buildings have individual heating, their façades are double-layer without insulation and between 50% and 70% of their windows have been replaced. Hence focusing on energy efficiency, a wide range of buildings present potential retrofitting improvements, especially in the envelope due to their non-insulated façades.
- Concerning structural security, most of the buildings are in good condition, only 2 buildings are in a critical situation and 20 buildings can be slightly improved in structural terms.

As a result of this analysis, a proposal for building intervention priority has been developed in order to point out which buildings need more urgent intervention, considering the building situation and the opportunity that entails each of them (Figure 42).

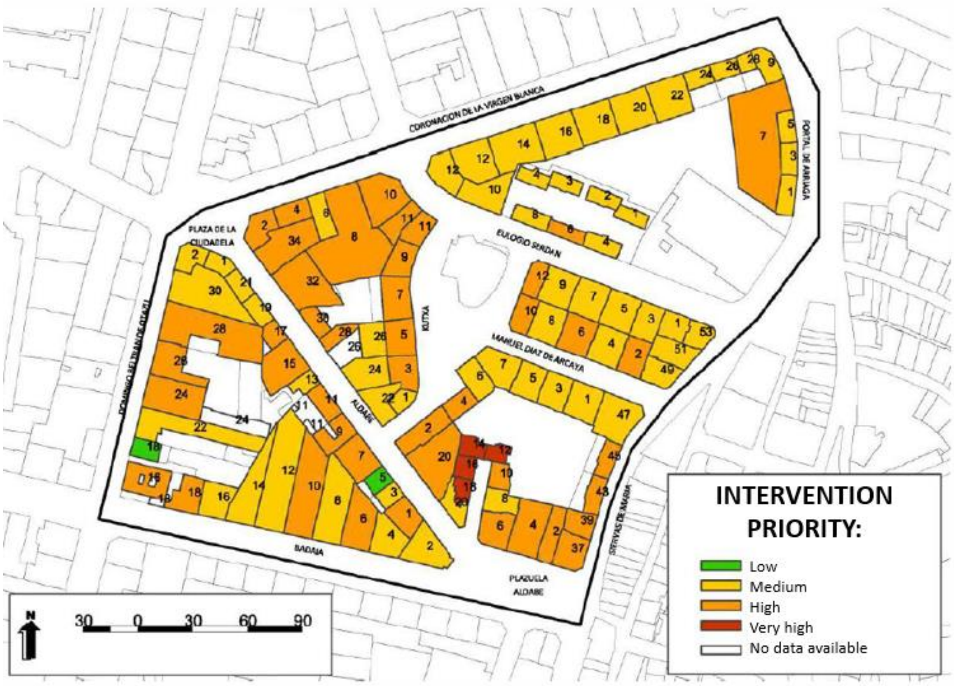


Figure 42. District plan of priority intervention per building (red: very high; orange: high; yellow: medium; green: low; white: no data available). Source: VISESA, H2020 project "SmartEnCity" and Municipality of Vitoria-Gasteiz.

Description of the renovation goal

The city of Vitoria-Gasteiz has a clear strategy to become greener, promoting energy efficiency, renewable energy, low carbon mobility, and smart infrastructures.

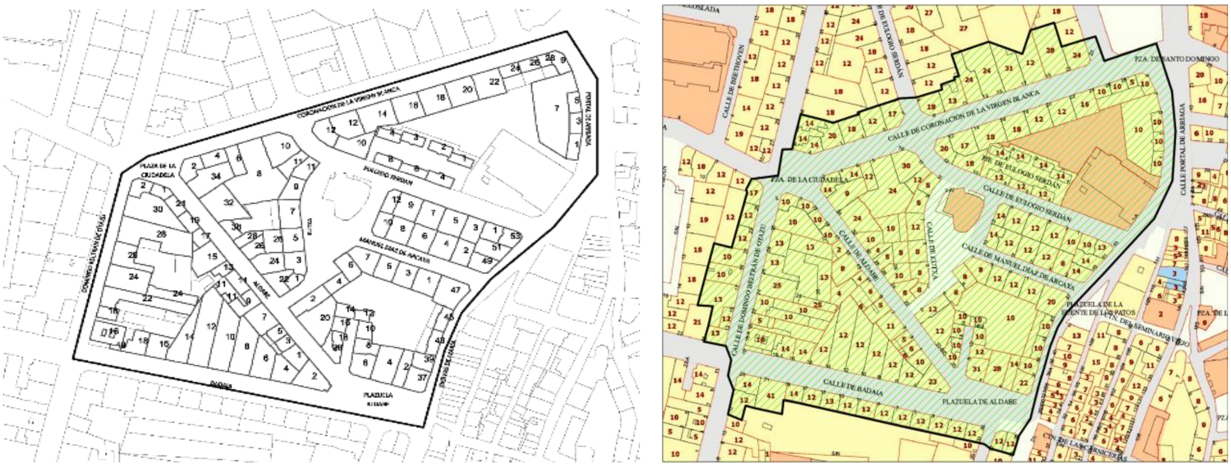
Coronación district renovation is part of SmartEnCity, a project funded under the European Union's Horizon 2020 in which Vitoria-Gasteiz is one of the three lighthouse demonstrator cities. Within the project SmartEnCity, Vitoria-Gasteiz seeks to:

- Demonstrate efficient building retrofitting: 655 equivalent dwellings in the Coronación district are being retrofitted (envelope), and their energy systems replaced with a connection to the district heating.
- Integrate new infrastructures: a new biomass (wood chips) district heating network will be deployed, and an integrated energy management system will optimise efficiency at the dwelling, building, and district levels. Before the renovation, each dwelling/building had individual heating systems.
- Promote sustainable mobility: acquisition of electric vehicles (EVs: taxis and private cars) will be granted, and the charging network will be extended.
- ICTs: an Urban Management System (UMS) will be developed and deployed.

The building renovation intervention consists mainly of envelope retrofitting, which involves the intervention in the façade and cover, improving insulation and air tightness, and installing new low-energy windows and doors if needed. Coronación neighbourhood was chosen in Vitoria-Gasteiz for this intervention as it was identified as the city's most vulnerable neighbourhood in terms of social aspects, stability, habitability, accessibility, and energy efficiency.

This district presents major challenges in retrofitting and implementing smart city concepts: very high-density, low-medium income families, and relevant social dimension.

Following the diagnosis of the residential buildings in the demo area (1,913 dwellings), six main typologies of buildings (from the energy point of view) have been identified. The refurbishment of up to 750 dwellings could be co-financed by the SmartEnCity project. Finally, the number of to-be-refurbished buildings reaches 655 equivalent dwellings (equating the tertiary buildings to housing buildings).



108 eligible buildings (1,305 dwellings) 147 eligible buildings (1,913 dwellings)

Figure 43. Initial intervention area (left) and extended final intervention area (right). Source: VISESA, H2020 project "SmartEnCity" and Municipality of Vitoria-Gasteiz.

Description of the renovation concept

The renovation measures include:

- Envelope: ETICS or ventilated façade (Upon tenants' decision) + double-glazing windows (if necessary) + roof insulation.
- Supply system: district heating network powered with biomass (wood chips)
- Renewable energy system: biomass for Heating and DHW.
- Building energy management system (BEMS): consumption data and energy-saving recommendations will be provided to the neighbours through a digital platform and a smartphone app.
- Optional improvement of accessibility: assistance in the step of removing any accessibility barrier.

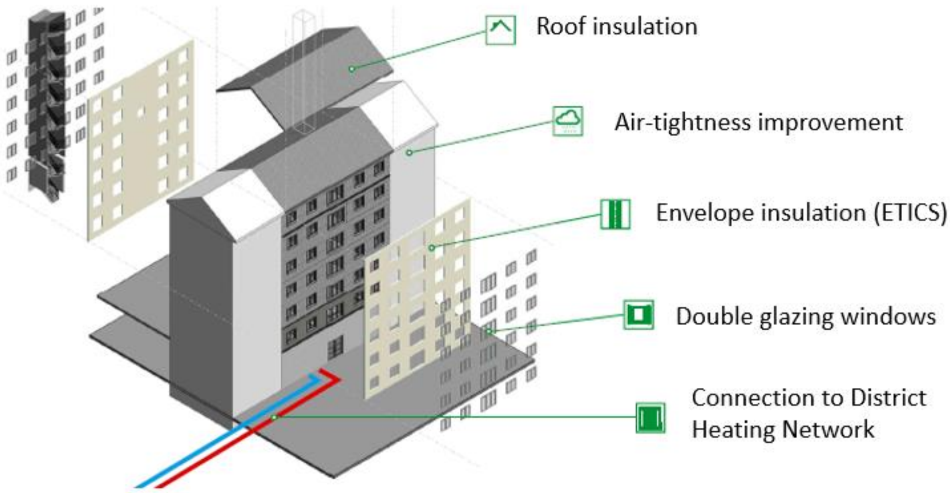


Figure 44. Diagram of the renovation measures undertaken. Source: VISESA, H2020 project "SmartEnCity" and Municipality of Vitoria-Gasteiz.

Table 26 summarises the thermal transmittance values of the different components of the envelope before and after renovation.

Table 26. U-Values of the building envelope before and after the renovation.

U-value summary	Before renovation U-values (estimated)	After renovation U-values (calculated)
Façades	1.69 (air cavity)	0.21 (ETICs or Ventil. façade)
Roofs	2.56 (non-ins. pitched or flat roofs)	0.21 (ETICs)
Ground floor slab	1.89 (non-insulated slab)	0.40 (ETICs)
Windows	Variable from 2.40 to 4.00	1.60 (replaced or added windows)

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	89,100	(the same)
Population in the area:	-	1,870	(the same)
Number of buildings in the area	-	152 in total 3 MFH 144 AB 5 tertiary Buildings	152 in total 3 MFH (3 renov.) 144 AB (24 renov.) 5 tertiary Bd (DH)
Heated floor area of all buildings	m²	49,187	(the same)
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	-	-
Multi-family homes (MFH) - up to three stories and/or 8 flats		3.5%	(the same)
Apartment blocks (AB) - more than 8 flats		65.4% (1,913 dwellings)	(the same)
Schools		-	-
Office buildings		12.6% (church, offices)	(the same)
Production hall, industrial building		-	-
Other (please specify)		18.5% (gym, civic centre)	(the same)
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	2.4%	1.0%
Medium consumers: AB, schools, etc. – 80-800 MWh/a		55.8%	34.0%
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		44.2%	65.0%
Property situation of buildings:			
Private	% of heated floor area	84.1%	(the same)
Public		15.9%	(the same)
Property situation of energy supply system (district heating):			
Private	% of heated floor area	80.9% (private systems)	41.9%
Public		19.1%	58.1%

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	151.0	70.0
Domestic hot water demand (calculated)	kWh/m²a	unknown	unknown
Cooling demand (calculated)	kWh/m²a	0 in dwellings, variable in other uses	(the same)
Electricity demand (statistical)	kWh/dwel a	3,487	(the same)
Heating consumption (measured)	kWh/m²a	unknown	unknown
Domestic hot water consumption (calculated)	kWh/m²a	unknown	unknown
Cooling consumption (measured)	kWh/m²a	unknown	unknown
Electricity consumption (measured)	kWh/m²a	unknown	unknown
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	69.8%	28.1%
***Decentralised* biomass boilers**		14.9%	0.0%
***Decentralised* heat pumps**		3.7%	3.9%
Decentralised portable heaters		5.8%	4.9%
***Building central* gasoil boilers**		5.8%	5.0%
Centralised (district heating)		0.0%	58.1%
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	kW_p	0	0
Other (biomass)	kW	0	to be defined 90% biomass (10% gas)

Financial issues:

Parameter	unit	before renovation	after renovation
total investment costs of the renovation	Euro/dwel	-	21,000
- **building envelope renovation costs**	Euro/dwel		15,750 (75% of total cost)
- **heating/cooling supply costs**	Euro/dwel	unknown	5,250 (25% of total cost)
- **renewable energy production costs**	Euro/m^2	-	under design
LCC available	yes/no	no	no

Description of the technical highlight(s) and innovative approach(es)

Innovative business model to foster the renovation of buildings.

Innovative role of the public company VISESA (VIS) as delegate promoter of the retrofitting actions, on behalf of the Communities of homeowners (residential buildings are privately owned).

Through agreements signed between both parties, VIS manages, contracts, supervises, and finances the correct design and execution of the refurbishment works, delivering the final product “turnkey” to its owners and charging them the total cost minus subsidies received.

VIS also manages the different administrative tasks to receive the subsidies (application, justification, etc.) as a "one-stop-shop agency“, relieving the neighbours of these cumbersome tasks.

The project also involved:

- Assistance with barrier-free improvements such as elevator installation or removal of other accessibility barriers, and any other work needed derived from the technical building inspection (compulsory for buildings older than 50 years). Even though these works were not included in the energy retrofitting, the direct help with them became a positive outcome.
- A citizen engagement toolkit, which includes multiple events and activities (See **Table 27**)
- The design of district heating in a consolidated urban area where there was no such infrastructure before.
- Large-scale monitoring of indoor conditions (Tª, RH%, CO_2) and energy consumption (electricity and heat) in around 200 dwellings out of the renovated 320 dwellings.
- A protocol to identify and prevent moisture-related pathologies in renovated buildings.
- The use of ICT and BIM to engage citizens through energy efficiency awareness and improvement campaigns, etc.
- Medium-scale retrofitting solutions for a heterogeneous neighbourhood (buildings from 5 to 62 apartments).
- Compressive management of local and regional grants compatible with European grants.
- Adaptation of taxes regulation for European grants, taxes exemption for energy-efficiency-based retrofitting.
- Adaptation of urban planning regulation to impulse energy-efficiency-based retrofitting.
- Impulse quality energy-efficiency based retrofitting to get A or B energy performance certificate.

Table 27. Number of citizen engagement actions and neighbours reached by different means.

Radio campaigns	2	**Meetings with Owner's Communities**	> 320
Informative events	10	**Telephone calls to owners**	> 400
Mailing campaigns	4	**"Door to door" campaign visits**	650
Informative videos	2	**District Information Office visits**	1600
Informative tours to similar projects	2	**Meetings with Owner's Communities**	> 320

Supplementary information: https://www.youtube.com/watch?v=vLI09ytbfU0

Decision and design process

General/organizational issues:

SmartEnCity started as a top-to-bottom project, where some public institutions at the local and regional levels thought that it would be positive that certain impoverished districts of the city went through a process of renovation of both buildings and services to improve citizens' life conditions and reduce carbon emissions produced by the city. After this decision was taken and an analysis of the necessities of city districts was performed, Coronación was selected as a suitable neighbourhood and the project consortium applied to an EU call for obtaining some public funds to carry out the drafted project.

Stakeholders involved

- Policy actors:
  - Vitoria-Gasteiz municipality
  - Basque Government, through its Housing Department
- Users/investors:
  - VISESA, Basque Housing Development Organization
  - Individual owners of dwellings
  - EVE, Basque Energy Agency
  - Shop owners and commercial companies located on the ground floors
  - Building administration companies
- District-related actors
  - Errota Zaharra Neighbourhood Association
- Energy Network Solution Suppliers:
  - GIROA VEOLIA
  - LKS KREAN (ESCO and engineering company), design of DH network and boiler room adaptation
  - ACCIONA
  - Public tender for construction of the DH and boiler room adaptation
- Renovation Solution Suppliers:
  - Basque Government Housing Department
  - Vitoria-Gasteiz municipality, Urban Department
  - Architecture & design studios:
    - ESPARZA Arquitectura y Rehabilitación Sostenible, Sueslan Arquitectos, Arquiplan Arkitektura, MUP ARQ Servicios Integrales de Arquitectura, Grupo VMA, AKTUA Rehabilitación Integral, AA Estudio, Abitura Arquitectos, RDL Arquitectura, Luis López de Armentia, MMMST, O+A Arquitectos, RF Arquitectura, VG4.
  - Renovation companies:
    - Kursaal Rehabilitacion SL, KAMY Vertical, Basabide, Indenor Proviser, Teusa.

- Other intermediaries:
    - TECNALIA technology partner, consultant
    - Mondragon corporation, technology partner, consultant
    - H-Enea, communication cooperative and citizen engagement
    - ATARI consultants (Door to door campaign)

Main steps

Three main steps were performed:

- Preliminary renovation projects definition
  Based on the identified building typologies, six basic renovation projects were proposed
- Offer adaptation
  Detailed projects according to local conditions, available grants, and cost affordability.
  Meetings with involved agents to listen and implement their needs.
- Project placement/marketing strategy

Resources available before the project

There used to be very few resources before this project. Only a brochure with general information about building renovation and occasional meetings about future urban improvements in the neighbourhood association.

Drivers and barriers (opponents)

The main drivers were:

- Building managers. They were a key agent to carry on or reject the renovation (their involvement was very heterogeneous, with some considerable issues that actually stopped the renovation in some cases).

The main barriers were:

- Spanish national and local regulations. The mandatory steps to approve every building renovation greatly delayed the project, from 3 to 10 months. This was an important risk for the project's success and thanks to this project; the local regulation simplified all the required verifications and reduced this delay.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Vitoria-Gasteiz Municipality Basque Government	Decision makers and influencers	Improving citizens life
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	VISESA Individual owners of flats EVE Shop owners Building admin.	Decision makers Influencer	Improving their comfort conditions and energy consumption
District-related actors (Community/occupants organizations, etc.)	Errota Zaharra neighbour association	Influencers	Improving district conditions
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	GIROA VEOLIA LKS KREAN ACCIONA Public tender DH construction	Project partners and decision-makers Delivery	Providing a profitable and quality district heating service to the district inhabitants
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	Basque Gov. Housing Dpt. Municipality Urban Dpt. Architectural firms (from a previously selected list) Construction companies awarded in the public tenders	Decision makers and influencers Technical advisors	Carrying out profitable and good quality retrofitting work on the selected buildings
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	TECNALIA Mondragon corporation H-enea ATARI consult.	Decision maker and influencer Technical advisors Technical advisors Social advisors	Providing methodology, partner coordination, and communication with stakeholders

Design approach:

The design target was based on carbon emissions reduction in order to reach an energy performance certificate (EPC) grade A in each community (building).

Once the compulsory basic solution was granted communities could decide to go further with the renovation works or even choose a more expensive constructive solution.

The main challenges in the design phase were that each community was different so they required particular attention. In the beginning, some designers were not fully prepared to fulfill all the design challenges required. Additionally, there was a lack of district heating systems knowledge.

Technical issues:

The major technical challenges/constraints regarding system design/implementation have been the following:

- Concerning the renovation: the main challenge has been to design and implement ETICS systems and other technical solutions within a constrained budget. Project's target is very sensitive to unexpected expenses due to its financial/economic weak position (high percentage of low incomes households among the district inhabitants).
- Concerning the district heating network:
    - Piping works need special trench wide and expansion joints that needed to be planned in detail because of their important impact on the streets, which tend to be narrow and full of other underground suppliers' services (gas, electricity, internet, water, etc.).
    - District heating boiler room facilities needed to be designed to store enough fuel (wood chips) to avoid excessive truck transit within the district, located in the city centre.
- Coordination between all the stakeholders in such a complex project.

Financing issues:

The project was partly financed (up to 54%) by different public institutions:

- 23% by European Commission
- 25% by Regional Government
- 6% by City Council

Additionally, this financing could eventually rise to 80% of the costs due to regular local and regional funds for energy retrofitting interventions not linked to the European Project.

Apart from this, it was constituted, in agreement with the regional government, a guarantee fund in the form of soft loans for those persons that could eventually need an additional amount to afford the cost of the project. It could cover up to 100% of the cost, taxes included.

In some cases, the combination of the abovementioned strategies could eventually lead to a 100% financing of the project's cost to certain people, depending on their situation.

Management issues:

The main challenges and constraints regarding project management have been:

- Local consortium was a multidisciplinary team with stakeholders with very different points of view. This always entails managing challenges.

- VISESA (local leader) acted as “delegated developer” on behalf of the Communities of homeowners. Through agreements signed between both parties, VIS manages, contracts, supervises, and finances the correct design and execution of the rehabilitation works, delivering the final product “turnkey” to its owners and charging them the cost difference fewer subsidies. VIS also manages the different subsidies administrative tasks (application, justification, etc.) as a "one-stop-shop agency“, discharging the neighbours of these cumbersome tasks. This novel role increases management complexity.

Policy framework conditions:

The police instruments that moved the district into action were a combination of the following ones:

- Carrot-policies:
    - Real Estate Tax: City Council reduces this tax to 50% to those dwellings with an A grade on the energy performance certificate. Dwellings that are retrofitted and connected to the district heating automatically reach an A so they directly get this benefit.
    - Provincial Government, in charge of revenue, approved a new regulation on taxes that made SmartEnCity’s funds exempt from paying taxes.
    - City council changed the urban planning directives to allow the deployment of a district heating network within the boundaries of the demo district Coronación. Later on, this directive was extended to the whole city, making easier and more attractive this kind of technical solution for both users and suppliers.
- Herd management policies:
    - The aforementioned “delegated developer” role of VISESA.
- Preaching policy:
    - One-stop shop agency
    - Local consultancy pop-ups
    - Information events and meetings

Lessons learned/interesting findings

The major success factor has been changing the idea from a product to a holistic retrofitting service, developed by a Housing Public Society, which was not specialized in urban-building retrofitting.

The major bottlenecks are related to:

- Lack of previous information.
- Regulation that is not currently adapted.
- Compulsory majority agreement in each community (per building), minimum 60%.
- Project was specifically designed for buildings with exclusively residential apartments not including the reality of the building with commercial premises and residential apartments.
- Lack of a district heating systems culture. Citizens are used to individual heating systems.

These bottlenecks can be grouped in:

- Social aspects: the greater bottleneck was that the project had a top-to-bottom approach so it was necessary to involve and convince the target audience to join the project. This was an enormous work carried out by building technicians with not enough preparation to treat the public. The effort needed to carry out this task was unexpectedly high and became one of the main time-consuming tasks of the project in its initial phases.
    - Solution: Professionals from the social sector were hired and a door-to-door campaign started, getting in touch with more than 650 persons in face-to-face conversations.
- Technical issues: it was difficult to convince the target audience about the advantages (less consumption, money saving, higher efficiency, lower carbon print, etc.) of the district heating network to be deployed.

Almost all the buildings had individual heating systems in each flat consisting of gas boilers and reluctance to change was very high. Some of the owners' communities initially agreed with the retrofitting but did not finally join the project because of this issue.

  - Solution: additional effort was put into information tasks to transmit the benefits of the technical solution for heating.

- Management issues: quite a high number of owners' communities (buildings) did not finally join the project because of the reluctance of the business/commercial premises located on the ground floor of the buildings. Many of these premises are empty, with no commercial use, so they are not interested in retrofitting or connecting to a district heating network. They don`t see the benefit of the actuation and, as a consequence, they vote against joining the project in the owners' community assembly. As they usually have bigger surfaces (in square meters) than the dwellings, they proportionally have as well a higher weight on the decision, tipping the scale to a negative decision despite the decision of the dwelling owners may have been affirmative.
  - Solution: there is no simple solution to this, it would require a law amendment in order that the ground floor premises aren't part of the minimum percentage of owners required to carry out an energy improvement of a building.

The major lessons learned have been the following:

- Communication with the citizens is crucial: opening an information site at the heart of the Coronación district made a difference. The main objective was to increase the proximity to the neighbours, putting at their disposal clear first-hand information on the SmartEnCity activities and solving any eventual doubt about the project to assist the decision-making process. It is essential to communicate directly with your audience. A sharp, very clear, specific message, without changes along the project (except for improvement) is needed. Face-to-face talks with the neighbours and listening to their feedback are essential.
- Starting with a bottom-to-top project could be more efficient. It is easier to implement this kind of intervention in districts that have already asked for it or shown their approval.
- Results have to be shown from the very beginning of the project to engage your target audience. The retrofit of at least one building in the project's first months (even if this means assuming some risk) allows the audience to "see and touch" a real example of what you expect to achieve with the project.
- The engagement of the district associations is very beneficial. Citizen engagement will be easier if the neighbour's associations or other social stakeholders from the demo district support the project.
- To be successful on medium-large scale projects a demo inside the demo is needed, so the project has to be defined in several phases or stages:
  - Lead users
  - Early adopters
  - Main Adopters
  - Rest
- It is important to consider the right timing. The larger the intervention scale, the longer it will take to implement.

3.12 Lourdes Neighbourhood, Tudela (Spain)

Country: **Spain**

Name of city/municipality: **Tudela (Navarra)**

Title of case study: **Lourdes Neighborhood**

Period of the renovation: **2010-2012**

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Link(s) to further project related information / publications, etc.:
http://www.tudela.es/docs/industria/lourdes-renove-presentacion.pdf

Domingo-Irigoyen, S., Sánchez-Ostiz, A., & Miguel-Bellod, J. S. (2015). Cost-effective renovation of a multi-residential building in Spain through the application of the IEA Annex 56 Methodology. Energy Procedia, 78, 2385-2390.
https://www.sciencedirect.com/science/article/pii/S1876610215019268

Schematic figure or aerial overview

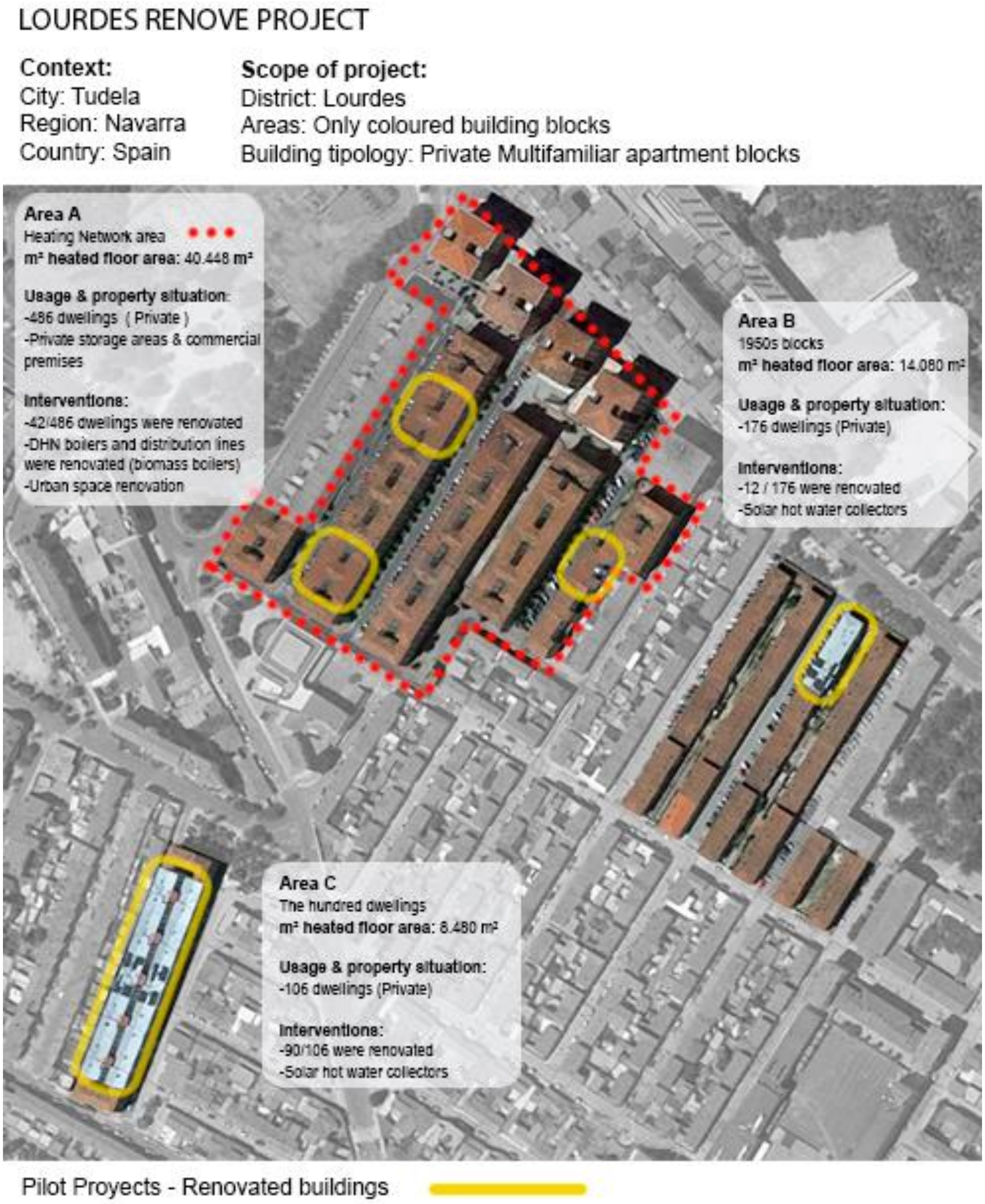


Figure 45. Schematic/aerial view of Lourdes renovation area. Source: Google Maps (modified by the author).

Introduction and description of the situation before the renovation

The area selected for this Success Story is located in the Lourdes Neighbourhood, on the outskirts of the city of Tudela (North of Spain). This district was built between 1954 and 1972 and was originally developed as a social housing area[8]. As a result of building and social degeneration processes during the last decades, this district became one of the most economically deprived districts in Tudela. For this reason, in 2009, the municipality of Tudela started a renovation process in this area.

This Success Story presents the highlights of the Lourdes Renove Project, defined as the first phase of an integrated energy and urban rehabilitation strategy in this district. Three particular subareas (A, B, C) were included in the scope of action of this project. In this report, the data summarized in the Project Fact Box concerns area A - marked with red dot lines (Figure 45) - from which more information was available. The main strategies carried out in areas B and C are also described.

In terms of building characteristics, different multi-family building block typologies are found in these areas, all sharing similar low-quality construction. Envelopes lacked thermal insulation, and the original wood-frame windows were nearly all replaced by residents during the last decades. Overall, buildings were highly energy inefficient and didn´t meet the current minimum requirements of the Spanish Building Code. Following, there is a description of the building and energy system features found in these areas and the number of dwellings, and the main morphology differences among them:

- **Area A** corresponds to the San Juan Bautista District Heating Network (DHN), which served 486 dwellings (total heated area: 40,448 m²). Before the renovation of this old facility, the heating distribution network had huge thermal losses, and it was connected to old inefficient oil boilers. Regarding heating control, no individual controls or energy meters were installed in the dwellings. The heating costs per dwelling were calculated by dividing the total heating costs according to the dwelling's area. Two main building typologies are found in this area: the "H-block" (due to the floor plane shape: Ground floor + 4 upper floors) and the Tower block (ground floor + 8 upper floors). Ground floors in these typologies are occupied by some commercial premises and storage private areas.

- **Area B** corresponds to the oldest buildings in this district, known as the 1950s blocks. Each building block comprises six dwellings following the linear block typology (ground floor + 2 upper floors) - two on the ground level floor, plus two additional floors with two dwellings per floor. This area accounts for a total amount of 176 dwellings (total heated area: 14,080 m²)

- **Area C** accounts for a total of 106 dwellings, divided into seven building blocks with 18 per block following the "H-block" typology - two dwellings on the ground level floor plus four additional upper floors with four dwellings per floor. (Total heated area: 8,480 m²)

In Areas B and C, heating was provided in different ways. Most buildings had a central heating system per building, but in some cases, dwellings had individual heating systems. In all Areas A, B, and C, - but mainly in the ones not included in the DHN (B and C) - there are reported cases that some dwellings used alternative heating systems such as butane stoves, electric heaters, or even there were dwellings with no heating system due to their vulnerable situation.

Domestic hot water is provided by individual electrical or gas boilers installed at different times by occupants, and some dwellings have installed individual air conditioning units for cooling in summer. No energy-saving systems for lighting or other appliances existed.

[8] Nowadays, most residents are owners, and an elevated percentage of households are private rented properties.

Description of the renovation goal

The Lourdes Renove Project responded to the need to promote the integral renovation of this deprived social housing area. This project acted on three levels with very specific goals:

- **Environmental level.** Reduce energy consumption and carbon emissions by:
  a.1 Improving the energy efficiency of the building envelopes
  a.2 Improving district heating network efficiency (new and more efficient boilers; replacing old distribution lines).
  a.3 Providing district heating with regulation and control systems. (Central regulation and individual smart meters in dwellings, radiator valves)
  a.4 Increasing the share of renewals (Biomass boilers for the DHN, solar collectors for domestic hot water).

- **Economic level.** Improve the value of the dwellings and reduce the energy demand and derived cost for families in this area with medium-low purchasing power.

- **Social level.** Ensure the permanence of the families in the dwellings and the social cohesion in the area by improving the neighbourhood quality and appeal.
  c.1 Renovating the exterior appearance of façades and urban space.
  c.2 Ensuring adequate accessibility (new elevators, elimination of accessibility barrier elements)
  c.3 Reducing the risk of mould and condensation, increasing indoor comfort conditions.

Description of the renovation concept

The most relevant aspect of this renovation was the simplicity and effectiveness of all the measures performed to reduce the most urgent deficiencies in the urban space, the buildings, and the energy systems. All the decisions were based on technical and economic criteria considering that occupants had to stay in their dwellings during the renovation works.

The renovation was carried out on three levels: urban space renovation (Area A), building renovation (Area A, B, and C), and energy systems (DHN renovation in Area A, and solar hot water collectors in Areas B and C).

Figure 46. Area A. Left: Building renovation. Source: M.A.R. Arquitectos. Right: District Heating Network renovation. Source: Nasuvinsa.

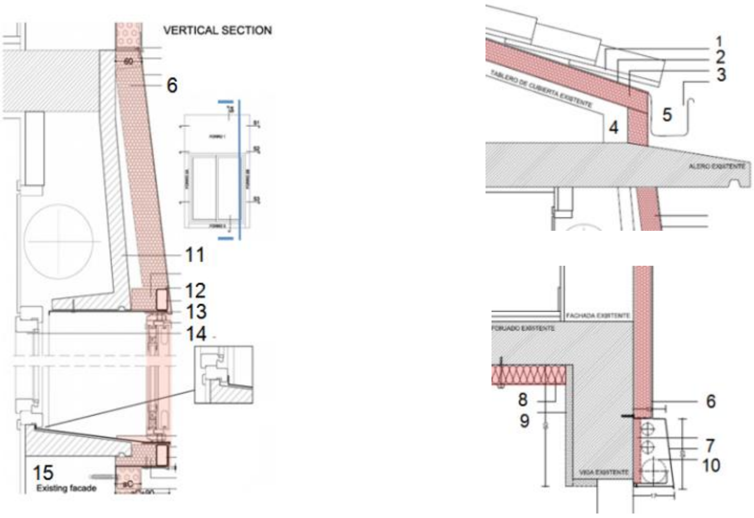
Building renovation: envelope and facilities

Three different design (architecture) renovation projects were developed for the different areas. However, a similar renovation concept was applied to each of them:

- Old facilities were removed from the façade and new openings for the exhaust pipes of existing and future gas hot water boilers were arranged.
- A single insulation layer (6-8 cm) was fixed to the wall and covered by acrylic and elastic mortar.
- Additional sliding windows were installed as a double layer outside the existing windows. Slightly different aesthetic solutions were applied depending on the existing façade morphology.
- The original old pitched roofs were repaired and insulated.
- New telecommunication systems were updated, and individual aerials were relocated from the façade to the roof.
- Terraces in the linear block (Area B) were extended and closed, conforming to new conservatories connected to the south façade.
- First-floor ceiling in contact with non-heated spaces (Areas A and C) was insulated with 10 cm of mineral wool where it was possible.

Figure 47. New conservatories in Area B. Source: LKS Ingeniería.

In the construction details (Figure 48), it can be seen the solution for the "H-block” typology in Area A:



1.Tilt Roof
2. Water proof membrane
3. 6cm extruded polystyrene
4. Original ceramic panels
5. Rain water gutter
6. 6cm expanded polystyrene
7. Folded Aluminium sheet
8. 10cm mineral wool
9. 3cm Cellular glass
10. Hidden distribution space
11. Existing prefabricated concrete
12. Holding System structure
13. Additional sliding aluminium window
14. Existing window
15. Existing façade

Figure 48. Construction details of renovation solution. Source: M.A.R. Arquitectos.

Table 28. Average characteristics and U-values before and after renovation.

	Before renovation	U-value (W/m²°C)	After renovation	U-value (W/m²°C)
Roof	Tilt roof, no insulation, unheated space under the roof	1.25	6 cm insulation (extruded polystyrene)	0.45
Façade	25 cm single brick wall, no insu-lation	1.89	6 cm (expanded polystyrene)	0.38
Window	Single glass/wood frame	5	Additional sliding aluminium frame. Old window maintained. Double Low E-coated glass 6.16.6/aluminium Ug1.6/Uw3.2	1.95
Floor	Concrete beam slab with ce-ramic hollow fillers,	1.47	12 cm insulation (mineral wool)	0.22

District heating network and other building systems

- The DHN distribution system was replaced and insulated in Area A, and new, more efficient biomass and gas boilers were installed.
- Regarding hot water production, in Areas B and C, new domestic hot water solar collectors were placed on the roofs, but no particular measure was applied in the production facilities. Individual electrical boilers and a few individual gas boilers installed during the last decades are the most common systems.
- Regarding heating control in the DHN Area (Area A), wireless thermostats were installed in every dwell-ing, and old radiators were retrofitted with new regulation valves allowing occupants to regulate heating according to their preferences.

Project Fact Box (A area) (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of Area A:	m²	-	-
Population in the area: Lourdes district	-	1,200	1,200
Number of buildings in the area	-	486 dwellings	42[9]/486 dwellings
Heated floor area of all buildings	m²	40,448	(3,360[10] / 40,448)
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	-	-
Multi-family homes (MFH) - up to three stories and/or 8 flats		-	-
Apartment blocks (AB) - more than 8 flats		100	8.31[11] / 100
Schools		-	-
Office buildings		-	-
Production hall, industrial building		-	-
Storage areas and commercial premises	unheated	unknown	unknown
Consumer mix in the area:			
Small consumers: SFH + MFH – <80 MWh/a	% of annual heat demand	(100)	(100)
Medium consumers: AB, schools, etc. – 80-800 MWh/a		-	-
Large consumers: industrial consumers, hospitals, etc. >800 MWh/a		-	-
Property situation of buildings:			
Private	%of heated floor area	100	100
Public		-	-
Property situation of energy supply system (district heating):			
Private	%of heated floor area	100	100
Public		-	-

[9] Share of buildings with renovated envelopes
[10] Share of buildings with renovated envelopes
[11] Share of buildings with renovated envelopes

Project Fact Box (A area) (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	-	-
Domestic hot water demand (calculated)	kWh/m²a	-	-
Cooling demand (calculated)	kWh/m²a	-	-
Electricity demand (calculated)	kWh/m²a	-	-
Heating consumption (measured)	kWh/m²a	89.57kWh/(m²a) [12]	46.38 kWh/(m²a) [13] 45.25 kWh/(m²a) [14] 23.93 kWh/(m²a) [15]
Domestic hot water consumption (calculated)	kWh/m²a	unknown	unknown
Cooling consumption (measured)	kWh/m²a	≈0	≈0
Electricity consumption (measured)	kWh/m²a	unknown	unknown
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	%of heated floor area	-	-
***Decentralised* biomass boilers**		-	-
***Decentralised* heat pumps**		-	-
Centralised (district heating)		100	100
Other *(please specify)*			
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	kW_p	0	0
Other (please specify) (Biomass)	kW	0	1440

Financial issues:

Parameter	Unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	-	-
- **building envelope renovation costs**	Euro/m²		283[16]
- **heating/cooling supply costs**	Euro/m²	-	60.62[17]
- **renewable energy production costs**	Euro/m²		-
LCC available	yes/no	-	no

[12] Before District Heating renovation (2010-2011)
[13] Total District Heating heating consumption (2012-2013)
[14] Not renovated building heating consumption in the DHN (2012-2013)
[15] Renovated buildings heating consumption in the DHN (2012-2013)
[16] Total cost of the building envelope renovation of 42 dwellings (3,360 m²) = 954,000 €
[17] Total cost of the district heating system (40,448 m²) = 2,614,000 €

Description of the technical highlight(s) and innovative approach(es)

Five key renovation facts

(1) Limited budget/ Less is more. This example highlights the simplicity and effectiveness of all the measures performed to solve particular necessities and overcome the financial constraints of this deprived area. Although sufficient subsidies and adequate financing were finally obtained (from European Framework Concerto Programme, regional government, etc.), the limited budget was always a concern that helped focus on effective energy consumption reduction strategies.

(2) Holistic district approach. The main drivers of energy consumption were taken into account in the project - district heating network, building energy efficiency, and user behaviour - addressing cost-effective energy-saving measures. Important factors behind this renovation included: leveraging already existing infrastructure, renewable energy use, energy consumption reduction, and community empowerment in the use of energy.

(3) Public initiative, control, and coordination between stakeholders during the renovation process. As crucial as the physical renovation strategies carried out, this example highlighted the importance of coordination between stakeholders: administration, neighbours, and private entrepreneurs. The initiative of the public authorities and the public housing company (Nasuvinsa) was essential support to promote, speed up, and control the whole process. Nasuvinsa, as a public intermediary, assumed the role of being the meeting point for decision-making during this process and the main coordination agent helping to counterbalance the different interests of the different agents involved.

(4) Community involvement. Personalized mentoring and agreement facilitator agent. Considering the fundamental barrier of community engagement in the renovation process, Nasuvinsa played a fundamental role in the promotion and information dissemination, resident guiding, and coordination in the participatory process involving all the community in the decision-making. The following strategies were carried out:

- Door-to-door interviews providing adequate information about the pros and cons of the renovation and about possible financing strategies;
- A customer service and information office in the neighbourhood;
- Coordination of events for collective participation and decision-making;
- Coordination of visits to other similar renovation projects in the area.

(5) A pilot intervention. Monitoring for validation. The Lourdes Renove Project was conceived as the first stage that laid the groundwork for the full renovation of this deprived area in the future. As a trial, all the developed actions have been carefully evaluated during the last years in order to validate or modify future interventions in this area. To evaluate these measures, different monitoring actions were carried out. Thanks to the energy meters installed during the DHN renovation, all the heating data was centralised and supervised to control the heating performance and energy savings. Also, post-occupancy assessments were carried out after renovation evaluating the improvements in terms of comfort during winter and summer periods.

Decision and design process

General/organizational issues:

The Lourdes Renove Project responds to the need to promote the integral renovation of this deprived social housing area and upgrade the inefficient district heating. This project acted on three levels:

- Environmental level. By improving the energy efficiency of the building envelopes and district heating boilers and distribution pipes aimed to reduce energy consumption and carbon emissions.
- Economic level. By promoting new employment in the area and reducing energy consumption, and derived economic burden on families in this area with medium-low purchasing power.
- Social level. By renovating the exterior appearance of façades and urban space, ensuring adequate accessibility and energy efficiency aimed to improve the neighbourhood quality and appeal to ensure the permanence of families in their dwellings and the social cohesion in the area.

Stakeholders involved

The success of this renovation initiative was the result of the implication of multiple stakeholders; the leadership of the Tudela city council and other public institutions (Navarra Government and Spanish Department of Economy, Finance, Industry, and Employment), the support and participation of the neighbourhood population, the construction and research sector (Zabala, Cener, Cenifer) and the coordination and management of a semi-public housing company, Nasuvinsa.

Main steps

Different actions and steps were followed to support this successful implementation.

- The project "Lourdes Renove" was framed within the scope of action of the CONCERTO Programme. It started in 2010 after the signing of the agreement between the Municipality of Tudela and the public company NASUVINSA.
- As a key strategy, in 2010, Nasuvinsa opened a neighbour service point, the Lourdes Renove Office, a meeting point for technicians and neighbours and a dynamizing agent of the process.
- A master plan was set up to prioritize three key intervention areas: (1) The thermal envelope, (2) the district heating network, and (3) the improvement of energy use by families.
- At the same time, the Tudela city council promoted and developed a Social Activity and Involvement Plan boosted by a social worker to interact within the community. Neighbourhood Associations and Neighbours' Association presidents were engaged in the process.
- In 2010, the Tudela city council called four architectural ideas competitions for each of the different building typologies in the area. The winning proposals were implemented in 2011 and were practically finished at the end of the year.
- All building and facilities renovation projects had to be implemented in a short timeframe (14 months). In this short period, the following actions had to be taken:
  - Project definition.
  - Seeking subsidies and financing: identification of possible money sources, dossier presentation, and definition of the economic strategy;
  - The call for tenders related to the works and services set out above;
  - The adoption of the necessary agreements and resolutions among the community;
  - Process for licenses;
  - Coordination with the urban redevelopment plan;
  - Construction works (without interrupting the everyday life of dwellers).

Resources available before the project

Very limited resources were available before the project because of the low purchasing power of this area. This project successfully ended thanks to the subsidies and favourable financing opportunities.

Drivers and barriers (opponents)

This project was made possible thanks to the initiative of Tudela municipality and the extraordinary support and management of the public company Nasuvinsa. Both agents and the area's population made the interventions possible despite the opposition of a certain part of the residents. Nevertheless, if more people had agreed to be part of the renovation process, possibly more buildings would have been renovated. Undoubtedly the second most important driver was the financial assistance of the European Union and the regional and local administrations.

Stakeholders´ role and motivation:

Main stakeholder	Specify which organization (s) was (were) involved	Role (decision-maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors	Tudela city council	Main driver Financial/ regulations facilitator	Neighbourhood renovation
	Navarra and European Government	Direct subsidies	
Users/ investors	Building managers Neighbours	Influencer Community engagement	Dwelling improvement (comfort, energy savings, accessibility)
	Bank (Caja Navarra)	Financing	
District-related actors			
Energy network solution suppliers	Project developers: GIROA	Delivery & decision maker District heating Renovation	
Renovation solution suppliers	Project developers: Building renovation: (Mar Arch.) Urban renovation: (Blasco Arch.)	Delivery & decision maker Project development Technical assessment	
Other intermediaries (public bodies, (NASUVINSA) trade organizations, NGOs, consultancies, research institutes)	Public bodies (NASUVINSA)	Communication Agreement facilitator Coordination Nexus between tenants, municipality and technicians.	Neighbourhood renovation
	Research institutes (CENIFER, CENER)	Consultancy and Technical assessment	
	Consultancies (Zabala Innovation)	Consultancy (European Project Consultancy)	
	Research group (SAVIArquitectura, UNAV)	Post Occupancy Evaluation	

Design approach:

In 2010, Tudela municipality set up four architectural ideas competitions for the different existing building typologies in Areas A, B, and C. Design proposals must take into consideration the following requirements for pursuing an integral energy retrofit and general upgrade:

- Energy loss reduction through the envelope. New thermal envelope standards were set in 2006 by the Spanish Building Code (CTE DB-HE). More demanding regulations have already overridden this building code.
- Minimum impact during renovation works. Construction works should be fundamentally carried out from the exterior of the buildings, thus allowing people to live at home during this phase.
- Keeping budgets in check. Preliminary projects should be accompanied by an economic evaluation, broken by measures and types of action (accessibility, thermal envelope, and general facilities) facilitating neighbours' decision-making. These budgets had to be ratified by construction companies.

Decision steps

- Call for architectural ideas' competitions for the different existing building typologies. The proposals had to contemplate the integral energy retrofit of the buildings with high energy efficiency requirements.
- Organization of a project launch day for the neighbours (October 2010) in which the winning projects and financing possibilities were displayed.
- Meetings with neighbourhood communities for the adoption of agreements in every building block in the Lourdes Renove office and the final definition of the pilot projects.
- Meetings in the neighbourhood civic centre for informing about the renovation of the San Juan Bautista District Heating.

Main challenges in the design phase

The main challenges during the design phase were related to:

- Aesthetics. The final appearance of the renovated buildings shouldn´t be disruptive or interfere with the surrounding buildings, avoiding striking differences in neighbours and facilitating social cohesion.
- Limited time and budget. The project, formalities, and works had to be finished in a very short period (14 months). That´s why all the processes had to be well coordinated and timely. The involvement of the municipality and regional administrations was fundamental for streamlining this process. In addition, measures had to be defined from a time and cost-effective approach. For that reason, the defined measures had to be easy to implement. The reduced budget was also a challenge. However, the solutions adopted configured in the end a feasible and adequate strategy for future renovations in this neighbourhood.
- People kept living at home during the work. Measures applied had to consider the minimization of nuisances and pollution caused by works in the interior of the dwellings during the renovation process.

Technical issues:

Major technical challenges/constraints regarding system design/implementation

As stated before, this project faced a fixed deadline (14 months) that obliged the managers to anticipate any unforeseen setbacks in the renovation phases. One of the most challenging works was the exterior and interior rearrangement and renovation of telecommunication lines, water and gas pipelines, and air conditioning units which varied from one building to another. To meet the deadlines, all the construction work had to be carefully followed by the coordination agent (NASUVINSA) to meet every unexpected modification of the project in the shortest time possible (as it happened with distribution lines). Every modification of the project had to be approved by the neighbours, so regular meetings were held.

Financing issues:

This project was financed thanks to public grants and private loans. In particular, two loans were requested by the owners´ associations. Both loans covered the total cost of the interventions. The first loan was requested to cover the amount funded by grants, and the other one, the rest of the expenses. 59.5% of total expenses came from subsidies and private loans completely financed the rest.

- For thermal envelope renovation costs, owners pay an amount of 40 €/month for the next 10 years; considering 20 €/month discount accounting the 50% of energy savings got after the intervention. In 15 years, it is expected the return of the initial investment.
- For district heating renovation, the monthly flat-rate fee for heating was increased from 51€/month (only heating) to 67€/month (including heating costs + works loan). Total expenses will be paid in around 12 years.

Subsidies or other financial incentives

Subsidies and financing were vital to drive this project's development, considering the average medium-low purchasing capacity in this area and the financial crisis.

Main challenges/constraints regarding financing

Among the main limitations for financing the Lourdes Renove Project, we find three main causes due to Spain's huge economic crisis between 2008 and 2014.

Firstly, the situation of the banks was not very favourable, and the interest on the loans was very high (5-7%), discouraging the participation of many neighbours. Also, the economic situation of the families in this neighbourhood, already of low purchasing power, reached very critical levels during these years as a result of the crisis. And finally, as a consequence of the two previous causes, the total financing of the project had to depend on multiple sources of financing. Therefore, another relevant constraint was the complex management process carried out by Nasuvinsa dedicated to finding and getting European, regional, or state subsidies to reduce the expenses covered by the neighbours with private loans.

Business model

No business model was defined for the amortization of the project beyond what has already been described. The direct benefits obtained by the works performed in the envelopes or the renovation of the district heating system went directly to the tenants in the form of energy savings and the reduction of heating costs, among other benefits.

Management issues:

As is the case in most building renovation projects, especially at the district scale, appropriate management and coordination were crucial to the success of the intervention throughout the different phases - decision-making, subsidies, and financing, coordination between the actors involved, development and development, and evaluation. The Lourdes Renove project and, fundamentally, the principal agent in charge of the management faced the following challenges:

- Attaining the highest agreement possible on the decisions among the neighbours (>60%);
- A great economic vulnerability in the neighbourhood required complex management of economic aid and financing;
- The short period of 14 months, in which the whole project had to be designed, approved, organized and developed:
- Coordination between multiple agents with different interests.

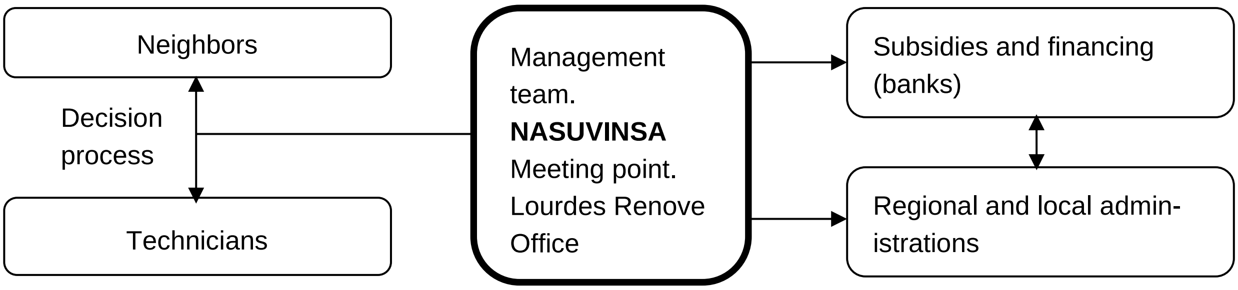


Figure 49. Decision process scheme.

Policy framework conditions:

Regulations that stimulated/hindered the process

A relevant regulation in promoting this project was Law 19/2009 of 23 November on measures to encourage the renting process and energy efficiency of buildings. Based on this law, the works that aim to improve the energy efficiency in buildings could have 3/5 (60%) of the parties' agreement between neighbours obliging all owners in the event of surpassing this majority.

At the local level, some funding ordinances were also important, such as the "Municipal Ordinance on aid for the execution of renovation works within the scope of the Lourdes Renove (Tudela) project". The Lourdes Renove project also benefited from different existing regional, state, and European regulations for obtaining funding.

Police instruments that moved the district into action

The local regulations helped the neighbours, especially the most vulnerable ones, to finance or subsidize the cost of the interventions. This activated the agreement among the unmotivated dwellers.

Lessons learned/interesting findings

Major success factors

Thermal envelope

- Thanks to the energy efficiency measures applied, between 40 to 45% of energy savings and emissions reduction were achieved. Total energy savings are around 649 MWh/year.
- Due to these measures, other improvements and co-benefits were possible:
    - The reduction of the U-values and the improvement of air tightness of the envelope improved thermal comfort and acoustic insulation and reduced the possibilities of surface condensations and mould formation.
    - It also reduced energy consumption and, consequently, carbon emissions.

Heating control

- (District Heating Network) Thermostats and energy meters allow users individual control, thus improving comfort and energy savings.

District Heating renovation

- A total of 70-75% of energy savings was achieved due to the improvement of the thermal envelope and district heating system renovation.
- The use of biomass reduced gas consumption by 88%, bringing down energy costs and dependency on fossil fuels.

Socio-economic benefits

- Thanks to the tight cost of these interventions, the subsidies gathered, and the attractive financing opportunities, no money ahead was given by neighbours fostering the participation of the most vulnerable groups in this renovation.
- Thanks to the multidimensional renovation approach of this intervention (urban space, building, and energy systems); the general perception of this area has improved, reducing social and urban degeneration processes.
- Energy efficiency measures helped reduce energy consumption and, therefore, in reducing the energy cost impact on these vulnerable families.

Management

- Decision and agreement in district renovation projects are important barriers to eliminate. In this case, the role played by Nasuvinsa, the management team, making coordination possible between the three pillars of the process, represents a great example of successful management for future interventions.
- After 8 years, the success of these interventions has encouraged other renovations in the area.

Major bottlenecks

- The lack of sufficient agreement within the communities hampered the integral renovation of this district. However, based on the success of this initial development in the area and the benefits of comfort and energy savings observed by neighbours in the pilot projects, a second redevelopment project in the district is currently under development, Lourdes Renove 2.
- Familiar economic constraints were also a major bottleneck. However, thanks to the efforts made by Nasuvinsa, 59% of the renovation costs were fully subsidized, and the rest was completely financed by suitable credits tailored to each family's particular situation.

Major lessons learned

- Communication with neighbours at all stages of development is the essential vehicle for developing these types of interventions.
- It is needed to promote global projects that consider all aspects of energy renovation (envelope, systems, and user awareness).
- District renovations are very complex processes that need the support of regional and local authorities and management teams that should act as facilitators of the processes (coordination of all the agents involved, definition of proposals, funding, agreement, information, and dissemination)
- Grants are effective resources to promote these interventions in vulnerable environments.
- The involvement of the potential beneficiaries of interventions from the beginning is essential.

3.13 Lake-water based district heating network in Weggis (Switzerland)

Country: **Switzerland**

Name of city/municipality: **Weggis / Canton Lucerne**

Title of case study: **Lake-water based district heating network in Weggis**

Period of the renovation: **Phase I: 2016-2020**

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Link(s) to further project related information/publications, etc.:
http://www.korporation-weggis.ch/waermeverbund.html (only in German)

The success story was described in 2019/2020.

Schematic figure or aerial overview

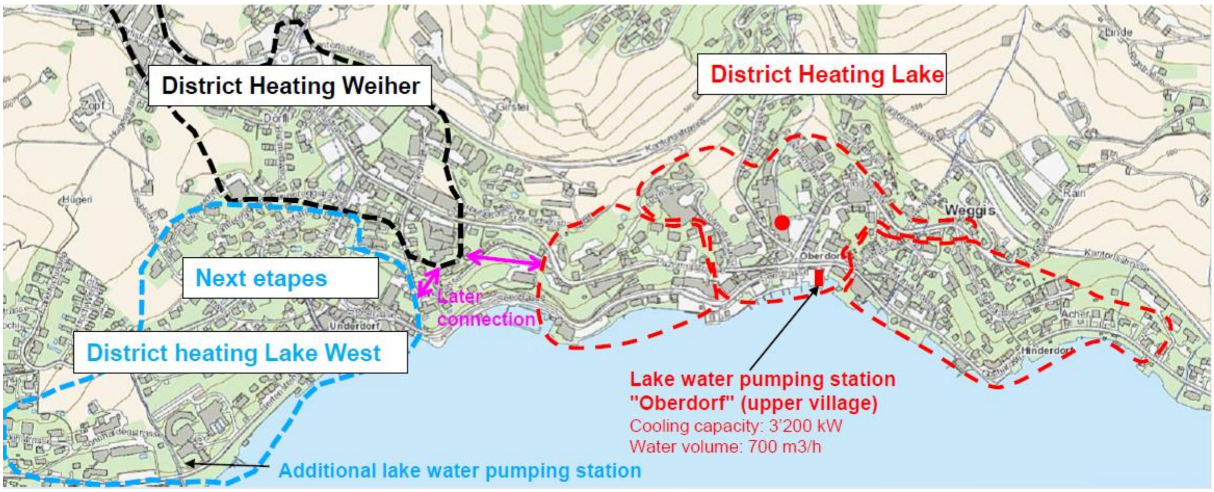

Figure 50. Schematic view of the different stages of the district heating networks in Weggis. Source: Corporation Weggis.

Since 2010 the corporation Weggis has been operating a district heating network with wood chips as an energy source in the Weiher district (marked in black in Figure 50). The plant generates almost 3 megawatts of thermal energy that supplies the Weiher industrial area and part of the village, including various commercial enterprises, private properties, and hotels. The generation capacity of this heating system has now been exhausted by the connection of many properties. The need to supply other properties in the municipality of Weggis with ecological thermal energy continues to be very high, which has created the opportunity to exploit the energy potential of nearby Lake Lucerne.

To supplement the existing heat network, a district heating network sourced with lake water was built in Weggis (District Heating Lake, marked in red in Figure 50). This project was initially designed to adapt to the needs of the community and local conditions, with limited financial risk. An additional network on the west side of Weggis is planned for a later stage.

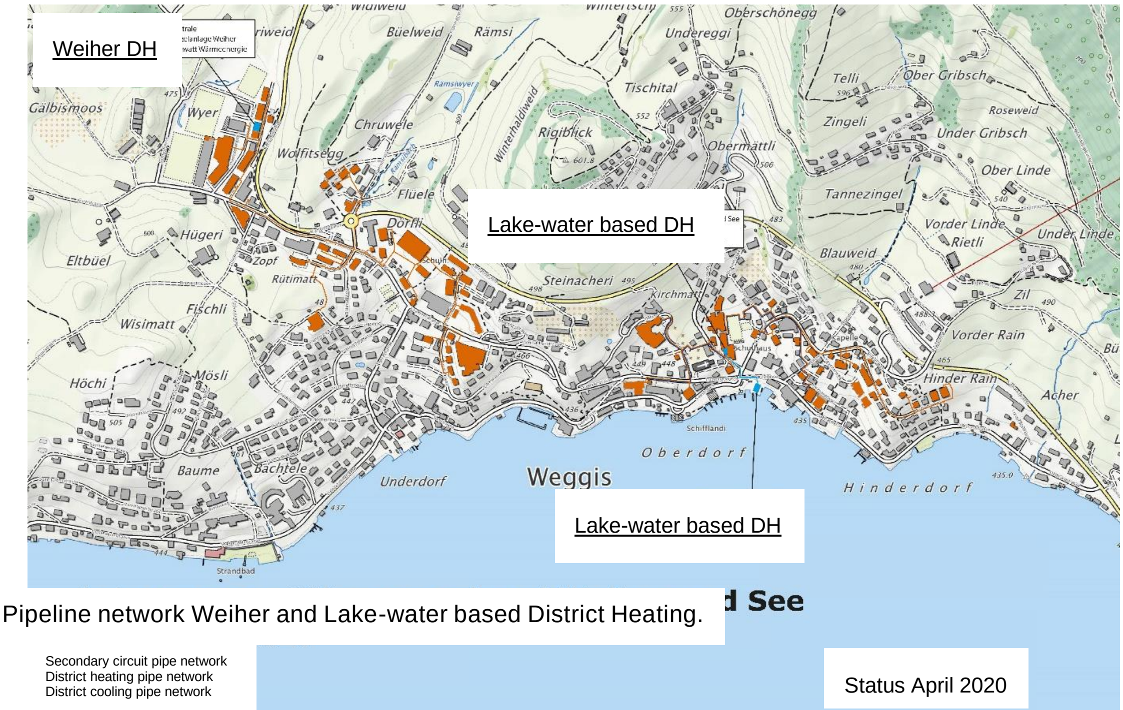

Figure 51. Schematic view of the building connected in April 2020 and existing pipeline network. Source: Corporation Weggis.

The information for this success story was gathered through participation in an open day event on site on 13 April 2019, an interview carried out with Mr. Lottenbach, the president of the corporation Weggis, which owns the district heating system, on 14 June 2019, further contacts with the corporation as a follow-up, and information provided through documents and the website about the district heating system.

Introduction and description of the situation before the renovation

In the municipality of Weggis, before the creation of the new district heating plant, the sources for heat generation in the buildings were as follows:

- Oil: 68%
- Electricity: 13.8%
- Wood: 9.3%
- Heat pumps (electric): 4.7%
- District heating: 1.7%
- Gas: 0.2%
- Others: 0.3%

As the heating capacity of the Weiher district was reached and the requests for new connections from the village residents were still high, the idea of creating a new district heating network originated. A private resident wanted to build a lake water-based heat pump for his property. The municipality extended this idea to create a new district heating network from which a substantial part of the population could benefit.

In the following text, reference is only made to the new district heating system, not the previously available wood district heating system, unless specified differently.

The construction of the lake water heating district network in Weggis started in 2016 and came into operation in 2017.

The district heating network provides heat mainly to residential buildings and single-family houses, but it also provides heat to all village school buildings, hotels, and banks. In spring 2019, the buildings connected were the equivalent of 150 residential units. To some tertiary buildings, it also provides energy for cooling. Only 5% of the connected buildings are new buildings.

In March 2020, the district heating provided 1,075 kW of heating power and 257 kW of cooling power. Additional distribution lines are planned, but it will take 10 years to complete the district heating.

Description of the renovation goal

The goal of creating a new district heating was, as explained in the previous section, to respond to the request of the residents to have a district heating network that produces heat from renewable sources.

The project includes different stages until completion with an installed power of 5.6 MW. Currently, the heat capacity is 1 MW (however, the total installed capacity at the end of the first stage will be 2 MW). The next extension of the network (stage 2) could increase the heat capacity by 2 MW, and the extension towards the hotel Gotthard (stage 3) could increase the heat capacity by an additional 1.6 MW.

In 2017, the heating network was put into operation. The schools and adjacent properties were the first properties to be supplied with thermal energy. The connection of additional 40 properties was carried out in

2018. Further expansion in the following years is foreseen due to the interest of the residents and businesses of the municipality of Weggis.

The project can be adapted to the connection requirements and the further development of the municipality of Weggis; the data collected here refers to the first phase.

The thermal envelopes of some buildings have been renovated during the process, but there is not any coordinated initiative for such a renovation of the buildings. However, the corporation recommends that the owners perform renovation works on building envelopes before connecting to the district network. In that case, building owners benefit from lower connection fees since these depend on the needed heating power. If they insulate the envelope afterwards, the energy costs will be reduced, but the connection fees have already been paid. For the corporation, it remains profitable to connect buildings with a lower heating need since they can provide service to other buildings (without having to increase the installed power) in such a case and, therefore, they profit from more connection fees, and they can amortize the installation in a shorter time.

The costs for the project in the first expansion phase amount to approximately 6 million Swiss francs (CHF)[18]. This includes the lake-water pumping station with the lake-water collection system, the heating plant with the heat pumps in the Weggis school building, and the long-distance distribution networks. In the further stages of expansion, there won't be any additional costs related to the lake water collection and the pumping station. The corporation finances the installation and recovers the investment through the connection fees.

The Foundation for Climate Protection and Carbon Offset KliK supports the project with CHF 100 per ton of CO_2 reduced. There was no financial support from the canton of Lucerne due to savings measures. The financing of the district heating will have to stem from the fees of the connected properties and the innovative operation of the heating association.

Description of the renovation concept

The lake-based heating network consists of a lake water pumping station, a heating plant with heat pumps (at the moment, there is only one heat generation unit), a distribution network consisting of district heating and cooling pipes and the decentralised transfer substations.

The lake water intake is built as an underground structure. The pumps suck in the lakewater with temperatures between 6-8 °C below 25 m depth and deliver it filtered through an approximately 100 m long extraction pipe to the separation heat exchangers in the lake-water pumping station. The heat exchangers transfer the heat from the lake water to an intermediate circuit filled with frost-proof propylene glycol. The COP of the heat pump in the heating plant is 4.

The lake water, cooled to around 2-4 °C, is returned to Lake Lucerne via a return pipe below the vegetation line at a depth of approx. 36 m.

In summer, the district cooling circuit can also be used for cooling, with a cooling capacity of 3'200 kW and a water volume of 700 m^3/h. The heating plant for the first phase is built in the Sigristhofstatt school building. The corporation owns the heat generation unit and operates the plant. The heat network will have a pipe network of approx. 3,500 m in the final stage. Public buildings such as schools, parish buildings and the local retirement home will be supplied with the district heating. However, most district heating and cooling customers are private and commercial properties and hotels.

[18] https://www.local-energy.swiss/arbeitsbereich/projektdatenbank/projekt/Projekte/2018/projektportraet-weggis-seewasser.html#/

Figure 52. Right: Lake-water pumping station. Left: 1 MW Heat pump. Source: Corporation Weggis.

The underground lake-water pumping station is visible from the surface through an access hatch. The hydraulic components of the pumping station essentially consist of the circulation pumps, heat exchangers, valves, piping distribution, and electrical components. The two lake-water pipes for the extraction and return pipes are connected to the lake-water pumping station.

The distribution networks can be extended over almost the entire municipal area, provided that the technical, ecological, and economic necessity arises. The heating plant heat generation unit consists of an ammonia heat pump, which uses the temperature level of the lake water and raises it to temperatures for space heating and domestic hot water heating. In the transfer substations for district heating and district cooling, which are located in the respective properties, the heat/cooling energy is transferred to the in-house distribution network.

All the distribution pipes and the energy consumption of all components are monitored, and the system can be controlled remotely.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	250,000	250,000
Population in the area:	-	4,369	-
Number of buildings in the area	-	ca. 2,800 dwellings	150 equivalent housing units (Spring 2019)
Heated floor area of all buildings	m²	-	ca. 20,000
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	n/a - not available	n/a
Multi-family homes (MFH) - up to three stories and/or 8 flats		n/a	n/a
Apartment blocks (AB) - more than 8 flats		n/a	n/a
Schools		n/a	n/a
Office buildings		n/a	n/a
Production hall, industrial building		n/a	n/a
other (please specify)		n/a	n/a
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	n/a	n/a
Medium consumers: AB, schools, etc. – 80-800 MWh/a		n/a	n/a
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		n/a	n/a
Property situation of buildings:			
Private	% of heated floor area	n/a	n/a
Public		n/a	n/a
Property situation of energy supply system (district heating):			
Private	% of heated floor area	n/a	n/a
Public		n/a	n/a

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	n/a - not available	n/a
Domestic hot water demand (calculated)	kWh/m²a	n/a	n/a
Cooling demand (calculated)	kWh/m²a	n/a	n/a
Electricity demand (calculated)	kWh/m²a	n/a	n/a
Heating consumption (measured)	kWh/m²a	n/a	n/a
Domestic hot water consumption (calculated)	kWh/m²a	n/a	n/a
Cooling consumption (measured)	kWh/m²a	n/a	n/a
Electricity consumption (measured)	kWh/m²a	n/a	n/a
(Thermal) energy supply technologies:			
Decentralised **oil or gas boilers**	% of heated floor area	70%	0%
Decentralised **biomass boilers**		10%	0%
Decentralised **heat pumps**		5%	0%
Decentralised **electrical heaters**		15%	0%
Centralised (district heating)			100%
Other *(please specify)*			
Renewable energy generation on-site:			
Solar thermal collector area	m²	-	-
Photovoltaics	kW_p	-	-
Other (please specify)	kW	-	-

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	CHF	-	-
- **building envelope renovation costs**	CHF	-	-
- **heating/cooling supply costs**	CHF	-	10-15 Mio. CHF at the end of the project (power installed 5.6 MW). Phase I: 5,66 Mio. CHF (2 MW).
- **renewable energy production costs**	CHF	-	-
LCC available	yes/no	-	No

Description of the technical highlight(s) and innovative approach(es)

As technical highlights, it can be said that the intake and return of the lake water are done at a depth of 25 and 36.5 meters, respectively, through 110- and 55-meter PE-HD pipes. The water temperature is 8 °C at the intake and 4°C when it returns to the lake.

The heat exchanger is located in the pumping station whereas the heat pump is located in a central heating plant, which is located at the school facilities and heats the water up to 70 °C. A delivery substation consisting of a heat exchanger, a heat counter, a heat water storage tank, and a control and adjustment panel is built in each connected building.

As an additional innovation could be considered the use of a big ammonia heat pump of 1 MW heating capacity which reaches a higher efficiency than the use of small heat pumps in each building. However, at the cost that the water in the distribution system has to be heated to relatively high-temperature levels to be able to fulfill the heating requirements of all buildings. Ammonia has zero ozone depletion potential and is not a greenhouse gas.

Decision and design process

General/organizational issues:

The project was initiated because the demand from the population to be connected to the existing district heating network was significant (however, it could not accommodate new connections since the full heat capacity was already reached), and the corporation decided accordingly to initiate a new district heating network.

The community and its citizens ultimately benefit from a modern, sustainable infrastructure. As early as 2017, the heating network was able to start provisional operation at the same time as the expansion of the distribution networks, the construction work in the heating plant generation unit in the Sigristhofstatt school building, and the lake-water pumping station. In the 2017/2018 heating period, the contractually binding heat deliveries were fulfilled.

Stakeholders involved

The main stakeholder involved in the project was the municipal corporation that acted as a policy actor and at the same time also as an investor.

In Weggis, various public tasks are divided between the corporate community and the municipality. The idea for using the heat of the lake water came from the private sector and the corporation Weggis was able to extend it to a district heating project. Therefore, Corporation Weggis played an important role in this project. The general planning of the project was taken over by the engineering company ENGIE Services AG. Numerous companies in the perimeter of the municipality of Weggis are involved in the implementation of the heating network and thus a large part of the economic benefit remains in the region.

Residents interested in connecting to the lake water district heating system can contact the corporation.

Stakeholders' role and motivation:

Main stakeholder	Specify which organization(s) was (were) involved	Role (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	Municipal corporation	Decision maker	First of all, ecological motivation. To provide a central heating system based on renewable heat sources (lake water) to the inhabitants of the municipality that were asking for it.
Users/investors (individual owners, housing association, building managers, asset managers, project developers)	Municipal corporation	Investor	The same as in the previous case.
District-related actors (Community/occupants organizations, etc.)	Active residents	Influencer	The wish of having a reliable and sustainable heat source for the dwellings/buildings.
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies)	ENGIE	Technical advisor	To build a reliable and efficient district heating network.
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	-	-	-
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	Foundation for Climate Protection and Carbon Offset KliK	Financial	Financial support to interventions that reduce carbon emissions, offsetting part of carbon emissions triggered by the use of fossil motor fuels of Swiss mineral oil companies.

Design approach:

The design targets of the intervention were to achieve a renewable, secure heat supply. Ecology was the driving factor followed by the economy. Ten years ago, the order of priority would have been different, but nowadays, ecology is a priority over the economy.

Obtaining construction permission is a long process, which includes planning how to protect the flora and fauna of the nature conservation area and the permission of the municipality and the regional and national governments.

The main challenges in the design phase were the high time effort that requires such a process and the need that all or at least a majority of the people who are part of the corporation agree with the project and the vision of a carbon-neutral Weggis.

Technical issues:

The main challenge was related to the project's rapid development, including the decision to build a new district heating network, approval from the authorities, and the various planning phases that required the flexibility and ability to innovate of all those involved in the project. This means that different project phases overlap, some are still in the conception phase while other sub-projects are already completed, which makes it also difficult to coordinate.

Financing issues:

The corporation Weggis, which is legally a public entity subject to the municipality's law, finances the project. The investment is recovered by the user connection fees. The corporation is participating in a subsidies program financed by the Foundation for Climate Protection and Carbon Offset KliK.

This foundation financially supports interventions that reduce carbon emissions by offsetting part of the carbon emissions triggered by Swiss mineral oil companies' use of fossil motor fuels. This program supports operators of district heating networks that use energy sources from renewable sources, which replace fossil fuel-based heating systems and reimburses the operator annually an amount of CHF 100 per reduced ton of CO_2 for a certain period. By the end of 2020, the amount expected to be given to the corporation Weggis is 255,000 CHF (approximately 5% of the construction costs).

To assess the profitability of the intervention, they performed calculations considering that only 50% of the power capacity would be used. Based on this, the project was deemed to be feasible.

Building owners connected to the district heating system benefit from the fact that they do not need to perform any revision of their own heating system at home, e.g. boiler or chimney.

Management issues:

The main challenge regarding project management is the long period that such an intervention requires.

Policy framework conditions:

Some regulations were an obstacle to the process. For example, building owners that substitute their fossil fuel-based heating system with a connection to a district heating network receive subsidies from the regional government. However, the corporation does not receive any money.

The residents were those that started this initiative. The corporation was the energy actor who was implementing it.

Lessons learned/interesting findings

The following success factors can be highlighted:

- The intervention was initiated due to the population's wish; therefore, acceptance among the population was high.
- The network operator is a public institution and therefore considered to be trustworthy by potential clients of the district heating network.
- The municipality has supported the project. Almost all public buildings are connected to the network as well. Consensual communication between the network operator of the Weggis Corporation and the municipality of Weggis has led to beneficial acceptance by the population.
- The lake-based heating network is characterized by the integration of sustainable, locally available energy resources. The environmental benefits of using such energy are key to high acceptance in the population.
- Synergy effects between the renovation of municipal supply lines, road rehabilitation, and the heating network reduce the overall costs for all parties involved.
- The energy potential of the lake is large and provides an efficient energy supply; this potential can best be accessed through a district heating network; individual buildings could not access this energy resource.
- The existence of the network has encouraged building owners to switch to renewable energy.
- As a large energy actor interested in making its renewable energy-based heating system a success, the corporation is a strong driver for encouraging people to switch to renewable energy.
- The possibility of expanding the network, combined with connection fees that provide revenues for each new building connected, makes energy efficiency measures on the building envelopes attractive for the district heating network operator. This allows for connecting more buildings without increasing the system's overall capacity.

As major bottlenecks, it can be pointed out the fact that the rapid development of the project, considering the decision to build, the approvals of the authorities, and the different planning phases, requires flexibility and innovative ability of all those involved in the project. Additionally, different project phases overlap. Some are still in the conception phase, while other sub-projects are already completed.

As major lessons learned, the project shows that it is necessary that communication with the local authorities and the population is carried out continuously throughout the entire process, from planning to system operation, and that it is continually adapted to the requirements to eliminate prejudices in advance. The project was actively communicated through presentations, published articles in the local media, open days, and events for schools. This is considered to have been an essential factor in ensuring the project's success. Information is deemed to be key to convincing the population of such a system's benefits and attracting building owners' interest to participate in a common solution.

3.14 Linero district, Lund (Sweden)

Country: **Sweden**

Name of city/municipality: **Lund**

Title of case study: **Linero district**

Period of the renovation: **2014-2021**

Author name(s): Erik Johansson, Henrik Davidsson
Author email(s): erik.johansson@hdm.lth.se, henrik.davidsson@ebd.lth.se
Link(s) to further project related information / publications, etc.:

Schematic figure or aerial overview

Figure 53. Aerial overview of Linero district in Lund, Sweden. Copyright: Creative Commons.

Table 29. Basic information (*CITyFiED* "Facts & Figures").

No. of buildings	16 (out of all 28)
No. of dwellings	379
No. of levels	3
Years of construction	1969-1972
Total heated floor area	40,400 m²
Population in the area	1,150 inhabitants
Owned by	Lunds Kommuns Fasighets AB (LKF) (public housing company)
Usage	residential

Figure 54. Linero demonstration site. Copyright: CITyFiED.

Introduction and description of the situation before the renovation

The intervention is located in Vikingavägen in the district Linero of Lund, Sweden.

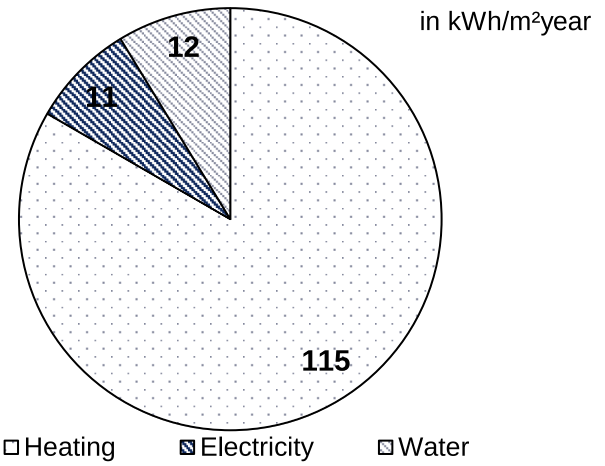

Figure 55. Energy demand before the renovation, based on statistical data from 5 years (2009-2013) measured by LKF (Heating and Water together ± 13 kWh/m²/year).

The main characteristics of the building systems before the renovation were:

District heating:

- One central substation
- 800 m of culvert
- Large distribution losses
- Uneven heat
- 100% renewable sources as of April 2018 (the shift was made by Kraftringen, independently of but concurrently with the retrofit project)

Heating system:

- Based on outdoor temperature curves
- No consideration for internal loads
- Uneven heat

There is neither on-site energy production nor cooling.

The envelope of the blocks presented a good state of preservation and did not call for a radical renovation. Ventilation flow was insufficient. The ventilation was through exhaust air only with two shafts coming out of each dwelling from the kitchen (9.2 l/s) and the bathroom (7.4 l/s). The Swedish building code requires 10 l/s for both kitchen and bathroom, but overall, the flow should not be less than 0.35 l/s per square meter of floor area, which depending on the size of an apartment, equates to 20 l/s to 30 l/s.

The area was losing appeal as the buildings, built during the 1970s as a part of the Swedish “Million Programme”, were increasingly more expensive to operate, therefore unsustainable and unattractive.

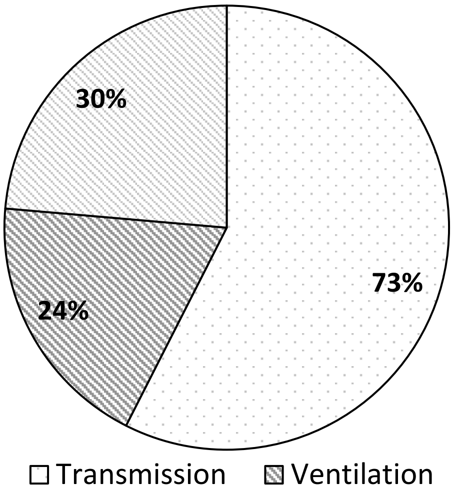

Figure 56. Heat loss distribution of the pilot dwellings. Source: Prime Project AB (2016): Kv Eddans pilothus – energi. Stadsdelsförnyelse avkvarteren Eddan 1&2 och Havamal 1&2, pilot. Lund: Prime Project AB.

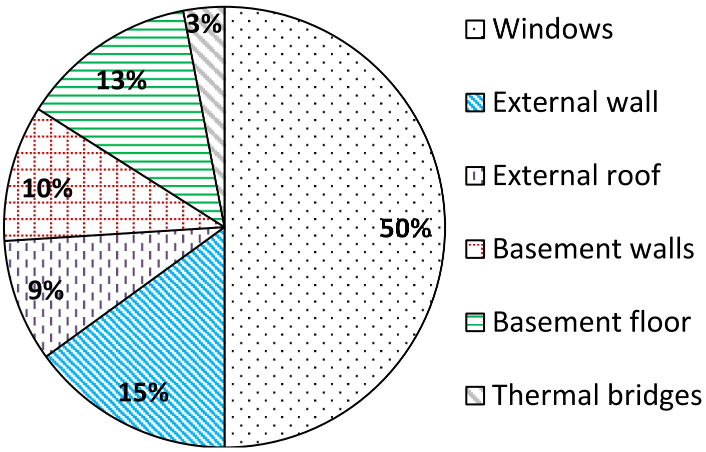

Figure 57. Heat losses from transmission for the pilot dwellings. Source: Prime Project AB (2016): Kv Eddans pilothus – energi. Stadsdelsförnyelse avkvarteren Eddan 1&2 och Havamal 1&2, pilot. Lund: Prime Project AB.

Description of the renovation goal

CITyFiED chose to pilot this renovation project (as one of three European urban sites) to develop a holistic and replicable collaboration model using innovative and cost-effective technology. The focus of the strategy was to reduce energy use and carbon emissions and to increase the use of renewable energy sources.

The project aimed to improve thermal comfort in the dwellings by raising energy standards. One of the chief objectives was to maintain affordability without raising the monthly rent for the tenants who rent the apartments from the public housing company. The area is widely regarded as a poor part of the city.

The project leaders decided to include the tenants in the process and encourage them to participate in the discussions throughout the project. Thus, a lot of weight was placed on communication and public acceptance.

Description of the renovation concept

The main features of the renovation works are:

Electricity:

- In the communal areas, the lighting was changed to LED (Estimated savings -> basement: 0; stairwells: 385; outside: 160; all values in kWh/year).
- Presence lighting control installed in stairwells, cellars, entrances, and gable ends.
- Washing machines in common laundry rooms with both cold and hot water intake installed (hot water from the grid and not electrically heated by the machine – 5 kWh/m²a reduction of electricity and 5 kwh/m²a increase in hot water use).
- Solar photovoltaic system installed with estimated electricity savings of 2 kWh/m²a (500 m² of solar panel area).

District heating:

- Six substations (before there was only one).
- 450 m of culvert (350 m less).
- Reduced distribution losses (200-350 MWh/year).
- About 3 years of payback time.
- Local district heating company to reach 100% renewable energy sourcing in 2018.

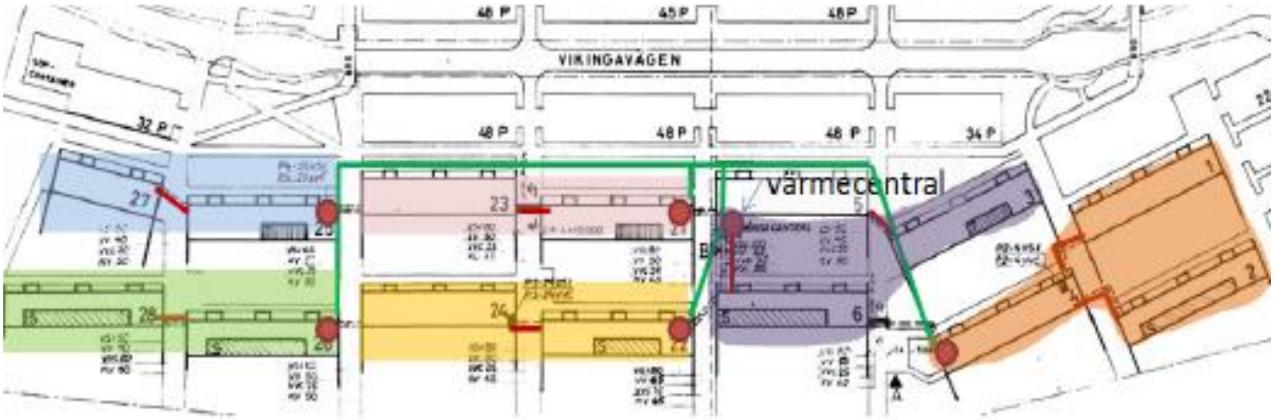

Figure 58. District heating network retrofit with 6 smaller substations. Source: Prime Project AB (2016): Kv Eddans pilothus – energi. Stadsdelsförnyelse avkvarteren Eddan 1&2 och Havamal 1&2, pilot. Lund: Prime Project AB.

Heating system:

- Temperature sensors in each apartment.
- Improved indoor comfort (by improvement of windows, insulation, and radiators' temperature). It is continuously measured with the NODA system.
- Target air temperature: 21°C (lowered by 1-2°C).
- Heating savings on a level of 30%.
- Radiator thermostats, adjustment, and shut-off valves were replaced.
- NODA system – automatic radiator hot water supply regulation, including indoor temperature sensors.

Domestic hot water:

- Individual hot water metering (replaced split-share common metering).
- Possibility to replace bathtubs with showers (around 50% of them were replaced partially owing to the individual water metering that was introduced).

Ventilation:

- Total ventilation flow for the pilot building augmented from 609 l/s to 850 l/s (basic flow).
- Heat pumps installed on exhaust air from ventilation only in buildings with district heating heat exchangers (6 substations). The heat recovered by heat pumps is added to domestic water and radiators (COP = 3.5 -> heating reduction of 26 kWh/m²a and electricity use of 7.5 kWh/m²a).
- Renovation of the ventilation system will yield an energy increase due to higher airflow, thus higher heat losses.
- Expected savings from replacing the fans with more efficient ones with lower pressure losses.

External envelope:

- Replacement of the windows and balcony doors such as windows with the least performing characteristics. Savings can reach up to 19 kWh/m²a (new windows U-value: 0.8 W/(m²·K)), but with the current prices, the investment payback time would exceed the expected 10 years period, being almost double.
- Balcony doors on level 1 to be replaced in order to accommodate wheelchairs. U-values thereof reduced from an estimated 2.7 W/(m²·K) to 0.9 W/(m²·K).
- Renovation of south-oriented façade (levels 1-2) to improve the external wall U-value from 0.5 W/(m²·K) to 0.2 W/(m²·K) with savings of 3,000 kWh/year and payback time of minimum 30 years.
- Insulation of the roof aiming to improve the U-value from 0.3 W/(m²·K) to 0.1 W/(m²·K), with an energy saving of 4 kWh/m²a, which was estimated as cost-efficient considering a 10 years period.
- An opportunity to glaze balconies (optional). The expected result is increased glazing of balconies from around 30% (existing) to 50% (after renovation) for a building, which by keeping a higher temperature in the balcony area would reduce the building's transmission losses.

Other:

- Discount on renovation for residents. There was not much interest initially, but now almost 2/3 are doing some extra renovation work. It provides an opportunity for those who have money to get a better standard.
- Electric cars fast-charging stations.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²	90,300	90,300
Population in the area:	-	1,150	1,150
Number of buildings in the area	-	28	28
Heated floor area of all buildings	m²	40,400	40,400
Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	0	0
Multi-family homes (MFH) - up to three stories and/or 8 flats		0	0
Apartment blocks (AB) - more than 8 flats		100	100
Schools		0	0
Office buildings		0	0
Production hall, industrial building		0	0
Other (please specify)		0	0
Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	% of annual heat demand	0	0
Medium consumers: AB, schools, etc. – 80-800 MWh/a		100	100
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		0	0
Property situation of buildings:			
Private	% of heated floor area	0	0
Public		100	100
Property situation of energy supply system (district heating):			
Private	% of heated floor area	0	0
Public		100	100

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	98-182	66-107
Domestic hot water demand (calculated)	kWh/m²a	12-30	21
Cooling demand (calculated)	kWh/m²a	0	0
Electricity demand (calculated)	kWh/m²a	11	9
Heating consumption (measured)	kWh/m²a	115	not available yet[19]
Domestic hot water consumption (calculated)	kWh/m²a	30	not available yet
Cooling consumption (measured)	kWh/m²a	0	not available yet
Electricity consumption (measured)	kWh/m²a	11	not available yet
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	0	0
***Decentralised* biomass boilers**		0	0
***Decentralised* heat pumps**		0	0
Centralised (district heating)		100	100
Other *(please specify)*			
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	kW_p	0	153
Other (please specify)	kW	0	-

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	-	4,200
- **building envelope renovation costs**	Euro/m²	-	860
- **heating/cooling supply costs**	Euro/m²	-	195
- **renewable energy production costs**	Euro/m²	-	50
LCC available	yes/no		yes

[19] Still under measurements. The results will be available after 2 years or more due to necessary calibrations and adjustments during the immediate years after completion of the project.

Description of the technical highlight(s) and innovative approach(es)

Good communication with the community prior to and during the retrofit process was a big success. The retrofit achieved a higher satisfaction rate since residents were included in the process from the early stages and appreciated being asked for their opinions and approval of the proposed changes. This approach has the potential to mitigate negative attitudes within the community and establishes communication between the parties. However, it should be noted that it can also be time-consuming and costly for the project and cause delays. One should keep in mind to commence communication with tenants early, prior to the start of the project, and approach residents with complete transparency to create mutual trust.
Strategies included in the approach:

→ *Local events*

Engaging the tenants in the process and encouraging active involvement is a good strategy to foster social acceptance and increase overall satisfaction with the retrofit project. Tenants will then be more likely to endure temporary living inconveniences, like noise and limited accessibility, which are inevitable during the retrofit. Through various workshops and meetings in the early stages of the project, the project team has an opportunity to acknowledge community ideas and needs. It is crucial to reach out and prepare events in a way that would attract many residents of different demographics.

→ *EM Energikollen*

A smartphone app was provided with the aim of helping tenants to keep control over their energy use. It leads to increased awareness among the users. However, the risk is that people would not be willing to use the app or would have trouble with the technology, depending on their background. Such app should therefore be adjusted to match the target users.

Decision and design process

General/organizational issues:

The project was initiated to maintain the affordability of the apartments by reducing current and future energy costs.

The project was one of the CITyFiED demo-site district retrofit projects, which were initiated and powered by the EU.

Stakeholders involved

Lund municipality, Lunds Kommuns Fastighets (LKF – Lund Municipality Property), CITyFiED, Boverket (Swedish National Board of Housing, Building, and Planning), Prime Project (energy-efficiency consultancy), Kraftringen (district heating company), IVL (Swedish Environmental Research Institute), Peire (Lund University).

The agents in charge of promoting this project were LKF, CITyFiED, and Lund municipality.

Main steps

The process for its successful implementation included a pilot study (carried out on just 4 apartments; measuring energy use and indoor climate and proposing retrofit measures; savings calculations) -> Communication with the tenants -> Implementation (some retrofits were optional).

Resources available before the project

Surveys with the tenants about problems, needs, and experiences (e.g. ventilation and window openings) and the pilot study aforementioned.

Drivers and barriers (opponents)

Drivers: EU, CITyFiED, Lunds Kommun, Boverket, living affordability, sustainability, energy, and comfort improvement.

Barrier: Funding (as the project was limited to the most cost-efficient retrofits in the projected investment period).

Main challenges regarding decision finding

Firstly, to receive extra funding for the maintenance budget from the board to refurbish old residential buildings from the “Million Program”.

Secondly, finding the optimum amount of renovation tasks in accordance with the budget, since there are a lot of target conflicts, and one needs to find a good middle ground.

The crucial parameters for go/no-go decisions were cost efficiency, energy savings, and residents' comfort and safety.

Stakeholders' role and motivation

Main stakeholder	Level of influence (1 min-5 max)	Type of influence (decision maker, influencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.) ***Lund Municipality, CITyFiED***	4	facilitator	Seeking new district retrofit approach models and trying innovative technologies.
Users/ investors (individual owners, housing association, building managers, asset managers, project developers) ***LKF***	5	decision-maker	Increasing the value of the area, and maintaining financial sustainability.
District-related actors (Community/occupants organizations, etc.)	3	influencer	Minimising the negative impact of the retrofit measures, maintaining affordable rent.
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies) ***Kraftingen***	2	delivery	Modernisation of the district heating network, maintaining customer trust and satisfaction.
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	1	delivery	Contracting for construction jobs.
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes) ***Prime Project, Peire***	3	technical advisor	Finding out the most energy- and cost-efficient solutions.

Design approach:

The design targets have been set based on the BBR – Swedish building code and regulations (buildings in Sweden have to comply) and the goals of the project CITyFiED – finding a strategy for developing the smart cities of the future, seeking innovative retrofit methods.

The decision steps to lead to the retained solution were as follows:

Estimate or measure the present performance -> Recognise highest energy reduction opportunities -> Estimate retrofit benefit -> Calculate savings -> Calculate maximum retrofit measure cost for a given investment period (LCC) -> Compare with market prices to check if investment cost-efficient -> Approve of the retrofit measure -> Present solutions to the community -> Account for residents' opinions

The tools used during the design phase consist primarily of simplified hand calculations combined with on-site measurements and surveys. LCC calculations were used assuming a fixed energy cost and investment time. There was no available information about the interest rates, inflation, or price change that had been used.

Technical issues:

The major technical challenges/constraints regarding system design/implementation have been the tenants staying in the buildings during renovation, faulty cables that were cut by mistake, and replacement of parts of the ventilation system that could not be replaced as they were old and no longer manufactured.

Financing issues:

Building and energy systems renovation was financed by public money, specifically by the EU and LKF (public housing company).

Financial incentives that were decisive in implementing the project came from the EU and Boverket (Swedish National Board of Housing, Building, and Planning). EU funding drove the project with 25 M SEK funding from CITyFiED. Boverket contributed another 12 M SEK.

The main challenges/constraints regarding financing were related to the renovation scope that had to be limited to avoid monthly rent increases. Secondly, determining the renovation tasks and putting all the design calculations together was challenging.

The actions performed in Linero were compared with a theoretical Business as Usual scenario, in which only basic investments considered inevitable are made over 30 years, and a Beyond Best Practice scenario where nearly zero energy performance was achieved. The purpose was to assess if a more ambitious way to manage and develop the buildings would be economically feasible. The study concluded that the investments made in CITyFiED scenario are the most financially viable option in the long term.

Policy framework conditions:

The key policy actors are Lund Municipality's politicians, as they have the opportunity to set the direction for LKF company and how the city should grow.

The main experts were the researchers from CITyFiED, the EU project, Peire – researchers at Lund University, LKF employees, and Prime Project employees.

There were links between the EU, Lund City, Lund University, and professional profile (energy-efficient buildings).

Some regulations hindered the process. Starting a large-scale renovation project means it will have to comply with the new building rules, especially regarding accessibility. It was required to install a lift in the area. Rules that stimulated were the ones that helped achieve various subsidies that eased the budget.

A preaching policy (communication actions, raising awareness) was performed.

Lessons learned/interesting findings

The major success factors have been:

- Pilot study.
- Community engagement.
- EU funding.

The major bottlenecks are related to cost and affordability.

LCC was performed and the most cost-efficient viable solutions were recognised. The final scope of works was limited by the available budget.

The major lessons learned have been the following:

- Pilot study – In a retrofit project, it is important to perform on-site measurements of the buildings to establish existing problems that would further determine the direction of renovation works. This study showed that performing a thorough analysis only on a few exemplary dwellings is sufficient.
- Community engagement – The decision to communicate with the residents from the early stages of the project led to a higher overall satisfaction rate. Raising awareness about the existing problems by explaining why renovation works are necessary for the area shows respect to the community, builds mutual trust, and ultimately benefits all involved parties.

From this intervention, it should be transferred that not all retrofit measures have been found cost-effective. The financial aspect was the driving factor of the renovation scope and can be a major limitation to progress toward urban sustainability. This project’s success depended on EU funding, and without this incentive, it would have been much more difficult for the housing company to cover all the costs. It might have transpired that the tenants would have had to pay for the retrofit works with increased rent prices over the following years, defeating the project's chief purpose, which was to maintain living affordability.

3.15 Housing cooperative Hagalund, Malmö (Sweden)

Country: **Sweden**

Name of city/municipality: **Malmö**

Title of case study: **Housing cooperative Hagalund**

Period of the renovation: **2017–18**

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Link(s) to further project related information / publications, etc.:

Schematic figure or aerial overview

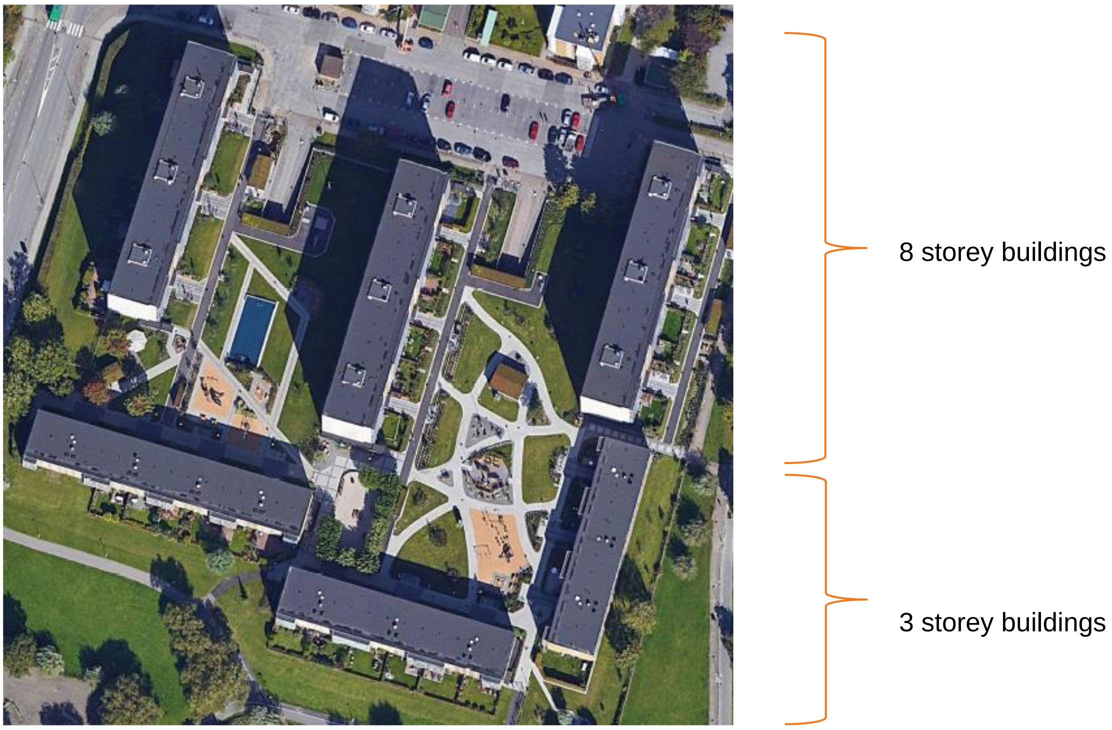


Figure 59. Aerial overview of Hagalund housing cooperative in Malmö, Sweden. Source: Google Earth.

Table 30. Basic information.

No. of buildings	6
No. of dwellings	276 apartments and 2 premises
No. of levels	8 (3 buildings) and 3 (3 buildings)
Years of construction	1967
Total heated floor area	23,307 m²
Population in the area	Ca. 550
Owned by	Bostadsrättsföreningen Hagalund (housing cooperative)
Usage	Residential

Figure 60. A 3-storey building in Hagalund housing cooperative. Source: https://www.hsb.se/malmo/brf/hagalund/om-foreningen/

Introduction and description of the situation before the renovation

The housing cooperative Hagalund is situated in the suburb Söderkulla in the south of Malmö, Sweden. The buildings are typical for the period 1965–1975 when 1 million housing units were built in Sweden, most of them as multi-family houses. Apartment buildings during this period were typically 3 and 8 floors as in the case of Hagalund.

Before the current renovation, where the energy supply system was changed from district heating to ground source heat pumps and solar PV panels were installed, the buildings had gone through several renovations to improve their energy performance. In 1983, the regulating equipment of the heating stations as well as some windows were replaced. In 1986, additional insulation was added to the roofs, and, in 1989, an additional window pane was added to the existing windows to achieve triple glazing. During 1999–2000, the balconies were extended and equipped with glazing, see **Figure 60**. All district heating sub-stations were changed in 2011 and the elevators (in the 8-storey buildings) were replaced in 2017.

The exact U-values of walls, roofs, and windows are not known. However, using statistics from the most common construction types of the construction period allows making the following approximations for the U-values:

- Walls: 0.4 W/(m²K)
- Roofs, where additional insulation was added: lower than 0.2 W/(m²K)
- Triple-glazed windows: 1.9 W/(m²K).

These approximations are based on information found in the following report: ”Teknisk status i den svenska bebyggelsen – resultat från projektet BETSI, Boverket 2010”[20].

There is no existing renewable energy generation on-site; solar energy is considered a possibility to produce renewable on-site.

Description of the renovation goal

The overall aim of the project was:

- replace district heating with geothermal heat pumps in order to reduce energy use and to reduce the costs for the housing cooperative and
- increase the share of renewable energy by installing PV panels.

However, the buildings are still connected to the existing municipal district heating grid to receive additional energy during extremely cold periods (below -10°C). It is estimated that 90% of the supplied energy comes from the heat pumps. The remaining 10% comes from district heating. The geothermal heat pumps were installed in four substations, connected to 48 boreholes of 330 m depth. The heat pump installation was funded by the private company Skånska Energilösningar which will be the owner of the energy production during the first 10 years. After this period the ownership will be taken over by the housing cooperative.

The drivers for the district renovation were mainly to improve the economy of the housing cooperative but also to become more environmentally friendly. It was believed that this would make it more attractive to live in the district.

[20] https://www.boverket.se/globalassets/publikationer/dokument/2011/betst-teknisk-status.pdf

Description of the renovation concept

Since some envelope renovation had already taken place as described above (windows and roofs), the renovation focused on the heating and energy supply system by first replacing the existing district heating as the main heating system source, which had become expensive, with ground-source heat pumps, and then by installing solar PV panels on the flat roofs. The change of the heating system also included a change of radiators in the apartments. This was very important since the new radiators were more efficient and enabled a lower brine temperature.

The 6,210 m^2 solar PV panels installation is estimated to produce annually 587,000 kWh of electricity. The PV system was financed by the housing cooperative. No financial risk was identified with purchasing the system.

The housing cooperative states that the company Skånska Energilösningar took the initiative to install ground source heat pumps to replace the district heating. The goal of the installation was to supply 90% of the annual heating needs using heat pumps. The housing cooperative also states that the entire design process for the heat pump project was solved without any problems.

Project Fact Box (I)

General information:

Parameter	unit	before renovation	after renovation
Urban scale of area:	m²		
Population in the area:	-	ca. 550	ca. 550
Number of buildings in the area	-	6	6
Heated floor area of all buildings	m²	23,307	23,307

Building mix in the area:			
Single-family homes (SFH)	% of heated floor area of all buildings	0	0
Multi-family homes (MFH) - up to three stories and/or 8 flats		0	0
Apartment blocks (AB) - more than 8 flats		100	100
Schools		0	0
Office buildings		0	0
Production hall, industrial building		0	0
Other (please specify)		0	0

Consumer mix in the area:			
Small consumers: SFH + MFH – < 80 MWh/a	in% of annual heat demand	0	0
Medium consumers: AB, schools, etc. – 80-800 MWh/a		100	100
Large consumers: industrial consumers, hospitals, etc. > 800 MWh/a		0	0

Property situation of buildings:			
Private	% of heated floor area	100	100
Public		0	0

Property situation of energy supply system (district heating):			
Private	% of heated floor area	100	100
Public*		0	0

* Public district heating exists as a backup.

Project Fact Box (II)

Specific information on energy demand and supply:

Parameter	unit	before renovation	after renovation
Heating demand (calculated)	kWh/m²a	n/a - not available	n/a
Domestic hot water demand (calculated)	kWh/m²a	n/a	n/a
Cooling demand (calculated)	kWh/m²a	0	0
Electricity demand (calculated)	kWh/m²a	n/a	n/a
Heating consumption (measured)	kWh/m²a	n/a	n/a
Domestic hot water consumption (calculated)	kWh/m²a	n/a	n/a
Cooling consumption (measured)	kWh/m²a	0	0
Electricity consumption (measured)	kWh/m²a	n/a	n/a
(Thermal) energy supply technologies:			
***Decentralised* oil or gas boilers**	% of heated floor area	0	0
***Decentralised* biomass boilers**	% of heated floor area	0	0
***Decentralised* heat pumps**	% of heated floor area	0	100
Centralised (district heating)	% of heated floor area	100	0*
Other *(please specify)*			
Renewable energy generation on-site:			
Solar thermal collector area	m²	0	0
Photovoltaics	kW_p	0	6’210 m²
Other (please specify)	kW		

* Public district heating exists as a backup.

Financial issues:

Parameter	unit	before renovation	after renovation
Total investment costs of the renovation	Euro/m²	-	
- **building envelope renovation costs**	Euro/m²	-	n/a
- **heating/cooling supply costs**	Euro/m²	-	n/a
- **renewable energy production costs**	Euro/m²	-	n/a
LCC available	yes/no		no

Description of the technical highlight(s) and innovative approach(es)

The innovative approach was to change from the original district heating system to ground-source heat pumps. The approach included an active role by an energy service company (ESCO) which analysed the housing cooperative and designed an energy-efficient solution. The same company installed the heat pumps and will operate the system for 10 years. Energy will be sold to the housing cooperative. This covers the payback period of the investment plus a profit for the company.

The PV system was financed by the housing cooperative.

Decision and design process

General/organizational issues:

The main reason why the project was initiated, the main driver, was the ambition of the housing cooperative to reduce operational costs.

Stakeholders involved

The stakeholders involved were the housing cooperative and the energy service company. The latter also promoted the project.

Main steps

The company Skånska Energilösningar contacted the housing cooperative. They planned and executed the installation.

Main challenges regarding decision finding

No challenges were reported for the project.

Decision-making issues:

Main stakeholder	Level of influence (1 min- 5 max)	Type of influence (decision-maker, in-fluencer, technical advisor, delivery)	Driver/motivation
Policy actors (municipality department, government body, innovation agency, etc.)	1		
Users/ investors (individual owners, housing association, building managers, asset managers, project developers) **Housing association**	5	decision-maker	reducing operational costs
District-related actors (Community/occupants organizations, etc.)	1		
Energy network solution suppliers (Distributor system operator, energy supply company, energy agency, ESCO, renewable energy companies) **ESCO**	5	influencer, technical advisor, delivery	profit
Renovation solution suppliers (Planning and construction parties, urban planners, architects, design team general contractors, products suppliers, ESCO, contractor, energy monitoring, facility manager, installation provider, one-stop-shop, etc.)	1		
Other intermediaries (public bodies, trade organizations, NGOs, consultancies, research institutes)	1		

The main drivers of the intervention were the housing association as a decision-maker and the ESCO as an influencer, technical advisor, and solution provider.

Design approach:

The design target was to supply 90% of the needed energy with the heat pump system. The rest of the energy is supplied with district heating.

Technical issues:

Drilling tests were performed before initiating the project. The installation created some smaller inconveniences for the dwellers but was not really a problem. Good communication with the members of the housing cooperative was obviously necessary.

So that the heat pumps could work efficiently, the existing radiators had to be replaced by more efficient ones, with a higher heat transfer rate.

Financing issues:

The project's success was mainly because it could be implemented without increasing the condominium fees, so no particular resources were needed.

The energy supply renovation was financed privately. The business model was a renovation promoted, designed, and ran by an energy service company - ESCO. This meant no or very small economic risk for the housing cooperative. The PV system was financed by the housing cooperative. No challenges were reported for the PV investment.

Policy framework conditions:

The was not a specific policy framework that drove the process. It was more market-driven, with the ESCO (Skånska Energilösningar) as the main initiator.

Neither other links nor networks were involved during the process.

No regulations hindered or stimulated the process.

Lessons learned/interesting findings

The main lesson and at the same time the main transfer from this success story is the extreme importance that the ESCO company, Skånska Energilösningar, played. They contacted the housing cooperative and offered a financial solution that was perceived to carry a very low risk by the housing cooperative.

No main bottlenecks were identified. One possible technical bottleneck was that the radiators in the buildings had to be upgraded to new ones with a higher heat transfer rate. However, this was not really an issue, as it was solved without hindering the process.

4. Analysis of the success stories

4.1 Goal of the interventions

Most of the success stories had the primary goal of improving the quality of life, sustainability, and energy efficiency of a district (AT, DK, IT2, PT1, PT2, PT3, ES1, ES2, and SE1), while others set the focus on the improvement of the energy systems (IT1, IT3, IT4, IT5, CH and SE2; in SE2, district building renovation has been performed previously), which indirectly leads to improved sustainability and quality of life, through lower energy costs or reduced pollutant emissions. Reducing energy costs was a common goal of all interventions (except in CH, where it was not a specific objective), as well as increasing environmental sustainability and reducing carbon emissions. However, in some cases (IT1, IT4, and IT5), this is not pursued by improving the energy efficiency of buildings or by implementing renewable sources but by creating a new district heating (IT1 and IT4) or by renovating and expanding it (IT5).

Interventions had diverse strategies to achieve this overarching goal, including the following.

Related to the buildings:

- Adapting the buildings to a contemporary standard of living, improving comfort, and eliminating building pathologies, where present (AT, DK, IT3, PT1, PT2, PT3, ES1, ES2, and SE1)
- Improving the quality and increasing the value of the building stock to ensure rentability (AT, DK, ES2, and SE1)
- Creating new apartments / increasing the living space (AT, PT1)
- Maintaining affordability – no increase in rent or low investment cost for the owners – (DK – with a reasonable rent increase – ES1, ES2, and SE1)
- Improving accessibility (ES1, ES2, and SE1)
- Demonstrating efficient building retrofitting (including district heating) as a role model (ES)

Related to the energy systems:

- Using renewable energy (AT, CH, DK, IT2, IT3, PT1, PT2, PT3, ES1, ES2, SE1, and SE2)
- Reducing fuel poverty (IT1, IT2, ES1, and ES2)

Related to the district and the inhabitants:

- Improving the quality of open space, the attractiveness and image of the district (AT, DK, PT2, PT3, and ES2)
- Improving social diversity and cohesion in the neighbourhood (DK, PT2, ES1, and ES2)
- Renovating or creating new outdoor areas (AT, IT5, PT2, and PT3)
- Improving traffic and mobility (DK, PT2, and PT3)
- Improving the quality of air in the district (IT1 and IT5)
- Social improvements, such as promoting better qualifications to access the employment market (PT2 and ES2)
- Promoting sustainable mobility: acquisition of electric vehicles and/or charging stations (ES1, SE1)
- Deployment of an urban management system (ES1)
- Conducting research (IT4)

4.2 Renovation measures

Success stories show actions taken to improve energy efficiency or systems in a district. Renovation measures to achieve this objective included renovating the thermal envelope of existing buildings, renovating an existing energy supply system, or constructing a new energy supply system using renewable energy sources. Table 31 summarizes the interventions performed.

All interventions that include renovation measures in both the buildings and the energy supply system (AT, DK, IT2, PT1, ES1, ES2, and SE1) have sought to achieve a balance between the degree of intervention achieved in building envelopes and the energy supply system (including the use of renewable energy) with the objective of either achieving the most cost-effective solution for reducing the carbon emissions or efficiently using the available budget. In those success stories, this balance was based on estimates and the experience of the agents involved; there is only one success story in which this balance has been calculated. In DK the calculations showed that, comparing energy losses in the distribution network – which would account for more than 50% of the total energy needs even if the DH could be lowered to 50 °C (usual temperature 70-80 °C) – with the energy losses at the building level, it made sense that the renovation of the building envelope was less ambitious than initially planned and more effort was made into reducing the thermal losses in the distribution system. Additionally, the appropriateness of converting the district into self-sufficiency (generating all the required energy by renewable energy systems on-site) was performed by a socio-economic analysis. It was found that this would result in an overinvestment in infrastructure, so it was considered appropriate if the district remained connected to the existing energy system and if the share of renewable energy was increased through the larger district heating system to which the district is connected. To enable a long-term shift to a low-temperature district heating system, radiators were installed with a capacity that takes into account a future low-temperature model.

In the cases of AT and SE1, cost-effectiveness calculations for the renovation of the building envelope were performed, however, without seeking an appropriate balance with renewable energy. In the case of AT, three renovation scenarios with different levels of energy efficiency were compared, as well as the possibility of producing electricity on-site. In SE1, a theoretical Business as Usual scenario, in which only basic inevitable investments were considered, was compared with a Beyond Best Practice scenario where a nearly-zero energy performance was achieved. The purpose was to assess if a more ambitious way to manage and develop the buildings would be economically feasible. The implemented measures did not reach a near-zero energy performance but were the most financially viable option in the long term.

Cases where only measures on the energy system were undertaken included new efficient district systems, even without renewable energy, a new lake-water-based district heating system with a centralised heat pump, a switch from a district heating system to geothermal heat pumps, the use of solar thermal for domestic hot water or sports facilities, or the installation of PV,

Cases where mainly only measures on the building envelopes were undertaken included comprehensive measures on the building envelopes.

Table 31. Summary table of the renovation measures performed. Interventions where only energy systems have been renovated are marked in grey. Interventions where the thermal building envelope has been mainly renovated (renewable energy sources have also been included without substituting the energy supply systems) are marked in yellow.

Nomenclature	Renovation of Thermal envelope	Renovation of energy supply system	Calculation on balance between energy efficiency and renew. energy
AT	Yes, including mechanical ventilation. Part of the buildings were demolished to build new ones	Connection to the thermal solar system micro-grid of the neighbouring city district	No, cost-effectiveness in building renovation
DK	Yes, energy efficiency level reached balance with the energy supply measures	Renovation of the DH, replacement of radiators (by high-capacity ones) to make compatible with low-temperature DH, long-term increase of renewables in the share of DH envisioned	Yes
IT1	No	New efficient DH (cogeneration plant), yet without renewable energy	No
IT2	Yes, major energy renovation of 3 buildings	Replacement of the climatic control unit in the existing DH. Replacement of individual electrical boilers by one air-to-water heat pump per building for producing DHW in the summer period	No
IT3	No	New biomass DH plant with remote maintenance and solar thermal to supplement the summer DHW needs of the nursing home	No
IT4	No	New efficient DH (trigeneration plant), yet without renewable energy	No
IT5	No	Renovation of an existing power plant in the DH and construction of a new station to make DH more efficient, yet without renewable energy	No
PT1	Yes. Part of the buildings were demolished to build new ones	New heating and cooling systems (Multi-Split HVAC). DHW: New electric heater with a storage tank with renewable energy supply (3 m^2 solar thermal per flat)	No, expert estimation
PT2	Yes	No change in the main energy supply; solar thermal for DHW	No
PT3	Yes. Part of the buildings were demolished to build new ones	No change in the main energy supply; solar thermal in the sports facilities	No
ES1	Yes	New biomass DH with integrated energy management	No, expert estimation
ES2	Yes	DH renovation (new biomass plant and renovation of distribution network); solar thermal for DHW. Smart meters in the dwellings, wireless thermostats, and radiator valves	No, expert estimation
CH	No	New lake-water-based DH, remotely monitored and controlled	No

Nomenclature	Renovation of Thermal envelope	Renovation of energy supply system	Calculation on balance between energy efficiency and renew. energy
SE1	Yes, including renovation of ventilation system	Renovation of DH: new substations, fewer distribution pipes; PV installation. At the dwelling level: automatic regulation of radiators, indoor temperature monitoring, radiator thermostat, and individual DH metering	No, cost-effectiveness in building renovation
SE2	Yes, at different times before the DH renovation (no coordination between the projects)	Replacement of DH with geothermal heat pumps; PV installation. DH as a complementary system for especially cold periods (<10 °C). Replacement of radiators with more efficient ones	No

Additionally, in some of the success stories, supplementary measures were taken to achieve specific project goals, such as updating the buildings to a contemporary standard of living and improving the mobility of accessibility in the dwellings. Table 32 summarizes the measures undertaken.

Table 32. Additional measures not directly related to improving the energy efficiency of buildings or the energy supply system. Interventions, where only energy systems have been renovated are marked in grey. Interventions where the thermal building envelope has been mainly renovated (renewable energy sources have also been included without substituting the energy supply systems) are marked in yellow.

Nomenclature	Measures
AT	New balconies and new open spaces
DK	Other measures related to traffic, mobility, roads, landscaping, rainwater use, climate change adaptation
IT1	-
IT2	-
IT3	-
IT4	-
IT5	-
PT1	Bigger windows in the living room
PT2	Urban scale: reorganising the road system, creating green areas and new walking zones. Other social actions: promoting the qualification of minorities living in the neighbourhood and better conditions for the young population to access the employment market
PT3	LED Lighting at the school and streets, free wireless network, new equipment in the neighbourhood (eco-gardens) and pedestrian circuits among others
ES1	Building management system (BMS) and accessibility improvement. Acquisition of electric vehicles and charging stations. Deployment of an urban management system and a citizen engagement toolkit, which includes multiple events and activities
ES2	Improvement of the accessibility in the dwellings
CH	**-**
SE1	LED and presence lighting and EV fast-charging station
SE2	-

4.3 Main energy parameters

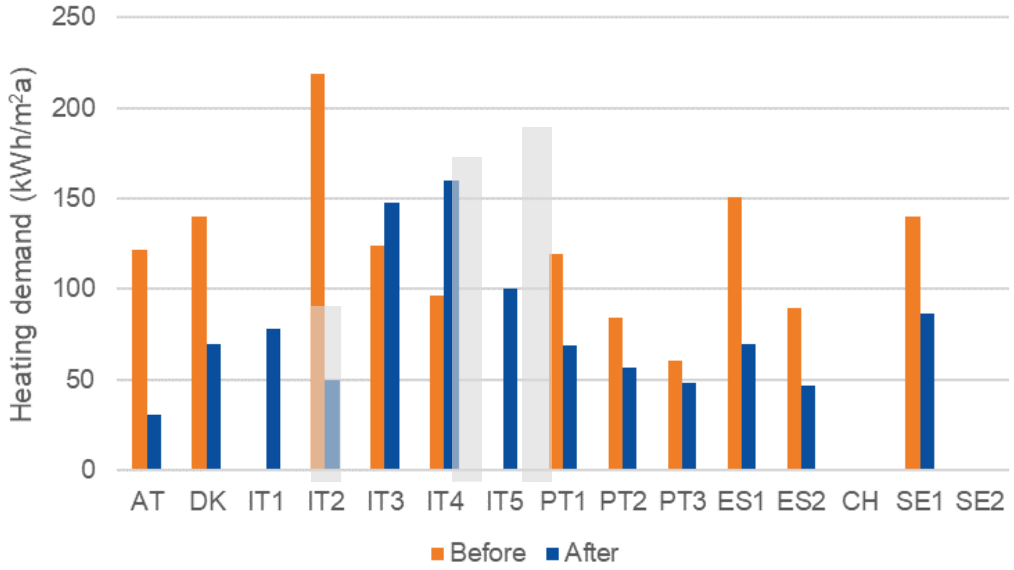
The energy demand for heating, DHW, cooling, and electricity is summarized in **Table 33**. **Figure 61** and **Figure 62** present the energy demand for heating and domestic hot water and the reduction of the energy demand for heating and domestic hot water after the renovation. In most of the districts, there is no cooling system, and the electricity consumption has not been determined in most of the cases.

The heating energy demand before the renovation ranges from 60.5 kWh/m^{2}a in PT3 to 219 kWh/m^{2}a in IT2. These two districts present the lowest and highest reduction in heating energy demand, 20% in PT3 and 77% in IT2. There are two cases where the heating energy use increases after the intervention, IT3, and especially in IT4. However, since this intervention cannot be considered a best practice, as stated in Section 1.2, this has not been analysed in more detail. The average demand reduction achieved is slightly less than 50%.

Table 33. Energy demand for heating, DHW, cooling, and electricity before and after the renovations. Interventions where only energy systems have been renovated are marked in grey. Interventions where the thermal building envelope has been mainly renovated (renewable energy sources have also been included without substituting the energy supply systems) are marked in yellow. n. a. = not available. * corresponds to measured energy consumption.

Nomenclature	Energy demand (kWh/m^{2}a)							
	Heating		DHW		Cooling		Electricity	
	Before	After	Before	After	Before	After	Before	After
AT	93-150	27-35	Included in the heating		No cooling		n. a.	
DK	140	70 (30 new buildings)	52	23	No cooling		n. a.	
IT1	n. a.	~78	n. a.	Included in the heating	n. a.		n. a.	
IT2	219 (197*)	50	54 (22* elect.)	22 (14 gas, 3 elect.)	No cooling		n. a.	
IT3	124 (140*)	148 (200*)	Included in the heating		No cooling		Included in the heating	
IT4	96.6*	160*	Included in the heating		n. a		97.1*	82.7*
IT5	n. a.	~100	n. a.		3.66* MWh/a	3.96* MWh/a	11.67* MWh/a	10.27* MWh/a
PT1	119	69	37	27	6.5	8	4.1	1.3
PT2	84	57	30	30	n. a.		n. a.	
PT3	60.5	48.2	30	20	n. a.		n. a.	
ES1	151	70	n. a.		0 in dwellings, variable in tertiary. Unchanged		~78	
ES2	89.6	46.4 (23.9 renovated buildings)	n. a.		~0		n. a.	

Nomenclature	Energy demand (kWh/m²a)							
	Heating		DHW		Cooling		Electricity	
	Before	After	Before	After	Before	After	Before	After
CH	n. a.		n. a.		n. a.		n. a.	
SE1	98-182 (115*)	66-107	12-30 (30*)	21	No cooling		11*	9
SE2	n. a.		n. a.		No cooling		n. a.	



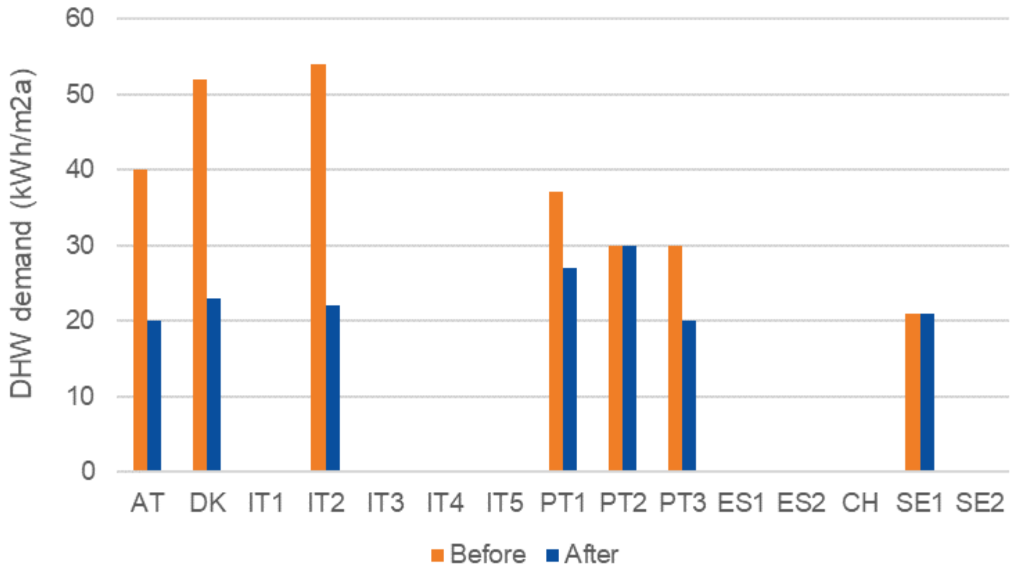


Figure 61. Top: Heating demand before and after the renovation, highlighted in grey are those cases in which the DHW demand is also included. Bottom: DHW demand before and after the renovation. IT4 corresponds with energy consumption and not demand.

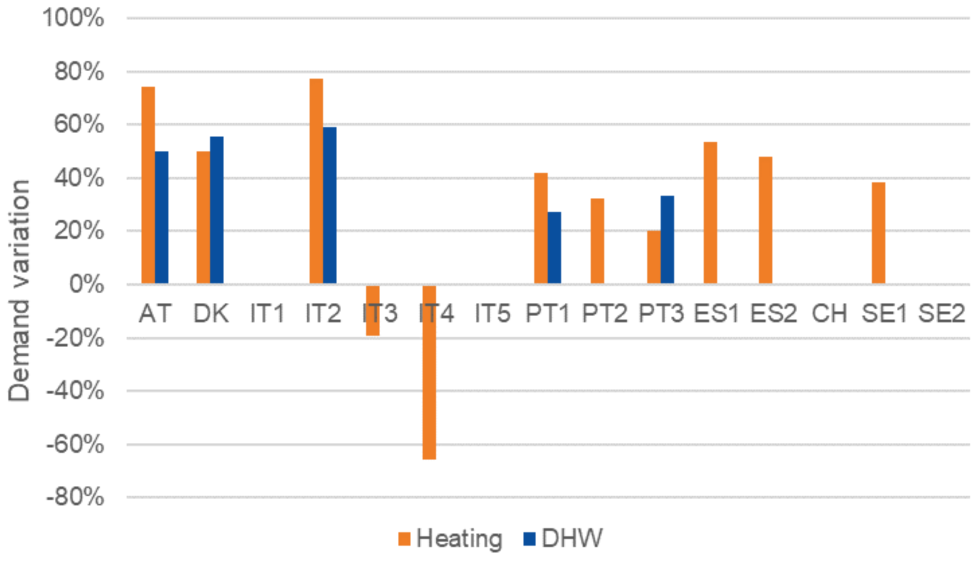


Figure 62. Variation of heating and DHW demand after the renovation. IT4 corresponds with energy consumption and not demand.

Table 34 shows the type of energy supply system and energy source for heating and DHW and the size and type of renewable energy production system per case. The reported renewable energy production before the renovation was zero in all success stories and is not included in the table. As can be seen, most of the interventions incorporate some renewable energy use except IT1 and IT4, which, as mentioned above, are not examples of good practices in terms of energy efficiency. In most cases, renewable energy is used for heating through a DHN. Solar thermal is present in 6 districts and PV in 4 of them. Two districts have decentralised heat pumps: IT2 (air-to-water, for producing DHW in the summer period) and SE2 (geothermal); in the latter case, the decentralised heat pumps have replaced the centralised system, which is used as a support system especially in the cold period.

The size of renewable energy production systems through solar thermal or PV per m^2 of gross heated floor area varies considerably, as shown in

Figure 63. AT, IT3, PT1, PT2, and PT3 have solar thermal systems with an area of 0.6, 0.0035, 0.1, 0.004, and 0.001 m^2 of solar thermal per m^2 of gross heated floor area. In ES2 there is also solar thermal for DHW (as required by regulation, as is also the case in Portugal), the size of the system is unknown. IT2, IT5, SE1, and SE2 have a photovoltaic installation, the installed power per m^2 of heated surface is as follows: 2.1 (13.3 referred to the three buildings involved), 0.02, 3.8, and 34 W_p/m^2.

Table 34. Type of energy supply system and renewable energy production before and after the renovation. Interventions where only energy systems have been renovated are marked in grey. Interventions where the thermal building envelope has been mainly renovated (renewable energy sources have also been including without substituting the energy supply systems) are marked in yellow. The systems in which the energy source is renewable are marked in blue.

Nomenclature	Type of energy supply system		Renewable energy production after renovation	
	Before renovation	After renovation	Absolute	Per m² gross heated floor area
AT	Decentralised fossil	Centralised (partially fossil), 25% renewable energy generation on-site	2,048 m² solar thermal	0.6 m²/m²
DK	Centralised (mostly renewable)		Unknown	Unknown
IT1	Decentralised fossil (gas)	Centralised fossil (gas cogeneration plant)	0	0
IT2	Centralised fossil DH (gas, individual electric boiler for DHW)	Centralised DH (Decentralised air-to-water HP for DHW in summer for 3 buildings)	303 m² PV (49 kW_p)	2.1 W_p/m^2 (13.3 referred to the three buildings involved)
IT3	Decentralised fossil (gas)	Centralised renewable (wood chips)	13.8 m² solar thermal	0.0035 m²/m²
IT4	Decentralised fossil 80% (gas) and renewable 20% (HP)	Centralised fossil (gas tri-generator)	0	0
IT5	Decentralised fossil	Centralised fossil (gas)	372.5 GWh PV and 0.1 GWh eolic	0.02 W_p/m^2
PT1	Decentralised electric (electric heaters)	Decentralised electric (Multi-Split HVAC)	540 m² solar thermal	0.1 m²/m²
PT2	Not renovated		~500 m² solar thermal	0.004 m²/m²
PT3	Not renovated		118 m² solar thermal	0.001 m²/m²
ES1	~80% decentralised fossil, ~20% decentralised renewable	~60% centralised renewable (wood chips), ~35% decentralised fossil & ~5% decentralised renewable	Unknown	Unknown
ES2	Centralised fossil (oil)	Centralised mixed (biomass + gas boilers)	Unknown (solar thermal)	
CH	85% decentralised fossil, 15% decentralised renewable (biomass + HP)	100% centralised renewable (lake-water based)	1,075 kW heating power, 257 kW cooling power	Unknown
SE1	Centralised mixed	Centralised renewable	153 kW_p	3.8 W_p/m^2
SE2	Centralised mixed	90% decentralised renewable (geothermal) + 10% centralised mixed	6,210 m² PV	34 W_p/m^2

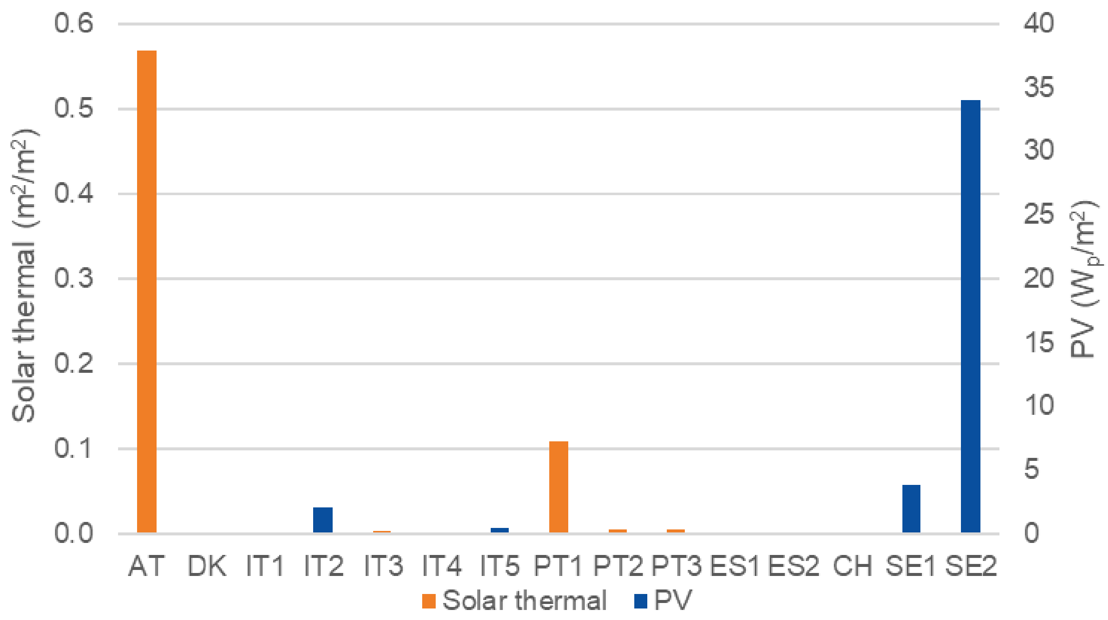


Figure 63. Size of the solar panels and PV installation, in relative terms, compared to the gross heated floor area.

4.4 Key actors in the decision-making process

A considerable number of stakeholders are involved in each district renovation. The key actors involved in the decision-making process are summarized in **Table 35**.

Municipalities (AT, DK, IT1, IT3, PT3, ES1, ES2, and SE1), regional entities (IT2, ES1, and ES2), municipal social housing company (PT1, PT2, and PT3), and a public corporation (CH) were the main policy actors taking the role of decision-makers, being in some cases investors and/or owners. In some districts (PT2, PT3, ES2, and SE1), the European Union, among others, took the role of a financier.

The main decision maker was either the municipality (AT, IT1, IT3, IT5, PT3, and ES1) or a housing association (or company) that owns the dwellings or energy systems such as the municipal or public housing company (PT1, PT2, PT3, SE1, and SE2), a public corporation (CH), the housing association (DK), the Regional Company for Residential Buildings (IT2) or the university board (IT4).

The investor was often the institution or organisation that owns the buildings (AT, ES1, ES2, and SE2), including the university to which the buildings belong (IT4). An ESCO was also an investor in some districts (IT1, IT2, IT4, IT5, and SE2) and a real estate development company in one of the districts (PT1). In several cases, part of the financing comes from municipal funds (IT1, PT1, PT2, and SE1), funds from a public corporation (CH), regional funds (IT2 and IT3), or European funds (PT1, PT2, PT3, and SE1). In two districts, funding was coming from the three bodies mentioned above (ES1 and ES2). In the Swiss district (CH), subsidies were provided by a foundation that finances emission reduction projects to provide certificates for compliance with a national law requiring fossil fuel companies to offset part of their emissions. In the Danish case (DK), it is unknown who the investor is.

The tenants (or active residents), residents' association (or tenants' or neighbourhood association) were the main district-related actor in many of the success stories (DK, IT2, IT3, PT2, PT3, ES1, CH, and SE1) taking the role of influencers. This role was undertaken by a sociologist in one case (AT), by the university researchers – who also worked as scientific advisors – and students (IT4), or by a territorial committee (IT5).

Most of the success stories cited a municipal company (AT, DK, IT5, and SE1), a public corporation (CH), or a private energy supply company (IT3, ES1, and ES2) as energy network suppliers. These took different roles, from technical advisors to decision-makers. In several cases (IT1, IT2, IT4, and SE2), it was an ESCO that overtook the investment and the energy delivery. In ES1 an ESCO acted as the decision-maker. IT5 also cites a renewable and environment company that acted as a technical advisor. In ES1 an engineering firm was taking part in the decision making and, apart from the energy supply company, there was a public tender for the construction of the district heating. In PT3, the national energy agency was involved as a technical advisor.

Many different agents cited as renovation solution suppliers were undertaking mainly the role of technical advisers. Architects (AT, DK, PT1, ES1, and ES2), other consulting firms or engineering companies (AT, CH, DK, IT3, and ES1), or research institutions such as universities or laboratories (IT2, IT5, PT2, and PT3) were the most cited. Additionally, municipal energy agencies (PT1, PT2, and PT3), other regional/municipal bodies (AT and ES1), or ESCO (IT1, IT2, and IT3) took part in the supply of renovation solutions.

In many districts, other stakeholders were involved, such as research centres and universities (DK, IT4, ES1, ES2, and SE1) and other consulting firms (DK, IT1, IT4, PT3, ES1, ES2 and SE1) providing mostly technical and scientific advising as well as post-occupancy evaluation or social advising in some cases. Other agents were an institute for regional planning and housing (AT, ES2) as project developers or coordinators and a foundation that provided some subsidies (CH).

Table 35. Key actors and roles undertaken during the decision-making process. DM: decision maker, I: investor, In: influencer, TA: technical advisor, A: advisor, PD: project developer, SA: scientific advisor, D: delivery, PF: public financier, F: financier, O: owner, SoA: social advisor, FF: financial facilitator, RF: regulation facilitator, PD: project development, C: coordinator, Com: communication, POE: post-occupancy evaluation, EU Con: European project consultancy, Fac: facilitator.

	Policy actors	Users/ Investors	District-related actors	Energy Network suppliers	Renovation Solution suppliers	Other
AT	Municipality (DM)	Non-profit building association (I)	Sociologist (In)	Salzburg AG (TA)	Development and architect (TA); Housing Office of Salzburg (In)	Institute for regional planning and housing (A, PD, SA)
DK	Municipality	Housing association (DM)	Tenants (In)	Aalborg DH (D)	Architects, landscape, traffic consults (TA)	Aalborg University, Danish Building Research Institute, COWI, Kuben Management (TA, SA)
IT1	Municipality (DM, I)	Municipal housing association (In)	-	ESCO (DM, D, I)	ESCO (TA)	Dedicated agency (TA)
IT2	Regione Lomardia (PF)	Regional Company for Residential Buildings (DM), ESCO (F)	Tenants' association (In)	ESCO (I, D)	Politecnico Milan, ESCO (TA)	-
IT3	Municipality (DM)	Regione Veneto (PF)	Occupants’ organization (school and nursing home) (In)	Energy supply company (DM, D)	Consulting firm (TA)	-
IT4	University IAUV board (DM)	University IAUV board and management (I)	University IAUV researchers and students (In, SA)	ESCO (DM, D, I)	ESCO (TA)	ESCO, University IAUV researchers (TA, In)
IT5	Municipality (DM), Service Utilities Financing company (F)	-	Territorial committee (In)	Public energy supply company, renewable and environment company (TA)	Politecnico di Torino, Università di Torino (TA)	-
PT1	Municipal social housing company (O, DM)	Municipal social housing company (O/DM); Real estate development company (I)	-	-	Architect, municipal energy agency (In, TA, D)	-
PT2	Municipal social housing company (O, DM, I) European Funds (F)	Owners’ association, parish council (In)	Residents’ association (In)	-	Research Centre University of Porto, Municipal energy agency (TA)	-
PT3	Municipality, Municipal social housing company (O, DM), European Funds (F)	Residents’ association (In)	Residents’ association (In)	National Agency for Energy (TA)	Municipal Agency for Energy and Environment and the National Civil Engineering Laboratory (TA, D)	Public transport company, municipal waste management company (TA), social solidarity private institution (SoA)

	Policy actors	Users/ Investors	District-related actors	Energy Network suppliers	Renovation Solution suppliers	Other
ES1	Municipality, Regional government (DM, In)	Individual flat and commerce owners, municipal social housing agency and regional energy agency (DM), building owners (I)	Neighbour association (In)	Engineering firm and ESCO (DM), energy supply company, and public tender DH construction (D)	Regional housing department and municipality urban department (DM, In), architectural firms and construction companies (TA)	Research centre (DM, In), other social, technical consulting firms (TA, SoA)
ES2	Municipality (In, FF, RF), Regional government, and European Union (F)	Building managers, neighbours (In), Bank (F)	-	Energy Supply company (DM, D)	Architects (DM, PD, TA)	Regional social housing company (C, Com), Research Institutes (SA, TA, POE), Consulting firm (EU Con)
CH	Municipal corporation (DM, I)	Municipal corporation (DM, I)	Active residents (In)	Energy supply company (TA)	-	Foundation for Climate Protection and Carbon Offset KliK (F)
SE1	Municipality, European Project (Fac, I)	Public housing company (DM)	Tenants (In)	District heating company (D)	-	Energy-efficiency consultancy, Lund University (TA, SA)
SE2	-	Public housing company (DM, I)	-	ESCO (I, TA, D)	-	-

4.5 Main drivers and barriers

For most of the presented interventions, one or various key actors were indicated as the main driver for the successful implementation of the renovation. In most cases, the municipality (IT1, IT3, IT5, PT2, PT3, ES1, ES2, and SE1), the housing association (IT1, ES1, ES2 – public – and SE2 – private –), a residents' association or the wish of the inhabitants (IT5, PT3, and CH) initiated or supported the renovation process. In other cases, the main driver is a partnership between the municipality, public housing organizations, and an energy company (DK), the municipality and an energy company (SE2), or the university and an energy company (IT4). Three cases (AT, ES1, and ES) cited the support of a European funding programme as the main driver. In one case, funding in exchange for obtaining emission reduction certificates was also a driver (CH). The underlying driver for this was a law obliging fossil fuel companies to offset a part of their emissions. A driver is also the possibility of accessing a large renewable energy source. In the indicated success story, this was the thermal energy of the lake (CH). To enable specific combinations of energy efficiency and renewable energy-based district heating systems, a possible driver is to connect more buildings to the district heating system and obtain more connection fees, as the energy needs of the buildings already connected to the system decrease due to efficiency measures (CH).

The main barrier to successfully implementing the district renovation is the funding (IT2, IT3, PT1, PT3, ES1, ES2, and SE1). The allocation of the tenants, either because they must be relocated during the renovation works (AT, PT1, and PT2) or because they must stay (ES1), also constitutes a barrier. Residents can likewise constitute a barrier, if they are not included since the planning stage (IT1) or if they are the owners who must be convinced to invest (and have few financial resources) (ES1 and ES2). Legal aspects can constitute a barrier, either due to the requirement to carry out energy efficiency measures even though it was not the goal of the intervention (PT1) or due to the lengthy process to approve the projects (ES1). Political differences about possible gentrification derived from the renovation (AT), the discussion about the appropriateness of demolition or renovation (PT1), or the intervention in a historical context may prove to be a barrier.

Table 36 presents the main drivers and barriers that arose in the presented success stories.

Table 36. Main drivers and barriers for the successful implementation of district renovations as described in the success stories.

Nomen-clature	Main drivers	Main barriers
AT	EU's CONCERTO funding programme.	Political differences (discussion about possible gentrification derived from the renovation).
DK	The collaboration model for an energy partnership between housing organizations, municipality, and an energy company to create a smart grid.	No barriers found
IT1	The willingness of the municipality.	The residents of the area since the measures were taken top-down, without a participatory planning stage.
IT2	The housing company aiming at renovating its building stock. Regione Lombardia, awarding the call and financing the project for 1/3 of the total costs.	Unavailability of funds from the owner
IT3	The municipality and the large availability of woodchips in the neighbouring context, that allows an eco-compatible use of the district heating system with a drastic reduction of the pollutants emitted.	The unavailability of funds for the administration to face the project and an unexpected consequence after the intervention, because the strong noise coming from the central disturbs the neighbouring inhabitants.
IT4	University administration and energy company	The feasibility of the intervention in such a historical context with cultural heritage requirements to observe.
IT5	The intervention was performed to meet the request of the inhabitants of Turin and due to the wish of the municipality.	Unknown
PT1	The deterioration of the buildings	The need to comply with the norms: although energy renovation was not the focus of the intervention, it had to comply with thermal requirements imposed by national regulations, which increased complexity. The preliminary lack of financing to complete the necessary renovation works. The discussion on whether the best solution was to renovate or demolish. Need of temporal allocation for tenants.
PT2	The intervention was triggered by a strategic decision by the municipality to improve the liveability of the neighbourhood, the energy and indoor air quality of the buildings including other measures such as educational policies, sports, urbanism and public spaces, accessibility and road systems.	Need of temporal allocation for tenants
PT3	Inclusion of the neighbourhood at the Neighbourhoods and Priority Intervention Areas in Lisbon. The involvement of the residents' association (ARMABB) must also be highlighted they facilitate all actions within the scope of the "Eco-Bairro" project.	Funding

Nomen-clature	Main drivers	Main barriers
ES1	Willingness of the municipality and availability of European funds. The public housing company acting as a one-stop-shop. Building managers were key agents to carry on or reject the renovation.	Very high density, low-medium income families and relevant social dimension. National and local regulations: the delay for the project approval was long, from 3 to 10 months. The verification process for the local regulation was simplified during the project.
ES2	Municipality and the extraordinary support and management of the public housing company. The financial assistance of EU, regional and local administrations. Improving a deprived area of the city.	Low resources of the families. Opposition of part of the residents (more buildings could have been renovated with larger support of the residents). Short implementation plan (14 months from the project defining, search for subsidies to the construction works) and the permanence of the residents during the works.
CH	The initiative was started by village residents. A private resident wanted to build a lake-water-based heat pump for his property, and a local public corporation extended this idea to create a new district heating network for a bigger part of the population. Ecology was the driving factor followed by the economy. Further drivers were: emission reduction certificates and related funding by a foundation; possibility to access a large renewable energy source; possibility to connect new buildings as efficiency measures lower energy consumption in district heating system	No barriers found
SE1	Municipality and Swedish National Board of Housing, Building, and Planning Main drivers: living affordability, sustainability, energy and comfort improvement.	Funding (as the project was limited to retrofits that were found most cost-efficient in the projected investment period).
SE2	Ambition of the housing cooperative to reduce operational costs. A private energy service company (ESCO) company took the initiative to replace DH with heat pumps and provide 90% of the annual heating needs with them.	No barriers found

4.6 Challenges

Challenges faced in the renovations have been classified under the following five categories: design phase, technical issues, financial issues, management issues and policy framework conditions. Challenges include the main barriers identified above yet go beyond them. Some success stories do not include detailed information about the challenges encountered during the different phases of renovating a district. This shows that this type of information is not always recorded, and some of the lessons learned during the process are not transferred.

During the **design phase**, the main challenge reported was related to the decision-making process for finding the "optimal" renovation measures (IT2, IT3, PT1, ES1, ES2, and SE1). In some cases (IT2 and ES1), this was mostly due to the need to reach a certain grade in the energy performance certificate (EPC), either since it was too ambitious (IT2) or due to the lack of knowledge (ES1). In ES1, it is also pointed out the fact that each building (as well as its ownership) was different, so specific solutions were required. A limited budget (ES2 and SE2) impacted the scope of the renovation; in SE1, cost-efficiency, energy savings, and residents' comfort and safety were crucial parameters for deciding on the go/no-go of the intervention. In ES2, building renovation could not be aesthetically disruptive or interfere with the surroundings to avoid differences and facilitate social cohesion. In PT1 it was also discussed the possibility of demolishing the buildings. Energy efficiency was not the main objective of the renovation but, given the depth of the renovation to be carried out, all the thermal requirements imposed by the national regulations in force had to be fulfilled.

An additional challenge during the design phase was to plan the relocation of the tenants during the works (PT1 and PT2) or to plan that these were performed from the exterior of the buildings due to the buildings' continued occupancy (ES2), in SE1 tenants were also staying during renovation works. The lack of district heating knowledge was also a challenge in ES1 and a time constraint in ES2. In IT4 the definition of the feasibility, calculation of the energy profile, schedule and energy needs and economic convenience for the ESCO was a challenge. Whereas in CH, the high-time effort that requires such a process (planning flora and fauna protection, getting permission at different government levels, etc.) and the need that all or most of the corporation members agree with the project were the main challenges during the design phase.

The main **technical challenges** were related to unforeseen aspects/problems (IT1, ES2, and SE1), the location of the energy production systems (IT2, IT3, PT1, and ES1), pipes lying in a built area (IT1, IT4, and ES1) and the overlapping of renovation phases due to time constraints (IT3, IT4 – in both restricted to summer – and CH). Among the unforeseen aspects was a thicker façade cavity than expected, having to allocate money from another measure to it (IT2), the exterior and interior rearrangement and renovation of telecommunication lines, water and gas pipelines and air conditioning units which were a challenge due to the constrained time (ES2), faulty cables that were cut by mistake or the impossibility of replacing old parts of the ventilation system that were no longer manufactured (SE1).

IT5 reported the use of new technologies and the continuous planning of expansions in the network as major technical challenges whereas in PT3 a major challenge was finding the most adequate material for external wall insulation according to sustainability criteria. In CH, the rapid development of the project required flexibility and innovation and at the same time, project phases overlapped, making coordination difficult. In IT2 the grid-connected PV system did not work at first because of bureaucracy-related problems. Other technical challenges concerned the energy supply system: in SE2, so that the heat pumps could work efficiently, the existing radiators had to be replaced by more efficient ones with a higher heat transfer rate, whereas in IT3, keeping and adapting the existing boilers as the emergency system was a challenge.

In **financial terms,** the most cited challenge was finding funding to carry out the renovation – even though many of the presented success stories have publicly owned buildings/systems and thus most likely less economic burdens – and in many cases, district renovation would not have been possible without public funding (at all scales: European, national, regional, local or through a foundation providing subsidies due to a national offsetting requirement). In the case of the Italian success stories (IT1, IT2, IT3, IT4 and IT5), part of the investment not covered by public funds were financed by an ESCO or a service utilities company. Two success stories (PT1 – publicly owned – and SE1 – privately owned –) name the occupants' rent as a financial challenge. In PT1, a rent increase was reported after renovation. However, it is expected to be offset by a reduction of about 70% in energy costs for the residents of the renovated dwellings. In the case of SE1, the renovation scope had to be limited to avoid monthly rent increases; available funding made also challenging the selection of the renovation measures considering cost-efficiency, energy savings, residents' comfort and safety in the design calculations as these goals are conflicting (for example, the most cost-efficiency option will cause too much disturbance to tenants that cannot move during the renovation works and therefore an alternative solution has to be found). The low purchasing power of the dwellings' owners was also a challenge in ES1 and ES2; regarding ES1, it was reported that unexpected expenses were critical and ES2 that high-interest rates (5-7 %) for bank loans discouraged many owners. ES2 also points out the complexity of accessing public funds as a challenge.

In PT1, the municipality designed and implemented a financing model that allowed a private investor to retain a part of the neighbourhood's land and promote a new real estate development in exchange for being responsible for renovating and constructing a new social housing building. The complexity of the financing operation caused constraints to the initial planning for the neighbourhood renovation due to delays regarding the public tender and contracting.

The main **management challenge** cited is the coordination between all the stakeholders involved in the process (PT3, ES1, and ES2). In the case of PT3 and ES2, this was overcome thanks to the public housing company that coordinated the whole process, being the intermediary between the administration, neighbours, and renovation suppliers. Another important aspect is bureaucracy (IT2, IT3 and IT4). The relocation of tenants is also considered a challenge (AT, PT1 and PT2). In DK, cooperation between the housing association, the municipality and the district heating provider was foreseen, but they didn't reach an agreement. Regarding CH, the length of the process was pointed out as a challenge.

Not many challenges are cited under the **policy framework conditions** and are mostly related to regulations. Regarding SE1, it was considered that some regulations hindered the process; a large-scale renovation project means that it must comply with the new building rules. This was a challenge, especially regarding accessibility, since installing an elevator in the area was required. Regarding ES2, it was indicated that the need to reach an agreement of 60 % of the building owners to carry out a renovation is a challenge. The Portuguese success stories (PT1, PT2, and PT3) considered that thermal regulations and energy standards requirements forced the thermal renovation of the buildings. For example, in PT1, the decision to renovate the building was not related to reducing energy needs. However, due to the depth of the renovation intervention, it had to comply with the thermal requirements imposed by national regulations.

4.7 Financing

The financing methods of the success stories are varied, but it is worth noting that a considerable part of the investments is carried out with public investment or through subsidies, regardless of the type of ownership. This is also underlined in several of the success stories, which indicate that such interventions would not have been possible without public subsidies. The ownership of the renovated buildings is mostly public (DK, IT2, PT1, PT3 and SE1), being mixed in AT and PT2 and fully or mostly private in ES1 and ES2. Concerning the energy systems, publicly owned systems are abundant (IT1, IT2, IT3, IT4, IT5, CH and SE1), and most of these success stories included only the renovation of energy systems. In four successful stories, the ownership is private (AT, DK, ES1 and SE2) and, in one of them, it is mixed (ES1). Additional details about the financing sources can be found in **Table 37**.

Three types of business models have been identified into which the case studies can be classified: market intermediation model, One-Stop-Shop and ESCO.

Under the market intermediation model, there were considered those success stories where there is an intermediary, which could be a public (such as a public building association) or a private stakeholder (such as a utility company) that not only aggregates individual homeowners but also facilitates the process of providing comprehensive renovation solutions. This solution was implemented in different success stories, including measures for both envelope and building services renovation (PT1), renewable energy production on site (PT2 and PT3), connection to district heating (DK), or the creation of a new one (CH).

A One-Stop-Shop provides a single point of contact offering integrated renovation solutions with the main intention of simplifying the renovation process for homeowners, delivering the final product "turnkey" to its owners. Compared to the market intermediation model, this single point of contact plays many other roles in facilitating the process, such as seeking funding opportunities, incorporating solutions to new regulatory requirements, organising training and apprenticeship programmes, and supporting various awareness-raising activities. The projects that have used this model are all demonstration projects with European funding (either under the CONCERTO Initiative or the Funding Programme Horizon 2020). In each case, a non-profit building association took the leadership (AT, ES1, ES2, and SE1). All these interventions have a holistic approach, probably due to the requirements of the programmes in which they are framed and include the improvement of the performance of the building envelopes as well as the implementation of renewable energy.

An ESCO is a company that develops, designs, builds and/or finances energy-efficiency projects. An ESCO implements energy conservation measures or renewable energy systems and assumes the technical and performance risks associated with a project using a performance-based contracting methodology. This model has been implemented in several success stories (It1, IT2, IT3, IT4, IT5, ES2 and SE2) but only in the renovation of energy production systems. Energy renovation of buildings has longer payback periods and is linked to a higher risk, so ESCOs are less involved in this type of project.

Table 37. Source of funding and types of business models in which success stories can be framed. Interventions where only energy systems have been renovated are marked in grey. Interventions where the thermal building envelope has been mainly renovated (renewable energy sources have also been included without substituting the energy supply systems) are marked in yellow.

Nomen-clature	Financing sources	Business model
AT	Non-profit building association, public funds (EU's CONCERTO funding programme), creation of new dwellings	One-Stop-Shop
DK	Public funds, creation of new dwellings	Market intermediation model
IT1	Public funds (municipality), private investment	ESCO
IT2	Public funds (1/3 Lombardia Region), private investment (2/3)	ESCO
IT3	Public funds (region), private investment	ESCO
IT4	Public funds (60%), private investment (40%), no tax for the purchase of natural gas	ESCO
IT5	Public funds, private investment	ESCO
PT1	Private investment, public funds (municipality and the EU structural funds (Interreg)), creation of new dwellings. Initially, the municipality intended to support the costs of renovating the two-floor buildings but found it very difficult. As a way to promote private investment, a public tender was held by the municipality to find a developer who would demolish three apartment blocks to build new residential buildings as part of the financial operation	Market intermediation model
PT2	Public funds (80% funding from the EU and 20% from the municipality)	Market intermediation model
PT3	Public funds (Municipal and EU structural funding), private investment	Market intermediation model
ES1	Public funds (up to 54 % under the European Union's Horizon Project Demo Site, EU (23%), and national, regional (25%) and municipal (6%) funds). Additionally, this financing could eventually obtain up to the 80% of the costs due to regular local and regional funds for energy retrofitting interventions not linked to the Euro-	One-Stop-Shop

Nomen-clature	Financing sources	Business model
	pean Project. Soft loans were available. In some cases, the combination of the abovementioned strategies could eventually lead to a 100% financing of the cost of the project.	
ES2	60 % Public funds (European - CONCERTO Programme -, national and regional), 40% private investment (private loans, homeowners didn't have to pay in advance: they pay 40 €/month for the next 10 years for the renovation of the thermal envelope and an increase of the DH monthly flat-rate of 16€/month)	One-Stop-Shop / ESCO
CH	Public funds (corporation) and subsidies from a foundation that reimburses CHF 100 per ton of carbon saved in connection to a renewable-based DH, replacing fossil fuel-based heating systems (the funding amount corresponds to 5 % of the construction costs)	Market intermediation model
SE1	Public funds (European Union's Horizon Project Demo Site and national funds)	One-Stop-Shop
SE2	Private investment. The ESCO will be the owner of the energy production system during the first 10 years selling the heating to the housing company. This covers the payback period of the investment plus a profit for the company. After this period the ownership will be taken over by the housing cooperative. This meant no or very small economic risk for the housing cooperative. The PV system was financed by the housing cooperative. No financial risk was identified with purchasing the system.	ESCO

4.8 Lessons learned

One of the main goals of the success stories is to gather information that may be useful for future interventions. Hence, it is essential to know the major success factors, bottlenecks, and lessons learned. These are classified under the design phase, technical issues, financial issues, management issues and policy and regulatory framework conditions. The listed lessons learned in this chapter only cover those reported in the success stories, i.e., additional lessons could have been subtracted from each success story performing a deeper analysis. For example, under co-benefits, all success stories that included thermal insulation would have experienced improved indoor climate, but only three success stories mentioned this aspect.

Major success factors

Design phase

Strategies for emissions reduction and energy savings

- A holistic approach that allowed for achieving significant emissions savings (AT, DK, PT3, ES1, ES2, and SE1). In the case of PT3, this holistic perspective included its integration into a broader environmental program that aimed at raising energy and environmental awareness in the residents and other urban infrastructure improvements.
- DH using local renewable energy from a lake (CH); individual connections would not be allowed.
- Energy efficiency measures on the building envelopes are also attractive for the district heating network operator (CH) due to the connection fees and the fact that this allows connecting more buildings without increasing the system's overall capacity.

Co-benefits

- Significant energy and emission savings and higher quality in indoor comfort conditions (PT1, PT2, ES2).
- Other co-benefits, such as improvement of the acoustic insulation and less risk of superficial condensation and mould, as well as a general improvement of socio-economic aspects of the neighbourhood (ES2).
- The reduction of operation and maintenance costs allows to reinvest savings in the conservation of buildings, giving a benefit for the whole context in terms of buildings and energy systems (IT4).

Synergies

- The combination of energy efficiency measures with social actions (promoting the qualification of minorities living in the neighbourhood and better conditions for the young population to access the employment market) and measures at the urban scale (reorganization of the road system, creation of green areas and new walking zones) (PT2).
- Economic synergy effects between the renovation of municipal supply lines, road rehabilitation, and the heating network reduce the overall costs for all parties involved (CH).

Technical issues

Technology

- Heat storage optimizes a DH (IT5).
- In a district heating project, an advanced ammonia heat pump could be applied with high efficiency and with refrigerants that are not greenhouse gases (CH).

Knowledge

- The knowledge generated during the process (DK). In the case of DK, the housing association has developed a roadmap for its building stock and has gained a lot of knowledge.
- The existing deep knowledge of the city's urban development (IT5) made the planning of the DH a success.
- The district renovation served/will serve as a testbed for research purposes (IT4).

Financial issues

- The achievement of public funds (IT3, SE1).
- The involvement of an ESCO to finance part of the investment (IT2).
- A private tender that allowed to finance new social housing and renovate the existing neighbourhood (PT1).

Management issues

Stakeholders and renovation process

- Residents' Association (PT3) or public housing society (ES1) can provide a holistic retrofitting service, facilitating all actions within the project's scope.
- The involvement of a large number of project partners was considered essential for the success of all the associated actions (PT3).
- Detailed planning, monitoring, supervision, and strict deadlines are essential for such an intervention (IT5).
- A pilot study was essential for the renovation's success (SE1). This was carried out on just four apartments: measuring energy use and indoor climate and proposing retrofit measures performing savings calculations, including optional measures. This pilot study was used for communication with the tenants.

Communication/residents engagement

- Good communication with the tenants prior to and during the retrofit process and community engagement is essential for the successful implementation of district renovation (SE1).

Policy and regulatory framework conditions

- The support of the municipality or the fact that the operator of the DH is a public institution increases the trust in the system (CH).

- A private investor can be allowed to retain a part of the district's land in exchange for being responsible for the renovation and construction of a new social housing building to provide incentives for responsible renovation projects (PT1).

Major bottlenecks

Design phase

Strategies for emissions reduction and energy savings

- The choice of an effective technical solution regarding energy reduction and costs (IT3). In the case of IT3, this was made more difficult by the need to connect distant public buildings with different uses.

Technical issues

Technology

- The invasiveness of laying the piping of the DH in a built area (IT1 and IT5).
- Replacing the heating system implied that radiators in the dwellings had to be upgraded to new ones with a higher heat transfer rate (SE2). This was also needed in DK, but it was not seen as a bottleneck.

Knowledge

- The lack of technical knowledge of the renovation promoters (IT3). In the case of IT3, the municipal administration was obliged to seek external technical support to present a valid project for the regional call in terms of requirements and timing.

Financial issues

- Preliminary owner's lack of funding (IT2, PT1, ES2, SE1).
- High investment costs (IT5, SE1).
- The costs associated with the disposal of the old energy production system (IT3) forced to keep the existing boilers as an emergency solution.

Management issues

Stakeholders and renovation process

- A partnership was not reached between the city district heating company and the municipality (DK).
- The project had a top-to-bottom approach, so it was necessary to involve and convince the target audience to join the project (ES1). Professionals from the social sector were hired to perform a door-to-door campaign. Similarly happened with the DH; owners were reluctant to replace the individual heating systems and connect to the DH.
- The time constraint (CH) required flexibility and innovation of all those involved in the project as well as the overlap of project phases.

Communication/residents engagement

- The relocation of tenants (AT, PT1 and PT2), yet it could be solved thanks to a professional approach.

Policy and regulatory framework conditions

- Political differences due to the discussion about possible gentrification derived from the renovation (AT).
- Bureaucracy (IT4).
- Compulsory majority agreement in each community (per building), a minimum of 60% to carry out any building renovation works (ES1). In some cases, commercial premises on the ground floor did not agree with the renovation since the project was done for residential buildings.
- Carrying out a large-scale renovation project means it must comply with new building rules, even if not related to energy aspects, such as installing an elevator (SE1).

Lessons learned

Design phase

<u>Strategies for emissions reduction and energy savings</u>

- Balancing energy efficiency targets in buildings with the energy system is key; in the case of an old district heating system with high losses, renovating that system may have higher priority than investing in the most advanced building envelope measures when available financial resources are limited (DK).
- Seeking self-sufficiency based on renewable energy leads to an over-investment in infrastructure (DK).
- A holistic focus of the project is advantageous, considering all aspects of energy renovation (envelope, energy systems, and user awareness) (ES2).
- Not all the studied retrofit measures were cost-effective (SE1). The financial aspect strongly determines the renovation scope and can be a major limitation to progress toward urban sustainability.

<u>Synergies</u>

- The focus on the combination of social inclusion and improvement of energy efficiency as well as renewable energy measures is a success (PT1, PT2, PT3).

Technical issues

<u>Technology</u>

- District heating projects offer the opportunity to apply innovative heat pumps with high efficiency and less greenhouse gas emissions due to refrigerants (CH).

<u>Knowledge</u>

- Lessons learnt in projects (PT1), the planning methodology (IT5), or the feasibility of such an intervention in a historical context (IT4) could be transferred more actively to other municipalities and governance structures.

Financial issues

- The availability of public funds is essential (IT3, PT2, PT3, ES1, ES2, and SE1). In the case of IT3, the national incentive plan was crucial to help and involve small communities in reducing energy consumption and related carbon emissions of public buildings. In PT2 and PT3, EU structural and cohesion funds were perceived as a great opportunity for district renovation. In ES2, grants were considered effective resources to promote district renovation in vulnerable environments. In SE1, it was considered that it would have been much more difficult for the housing company to cover all the costs without public funding. It might have transpired that the tenants would have had to pay for the retrofit works with increased rent prices over the following years, defeating the project's chief purpose, which was to maintain living affordability.
- A partnership with a private promoter can be advantageous (PT1). Such a promoter can be chosen through an international public tender. In PT1, this allowed the creation of new social housing and facilitated renovation financing.
- An ESCO provides a financial solution that can be perceived as a low-risk decision for the owners (SE2).

Management issues

<u>Stakeholders and renovation process</u>

- The success of district renovation lies in a clear political decision and an integrative process of project development and execution (AT).
- District renovations are very complex processes that need the support of regional and local authorities, building associations and management teams that act as facilitators of the processes (coordination of all the agents involved, the definition of proposals, funding, agreement, information, and dissemination) (ES2).
- The engagement of the district associations is highly beneficial (ES1). Citizen engagement is easier if the neighbour’s associations or other district social stakeholders support the project.
- The management through a private company guarantees that customer satisfaction is reached (IT1).

- Right timing is essential (ES1). The larger the scale of the intervention, the longer it will take to implement. This is a limiting factor for what scale of intervention makes sense.
- Handling unforeseen challenges flexibly and managing overlapping project phases are key (CH, IT2, ES2, and SE1).
- A pilot study can facilitate the renovation process (SE1). In a retrofit project, it is important to perform on-site measurements of the buildings to establish existing problems that further determine the optimal direction of renovation works. This study showed that it is sufficient to perform a thorough analysis only on a few exemplary dwellings.
- A demo within the project framework is essential to be successful on medium-scale or large-scale projects (ES1).

Communication/residents engagement

- Communication with the citizens and community engagement are crucial (ES1, ES2, CH, and SE1). The decision to communicate with the residents from the early stages of the project led to a higher overall satisfaction rate; it is best if tenants are included by asking for opinions and approval of the proposed changes. Raising awareness about the existing problems by explaining why renovation works are necessary in the area shows respect to the community, builds mutual trust, and ultimately brings benefits to all involved parties. A sharp message, which is clear, specific, and with no changes along the project (except for improvement) is needed. Face-to-face talks with the neighbours and listening to their feedback are essential. However, it can also be time-consuming and costly for the project and cause delays.

Policy and regulatory framework conditions

- As listed under the topic of financial issues, the availability of public funds is key (IT3).
- Starting a district renovation with a bottom-to-top project could be more efficient (ES1). It is easier to implement this kind of intervention in a district where building owners or residents have already been asked for support or have even shown their approval.
- Renovations to improve energy performance could be accelerated if they would not make other works necessary to comply with other new building rules (SE1).
- Policy can offer special benefits for renovation projects that comply with specific building standards or ensure social inclusion (PT1).

5. Conclusions

District renovation is a complex activity due to the large number of stakeholders involved and the broad knowledge, and the large financial resources needed. The presented district renovations (mainly publicly owned, which largely conditions the conclusions of this report) have shown that reaching a high energy and emissions reduction by combining energy efficiency at the building or energy system level and renewable energy was possible in the analysed success stories and in the varying respective circumstances. In those interventions that have striven to reach this goal, the energy efficiency levels and renewables implemented exceed the minimum requirements set in the national regulations. In most cases, the balance between energy efficiency measures and renewable energy use is based on expert estimations and not on calculations. This is also cited as a main challenge or bottleneck during the design phase. There is, therefore, potential for improvement, and the methodology developed in the IEA EBC Annex 75 can help with more substantial planning and support decision-making and contribute to further emissions reductions in district renovation but not necessarily make the intervention itself easier.

An important goal of most interventions is the improvement of comfort and adaptation of the buildings to a contemporary standard of living as well as the improvement of the quality of open space, the attractiveness, and the image of the district. Improving the quality and increasing the value of the building stock to ensure profitability, maintaining affordability (with no or limited increase in rent or low investment cost for the owners) and improving the social diversity and cohesion in the neighbourhood were also drivers in several interventions.

Renovation measures at the district scale vary from one success story to another. However, most of those investigated have a centralised energy supply system; either centralised systems were newly installed, or an existing centralised energy system was renovated to improve its efficiency or to incorporate renewable energy sources. There is only one success story in which geothermal heat pumps replaced a centralised system to reduce operational costs and become more environmentally friendly. In most cases, renewable energy is used for heating through a district heating system. In six success stories, solar thermal was installed, and in four of them PV. The reduction in heating energy use ranges from 20% to 77%, with an average reduction of around 50%.

District renovation is mainly initiated by the willingness and support of the municipality, a housing association or a residents' association, or the wish of the inhabitants – in the case of publicly owned systems – and, therefore, these are key actors during the whole process. Investors and tenants/residents are also key actors in the implementation of the renovation. Usually, the investors are a building association that owns the buildings or individual building owners, a public body, an ESCO, or a real estate development company in one of the districts. It is important to note that many district renovations described in the success stories are partly financed (in some cases to a large extent) through public money, either as direct financing or via subsidies. Lack of financial resources is the most cited challenge that must be faced, and in many cases, the intervention would not have been possible without public funds. It is considered that the important role of public institutions and public funding is not just because particularly innovative district renovation projects were sought for description in the success stories, but rather that the success stories showcase that public support is key for many successful projects.

Citizens' engagement and communication with tenants from the early stages of the project led to a higher overall satisfaction rate and were considered to be key for the entire renovation process in the success stories. Clear and effectively communicating the reason why a renovation is needed, the measures that will be performed, and the expected results is essential. Including tenants in the process explaining the renovation goals, and asking for opinion and approval of the proposed changes is advantageous. Success is determined in many cases by the existence of a coordination figure, a facilitator. The inclusion of the district renovation in a European programme (Horizon Europe, CONCERTO Programme, Interreg, or European structural funds) can facilitate this task in a great measure since there is a clear goal and there are economic resources available for the coordination of all agents, normally under the form a One-Stop-Shop. This experience is in principle of interest for being taken up in any district renovation project, even without public support. Yet it can be speculated that without public support, it is hardly possible to carry out citizen engagement and communication as well as a strong leadership by a coordination figure or a coordination point up to the level required for carrying out successful district renovation projects, especially when they are combining energy efficiency measures and renewable energy measures.

The main barrier to a district renovation is the funding; however, many challenges can hinder or make the process challenging, such as the coordination of all stakeholders, the difficulty in finding the optimal renovation measures, the need to relocate the tenants during the renovation works as well as other technical aspects such as unforeseen problems, the location of the energy production systems and the pipe lying of a district heating system in a built area. Some of these challenges can be overcome with an appropriate business model, such as a market intermediation model, a one-stop-shop, and an ESCO. Other challenges, such as synchronising district energy supply measures and building-related renovation cycles or unclear framework conditions / dynamic legal framework, are more challenging to overcome.

The main take-away messages from the lessons learned in the presented success stories are:

- Energy-efficient measures for district renovation can be combined with renewable energy measures and beyond that with social or other improvements at the urban scale or in the infrastructure to bring more value to the intervention and make more efficient use of the financial resources available.
- There are no big technological barriers to the renovation of districts; on the contrary, there are technical opportunities, such as accessing a renewable source like a lake which could not be done through individual heating solutions, or by providing the opportunity to make use of innovative heat pumps with high efficiency and low non-carbon-related greenhouse gas emissions; however, there is a lack of technical knowledge and protocols to simplify such a complex process – including which entity initiates and coordinates the whole process, what steps are necessary from idea to implementation, etc. – and a lack of resources to carry out related coordination work. This aspect will also largely depend on the district and the structure of buildings and owners. The heterogeneity and complexity of the district will influence the magnitude of the technological barriers that may arise.
- Costs and fragmented interests, and revenue streams are important barriers. The availability of financial resources is essential. European funding or other public funding can be key in the process as they cover part of the investment costs and bring knowledge and experience in the field in such consortia. An ESCO can also finance the intervention, but they tend to invest in projects that are only linked to energy production systems.
- Good coordination between all stakeholders is needed to guarantee a successful renovation and timing. Furthermore, flexibility is required because such complex projects can hardly ever be developed exactly as planned, and project phases are required to overlap to shorten otherwise long project timelines. For that reason, the support of regional and local authorities, building associations, or management teams that act as facilitators of the processes for coordinating all the agents involved, the definition of proposals, funding, agreement, information, and dissemination is key. Such services could be covered through a one-stop-shop. The municipality has a key role when the district renovation involves bigger infrastructure solutions and decision-making processes. It could be that link between overarching energy supply and infrastructure planning and the individual measures on buildings is a great challenge that is not covered by a one-stop-shop but needs integrated planning and municipality action.
- Citizen and tenant engagement is necessary for the process to run smoothly. This is achieved through clear communication from before the start of the intervention and throughout the project, incorporating the feedback received by the citizens. This task is time-consuming and could be supported by a neighbour's association or other social stakeholders from the district supporting the project.
- Overall, public support is crucial to facilitate funding of district projects and enable sufficient stakeholder dialogue and coordination work for successfully carrying out district renovation projects, particularly if they combine both energy efficiency and renewable energy measures.

ANNEX 75

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