International Energy Agency

Shining Examples of Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation (Annex 56)

Energy in Buildings and Communities Programme

March 2017

EBC is a programme of the International Energy Agency (IEA)

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Published by University of Minho, Portugal

ISBN: 978-989-99799-5-6

Participating countries in EBC:

Australia, Austria, Belgium, Canada, P.R. China, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Republic of Korea, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and the United States of America.

Additional copies of this report may be obtained from:

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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 28 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 research and development in a number of areas related to energy. The mission of the Energy in Buildings and Communities (EBC) Programme is to develop and facilitate the integration of technologies and processes for energy efficiency and conservation into healthy, low emission, and sustainable buildings and communities, through innovation and research. (Until March 2013, the IEA-EBC Programme was known as the Energy in Buildings and Community Systems Programme, ECBCS.)

The research and development strategies of the IEA-EBC Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Buildings Forum Think Tank Workshops. The research and development (R&D) strategies of IEA-EBC aim to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy efficient technologies.

The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in five focus areas for R&D activities:

- Integrated planning and building design
- Building energy systems
- Building envelope
- Community scale methods
- Real building energy use

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 (*) (see following table):

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 & Evaluation Methods (*)
Annex 54: Integration of Micro-Generation & Related Energy Technologies in Buildings
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance & Cost (RAP-RETRO)
Annex 56: Cost Effective Energy & CO2 Emissions Optimization in Building Renovation
Annex 57: Evaluation of Embodied Energy & CO2 Emissions for Building Construction

Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements
Annex 59: High Temperature Cooling & Low Temperature Heating in Buildings
Annex 60: New Generation Computational Tools for Building & 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: Optimised Performance of Energy Supply Systems with Energy Principles
Annex 65: Long-Term Performance of Super-Insulation in Building Components and Systems
Annex 66: Definition and Simulation of Occupant Behaviour in Buildings
Annex 67: Energy Flexible Buildings
Annex 68: Design and Operational Strategies for High IAQ in Low Energy Buildings
Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 70: Building Energy Epidemiology
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 Public Communities
Annex 74: Energy Endeavour
Annex 75 Cost-effective building renovation at district level combining energy efficiency and renewables

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 - Survey on HVAC Energy Calculation Methodologies for Non-residential Buildings

Management Summary

This brochure is a selection of demonstration projects within Annex 56 partner countries that highlights successful solutions and provides general findings, similarities and differences emerging out of the demonstration projects selected in the participating countries.

The specific mission of the case study activity of the Annex 56 project is to provide significant feedback from practice (realised, ongoing or intended renovation projects) on a scientific basis.

Within Annex 56, the gathering of case studies is one of the activities undertaken to reach the overall project objectives, because it is a recognized fact that the process of decision-making has to be strongly supported by success stories from real life and experiences and lessons learned from practice.

The “Shining Examples” are gathered mainly for motivation and stimulation purposes, highlighting the advantages of aiming at far reaching energy and carbon emissions reductions, being still cost effective. The focus is to highlight advantages and innovative (but feasible) solutions and strategies.

In this report 18 Shining Examples are presented in a standard format:

- Austria:
    - Bruck an der Mur;
    - Kapfenberg
- Czech Republic:
    - Kamínky 5;
    - Koniklecová 4
- Denmark:
    - Sems Have;
    - Skodsborgvej;
    - Traneparken
- Italy:
    - Ca’ S.Orsola;
    - Ranica
- Netherlands:
    - Wijk van Morgen
- Portugal:
    - Lugar de Pontes;
    - Montarroio;
    - R. Dona Leonor Neighbourhood
- Spain:
    - Viviendas de Corazón de María
- Sweden:
    - Backa röd;
    - Brogården;
    - Maratonvagen
- Switzerland:
    - Les Charpentiers

A cross-section analysis of these Shining Examples has also been carried out to identify similarities, differences and general findings. The results of this analysis are presented in 5 sections covering: the co-benefits, the “anyway measures”, the which measures, the country/climate specific measures and the barriers & solutions.

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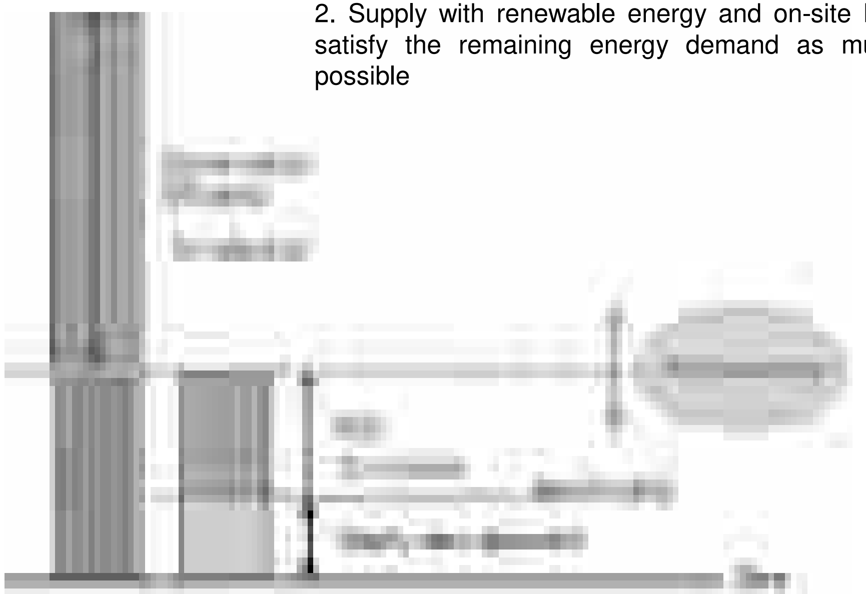
Introduction

Climate changes are evident all over the planet and it is no longer possible to ignore its relationship with the carbon emissions, deeply related to energy production and use. To tackle this problem different measures are being taken worldwide to promote energy efficiency and expand the use of renewable energy sources in all areas and particularly in the building sector, one of the most relevant energy consumers.

Several standards regarding energy consumption have emerged in the last decade, defining increasing requirements, and culminating with the recent emergence of the “nearly-zero energy” buildings concept. However, these standards are mainly focused on new buildings, often ignoring the existing buildings that represent the least efficient, the largest consumers and the largest share of the building stock. These standards do not respond effectively to the numerous technical, functional and economic constraints of this kind of buildings resulting often in very expensive measures and complex procedures, hardly accepted by owners or promoters.

Having in mind the overall objective of slowing down climate change, measures for the use of renewable energy can be as effective as energy conservation and efficiency measures and sometimes be obtained in a more cost effective way. *In existing buildings, the most cost-effective renovation solution is often a combination of energy efficiency measures and measures for the use of renewable energy.* Hence, it is relevant to understand how far it is possible to go with energy conservation and efficiency measures (initially often less expensive measures) and from which point the use of renewables become more economical considering the local context.

Two step approach:
1. Reduction of energy demand and carbon emissions by energy conservation and efficiency measures
2. Supply with renewable energy and on-site RES to satisfy the remaining energy demand as much as possible



Optimized building renovation concept (Geier S., Ott W.)

In this context, the International Energy Agency established an Implementing Agreement within the Energy in Buildings and Communities Program to undertake research and provide an international focus on Cost Effective Energy and Carbon Emissions Optimization in Building Renovation (EBC Annex 56). This is an ongoing project (2010-2015) that aims at developing a new methodology to enable cost effective renovation of existing buildings while optimizing energy consumption and carbon emissions reduction. This project is mainly focused on residential buildings as these account for 75% of the total stock in Europe and in 2009, were responsible for 68% of the total final energy use in buildings[1], comprising a less heterogeneous sector compared to the non-residential sector, suggesting a higher potential for improvement.

To achieve these goals, to have a bigger impact and to shorten the path to the application of the project results, it is important to take advantage of good examples and good practices already implemented as well as of existing and emerging efficient technologies with potential to be applied successfully.

This brochure is a selection of successful realised demonstration projects within Annex 56 partner countries that highlights successful solutions and provides general findings, similarities and differences emerging out of the demonstration projects selected in the participating countries.

The Operating Agent

Prof. Manuela Almeida

1 - Europe's buildings under the microscope
A country-by-country review of the energy performance of buildings
October 2011, Buildings Performance Institute Europe (BPIE)
ISBN: 9789491143014, Pages 8 and 10

Scope of the Brochure

Within Annex 56 the gathering of case studies is one of the activities undertaken to reach the overall project objectives because it is a recognized fact that the process of decision-making has to be strongly supported by success stories from real life and experiences and lessons learned from practice.

The specific mission of the case study activity of the Annex 56 project is to provide significant feedback from practice (realised, ongoing or intended renovation projects) on a scientific basis. The main objectives of this work are:

- To understand barriers and constraints for high performance renovations by a thorough analysis of the case studies and feedback from practice in order to identify and show measures to overcome them;
- To align the methodology under development in Annex 56 with practical experiences;
- To support decision-makers and experts with profound, scientific based information (as result of thoroughly analysed case-studies) for their future decisions;
- To show successful renovation projects in order to motivate decision-makers and stimulate the market.

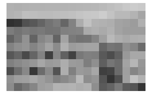
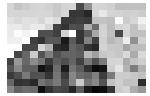
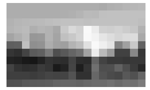
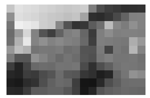
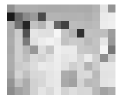
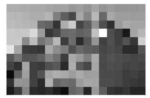
The Case Studies within Annex 56 will be studied at two different levels. Level 1 – the “Shining Examples” and level 2 – the “Detailed Case Studies”. It is expected that every country provides at least one demonstration project (preferentially more) in order to cover a broad variety of different climate and framework conditions. Within level 1, a selection of “Shining Examples” to encourage decision makers to promote efficient and cost effective renovations will be provided. In a second phase, within “Detailed Case Studies”, a deeper analysis will be performed in order to evaluate the impact and relevance of different renovation measures and strategies within the project objectives and also validating the methodology under development in Annex 56. The results from the level 2 analysis are on-going and will be reported separately.

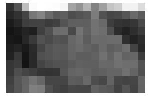
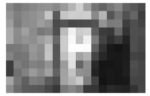
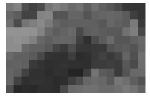
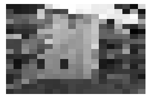
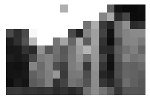
This brochure presents the Shining Examples collected from different partners, in a fixed format showing for each demonstration project pictures and easily comprehensible graphics, highlighting the added-value of the renovation process. The brochure presents 18 Shining Examples from 9 countries.

The “Shining Examples” are gathered mainly for motivation and stimulation purposes, highlighting the advantages of the energy and carbon emissions cost optimized renovation. The focus is to highlight advantages and innovative (and feasible) solutions and strategies. A cross-section analysis of the projects has also been carried out to identify similarities, differences and general findings. The results of this analysis are presented in 5 sections covering: barriers & solutions, anyway measures, rational use of energy/renewable energy supply (RUE/RES) balance of measures, co-benefits and country/climate specific measures.

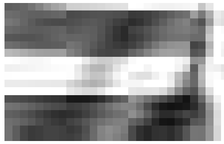
Case Studies
Location

Case Studies

N.	Country	Site	Building type	Barriers & solutions	Anyway measures	Which measures	Co - benefits	Country / climate specific measures	Picture
1	AUSTRIA	ARE, Bruck an der Mur	Non residential	√	√	√	√	√	
2	AUSTRIA	Johann Böhm 34/36, Kapfenberg	Multi family	√	√	√	√	√	
3	CZECH REPUBLIC	Kamínky 5, Brno-Nový Lískovec	Non residential	√	√	√	√	√	
4	CZECH REPUBLIC	Koniklecová 4, Brno-Nový Lískovec	Multi family	-	√	√	√	√	
5	DENMARK	Sems Have, Roskilde	Multi family	√	√	√	√	√	
6	DENMARK	Skodsborgvej, Virum	Single family	-	√	√	√	√	
7	DENMARK	Traneparken, Hvalsø	Multi family	√	√	√	√	√	
8	ITALY	Ca' S.Orsola, Treviso	Multi family	√	√	√	√	√	
9	ITALY	Ranica, Bergamo	Single family	-	√	√	√	√	

N.	Country	Site	Building type	Barriers / solutions	Anyway measures	Which measures	Co - benefits	Country / climate specific measures	Picture
10	NETHERLANDS	Wijk van Morgen, Kerkrade	Single family	-	√	-	√	√	
11	PORTUGAL	Lugar de Pontes, Melgaço	Single family	√	√	√	√	√	
12	PORTUGAL	Travessa de Montarroio, Coimbra	Single family	√	√	√	√	√	
13	PORTUGAL	Rainha Dona Leonor, Porto	Multi family	√	√	-	√	√	
14	SPAIN	Corazón de María, Bilbao	Multi family	√	√	√	√	√	
15	SWEDEN	Backa röd, Gothenburg	Multi family	-	√	√	√	√	
16	SWEDEN	Brogården, Alingsås	Multi family	√	√	√	√	√	
17	SWEDEN	Maratonvagen 36, Halmstad	Multi family	-	√	√	√	√	
18	SWITZERLAND	Les Charpentiers, Morges	Multi family	-	√	√	√	√	

1. ARE, Bruck an der Mur



Project summary

Energy concept: Biomass district heating, ground source heat pump, mechanical ventilation with heat recovery, automatic lighting and PV.

Background for the renovation:

The aim of this project was to gather information and experiences of the pilot project and the research, so that those information and experiences can be directly used in the planning and decision process of the building owner Austrian Real Estate (ARE) and other building owners. Thereby four main fields of investigation have been identified:

- Subsequent installation of ventilation systems with heat recovery
- Shading, daylight and lighting
- Sustainable cooling and summer comfort
- Innovative façade systems

Site:	**An der Postwiese 8** **8600 Bruck / Mur, Austria**
Altitude:	485 m
Heating degree days:	3710 (base temp 20°C)
Owner:	**Austrian Real Estate (ARE)** a subsidiary company of BIG
Architect:	Architekturbüro Pittino & Ortner
Energy concept:	Rosenfelder & Höfler Gmbh & Co KG, TB Köstenbauer & Sixl, Busz GmbH

Contact Person:	**Mag. Dirk Jäger** **BIG**
Renovation started:	2010
Renovation ended:	2012
Data collection:	February 2014

Building description /typology

- Built: in 1960s
- Official building which includes the district court, the financial authority and the Federal Office for Metrology and Surveying
- Gross heated floor area: 6486 m² (total)

View of renovated building (left © Markus Kaiser, Graz) and existing building (right © e7 Energie Markt Analyse GmbH)

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

The analysed building is an official building which includes the district court, the finance authority and the Federal Office for Metrology and Surveying. The building was constructed between 1963 and 1965. The finance authority is situated in a separate section of the building, has four floors and is connected to the other section of the building by a shared staircase.

The building is a typical building from the 1960´s, made of in a precast concrete skeleton construction without insulation. The existing building was heated by a central gas heating system.

The Federal Ministry of Justice, as the main tenant, claimed for a renovation and an enlargement of the existing building. Besides the need of more space (app. 840 m² (NFA)), there was also a desire for functional improvements. Especially public and frequented areas like the entrance hall, hearing rooms and waiting areas did not fulfil today´s requirements and needs. The existing building was not barrier-free accessible due the existing mezzanines.

Essential design parameters were:

- Barrier free access to all parts of the building
- Creating a service centre for the court
- It has to be possible to spatially divide the court from the other parts of the building
- Separated entrance for the court incl. double door system
- Renovation resp. renewal of windows, roof and façade based on the state of the art
- Improvement of the natural lighting
- Preservation of the existing parking area

Building before the renovation (© e7 Energie Markt Analyse GmbH)

Building before the renovation (© e7 Energie Markt Analyse GmbH)

Element	Area m²	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade	2895	1.32	< 0.155
Ceiling	1345	1.06	0.188
Windows, doors	908	3.00	< 1.380
Roof	1345	0.50	0.112

Energy renovation features

Three pillars of sustainability

Based on the three pillars of sustainability, criteria and requirements for the renovation were defined. Following points were included:

- Ecological sustainability: high heat protection in summer and winter, low primary energy demand, use of renewable energy sources, monitoring of the energy consumption
- Economic sustainability: adherence of the frame for the investment costs, low LCC
- Sociocultural sustainability: high thermal comfort in summer and winter, acoustic comfort, high ratio of daylight, possibility of natural ventilation

Building

New developed metal façade elements with solar comb for passive solar gains were used. A thermally insulated interlayer was mounted directly to the existing façade (compensation of e.g. irregularities of the surface). The pre-fabricated façade module with absorber (GAP-Solution) and the window modules were mounted to this interlayer.

The third floor of the district court was new constructed and thermally insulated with 32 cm mineral wool. The u-value of the new roof is 0.112 W/m²K.

The new window modules were already integrated in the new façade. The u-values of the new windows are between 1.03 and 1.38 W/m²K. Every room has minimum one openable casement. The remaining casements of the window modules cannot be opened. The sun protection is integrated in the windows and is controlled based on the solar radiation.

Systems

Heating:

As part of the renovation the existing gas heating was replaced by a biomass district heating. Additionally a two-condition refrigerator with deep drillings (80-100 m deep) is integrated in the ventilation system. In summer the cooling water from the deep drillings is used to condition the supply air (free cooling), in winter the supply air is heated by an additional heat pump.

All components of the HVAC system are controlled by a centralized computer system.

Ventilation:

After the renovation of the building, two different ventilation zones exist. In the part of the building where the financial authority is located, no mechanical ventilation is installed. In the part of the building where the district court is located, a mechanical ventilation system with high efficient heat recovery is installed. The ventilation of the hearing rooms is separated from the rest and is controlled by CO_2-sensors.

The air change rate in the offices is fixed to the minimum required hygienic air change rate (0.4 h^{-1}). In summer automatic night ventilation with higher air change rates is performed.

Lighting:

In the offices the lighting is controlled automatically according to the available daylight and the presence of the people in the building. The brightness of the luminaires is automatically adjusted to the requirements but can be overruled manually.

Photovoltaic installation:

On the roof of the building 140 m² photovoltaic modules were installed with a maximum power of 24 kWp. The calculated energy production of the photovoltaic installation is 22.500 kWh/a.

Calculated Energy Savings, CO_2 reductions and Life Cycle Costs

Heating energy demand corrected before and after renovation (calculated):	
before renovation:	145 kWh/m²year
after renovation:	24 kWh/m²year
calculated savings:	121 kWh/m²year (-83 %)
Primary energy demand before and after renovation (calculated):	
before renovation:	464 kWh/m²year
after renovation:	162 kWh/m²year
calculated savings:	302 kWh/m²year (-65%)
CO_2-emissions before and after renovation (calculated):	
before renovation:	78 kg_{CO_2}/m²year
after renovation:	19 kg_{CO_2}/m²year
calculated savings:	59 kg_{CO_2}/m²year (-75%)
Energy production from PV (calculated):	22.5 MWh/year
Total construction costs:	8M€ (excl. VAT)


Building after the renovation (© Markus Kaiser, Graz)


PV-modules on the flat roof (© Markus Kaiser, Graz)

Overall improvements, experiences and lessons learned

Co-benefits

- Thermal comfort in summer and winter
- Acoustic comfort
- High ratio of daylight
- Possibility of controllable natural ventilation

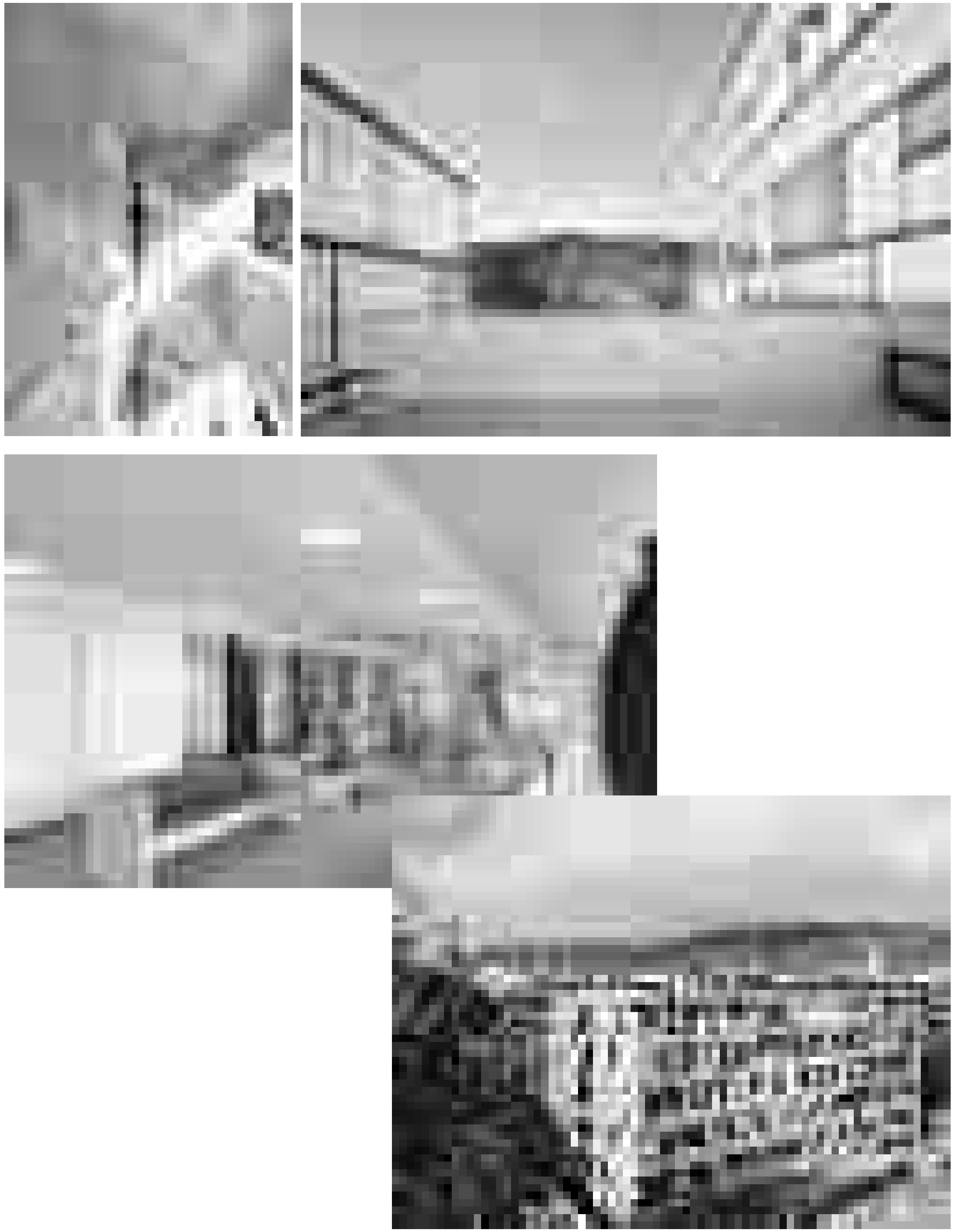
Indoor climate technical improvements

The indoor climate was improved due to:

- Mechanical balanced ventilation with heat recovery and a carefully adjusted supply temperature
- Less heat loss and draught through walls, windows and doors

Barrier to overcome and solution

Originally it was planned to renovate the pilot project with prefabricated timber elements with solar comb for passive solar gains. But due to the demands in fire protection no timber façade was possible. Therefore new metal façade elements with integrated solar comb had to be developed. This development required a close cooperation of all involved which increased the planning effort and also the costs of the renovation.



Impressions of the renovated building (© Markus Kaiser, Graz)

Summary

Summary of project

The definition of high requirements on the energy efficiency in the planning process enables the planning of a building, which can achieve high energy savings. Other renovations of the Bundesimmobiliengesellschaft (BIG) / Austrian Real Estate (ARE) can profit from these solutions and concepts.

In the planning process it is very important to define the sustainability criteria in an early stage and to check the adherence of the criteria continuously right up to the detailed planning and the tender. Only this ensures that the high quality requirements can be fulfilled.

In the preliminary draft different varieties for optimization have to be considered and checked. The building owner has to make suggestions and recommendations for improvements in the planning stage. Important is also that the building owner can ensure that there are competences in the sector of energy efficiency to check the technical solutions of the planners carefully. A dynamic building simulation can demonstrate critical points. Together with the planning team solutions for an optimized building design have to be developed.

At the same time the building owner and the tenants have to be informed about the construction costs and the future operational costs right from the project start, when the building is defined, or at the latest at the preliminary draft when the first plans are available. The comparison of the life cycle costs (LCC) of the regular renovation and the renovation with high requirements on the energy efficiency is the basis for the tenants to make their decision. The LCC are also very important to guarantee the ecological and economical sustainability. Impacts on the user comfort have also to be highlighted in the planning process.

Nevertheless the limited budgetary capabilities of the tenants have to be considered in all deliberations!

Prospect for future renovations

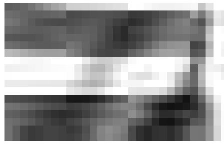
The energy efficiency measures planned and realized in this building should be recommended for all future renovations of the BIG-buildings of the 1950s to 1980s. However this quality standard has to be accepted from the ministries and the additional costs of the energy efficiency measures have to be budgeted. The ministries should not be exempted from their duties as well as without the active contribution of the tenants at the implementation and operation of energy efficient buildings such a high energy efficient level is not possible.

References:

[1] D. Jäger et al. (2011): Subproject 2: Demonstration building official building Bruck – planning process BIGMODERN SP2; Federal Ministry for Transport, Innovation and Technology; Vienna

[2] rosenfelder & höfler cons. eng. GmbH & CO KG (2012) – energy performance calculation

2. Johann Böhm 34/36, Kapfenberg



Project summary

Energy concept: Insulation, mechanical ventilation, solar thermal and PV-system

Background for the renovation:

The existing residential building was in high need of renovation. The overall intentions were:

- 80% energy efficiency – 80% reduction of the energy demand of the existing building
- 80% ratio of renewable energy sources – 80% of the total energy consumption of the renovated building should be provided by renewable energy sources
- 80% reduction of CO_2 emissions – 80% reduction of the CO_2 emissions of the existing building

Site:	**Johann Böhm Straße 34/36 8605 Kapfenberg, Austria**
Altitude:	502 m
Heating degree days:	3794 (base temp. 20º C)
Cooling degree days:	0
Owner:	ennstal SG
Architect:	Nussmüller Architekten ZT-GmbH
Energy concept:	AEE INTEC

View of existing (small picture) and the renovated building (large picture) (west elevation)

Contact Person:	Dir. Wolfram Sacherer ennstal SG
Renovation started:	2012
Renovation ended:	2014
Data collection:	Winter 2014

Building description /typology

- Built: 1960-1961
- Residential building with four floors
- On each floor six flats were located
- The living space varied from 20 to 65 m²
- Total gross heated floor area: 2845 m²

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

The analysed building is a residential building which was built between 1960 and 1961. The four-story building has a length of 65 m (east and west façade) and a depth of 10 m (north and south façade). On each floor nine apartments were located which varied from 20 to 65 m² living space. These apartments did not meet the current way of living because they were too small. For this reason not all flats were rented.

Building envelope

The existing building was a typical building from the 1960's made of prefabricated sandwich concrete elements without an additional insulation. Only the wood wool panels of the prefabricated concrete elements performed as a slight thermal insulation.

The basement ceiling was insulated with approx. 6 cm polystyrene. The old roof was a pitched roof with no insulation. The ceiling to the unheated attic was insulated with 5 cm wood wool panels.

The existing windows were double glazed windows with an U-value of 2.5 W/m²K. The missing airtightness of the existing windows caused high infiltration losses.

Heating, ventilation, cooling and lighting systems

In the existing building a variety of different heating systems was installed: a central gas heating, electric furnaces, electric night storage heaters, oil heaters, wood-burning stoves and coal furnaces.

The ventilation of the existing building was accomplished by opening the windows; no mechanical ventilation system was installed.

The enormous energy demand caused very high heating and operating costs. A high quality refurbishment of the building with a change in the layout of the apartments should make the building more attractive to new residents and young families.

Facade – before and after the renovation

Facade during the renovation

Element	Area m²	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade	1463	0.87	< 0.17
Ceiling	711	0.39	< 0.30
Windows, doors	349	2.50	< 0.90
Roof	711	0.74	< 0.10

Energy renovation features

Overall Energy Saving Concept

The retrofit concept is based on energy efficiency measures (reduction of transmission, infiltration and ventilation losses), on a high ratio of renewable energy sources and on an intelligent integration in the existing heat and electricity grid.

Building

Instead of conventional insulation systems the façade in this project is covered with large-sized active and passive façade elements.

These façade elements include on the one hand traditional rear-ventilated constructions (various surfaces possible) and on the other hand active elements to produce energy like solar thermal or photovoltaic panels.

The old pitched roof is removed and a new flat roof is established. The roof is highly insulated with approximately 35-40 cm. The windows are already integrated in the prefabricated façade modules and are of high thermal quality (triple glazing).

Inside works include among other things also the change of the layout of the flats to make them more attractive to new residents.

Prefabricated façade elements with integrated active energy production (photovoltaic and solar thermal panels)

Building Services

Heating: The basic heat supply of the renovated building is accomplished by the local district heating. Additionally 144 m² solar thermal panels are installed on the south facade. Heat provided by district heating and solar thermal system is stored in a 7500 litre buffer storage. From the buffer storage a 2-pipe-system (flow and return) brings the heat to the 32 flats where the heat for domestic hot water is stored in a small boiler. Radiators emit the heat in the flats.

Ventilation: A new mechanical ventilation system with heat recovery is installed (heat recover efficiency 65% / SFP 0.45 Wh/m³). The ventilation units are positioned on the flat roof and the existing stacks and installation ducts of the building are used for the ventilation ducts. In one half of the flats the ventilation system is controlled automatically based on the CO_2 concentration, in the other half of the flats the residents can control the ventilation system by a three-stage controller individually.

Photovoltaic: Photovoltaic panels with a size of 550 m² resp. 80 kWp are installed on the roof on a steel construction in form of a wing. Additionally 80 m² resp. 12 kWp are installed on the south facade.

Mounting of the photovoltaic panels on the roof (left picture), pv and solar thermal panels on the south façade (right picture)

Calculated Energy Savings, CO_2 reductions and Life Cycle Costs

Electricity demand before and after renovation:		
before renovation:	**79 MWh/year**	**33 tCO2/year**
after renovation:	**47 MWh/year**	**20 tCO2/year**
calculated savings:	**32 MWh/year**	**13 tCO2/year**
Energy demand for heating and hot water before and after renovation:		
before renovation:	**337 MWh/year**	**80 tCO2/year**
after renovation:	**85 MWh/year**	**4 tCO2/year**
calculated savings:	**252 MWh/year**	**76 tCO2/year**

Left building part already renovated – right building part in the middle of the renovation

Calculated energy savings:

The transmission heat losses from the building envelope can be reduced from 337 MWh/year (existing building) to 85 MWh/year (renovated building). This means energy savings of 252 MWh/year.

The infiltration heat losses can be reduced from 89 MWh/year (existing building) to 47 MWh/year (renovated building). This means energy savings of 42 MWh/year.

In total 294 MWh/year can be saved for heating and domestic hot water.

As a result of the renovation the usable energy gains in the building (internal and solar gains) are reduced from 126 MWh/year to 84 MWh/year. This means 42 MWh/year less energy gains are usable after the renovation.

As a consequence of that the calculated total energy savings are 252 MWh/year.

Calculated energy production:

The calculated energy production of the solar thermal system is 39.5 MWh/year; the energy production of the photovoltaic panels is about 80 MWh/year.

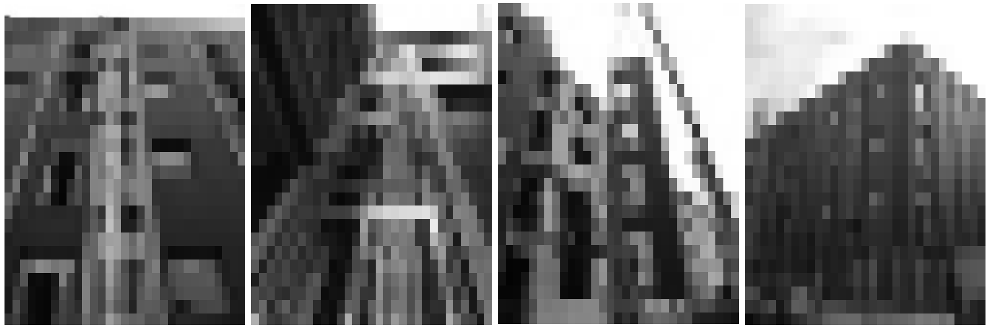
Total Renovation Costs: 4.3 M€

Solar thermal and PV panels on the south facade

Overall improvements

Co-benefits

- New and larger balconies for all flats:
    - Improvement of the reputation of the building
    - New functional area for the residents
    - Improved thermal quality by reduction of thermal bridges
- Barrier-free access to all flats by the installation of an elevator and an arcade
- Changed layout of the flats enables new modern living with windows to both, east and west, sides
- Better indoor climate by mechanical ventilation system with heat recovery
- Renewal of old heating and domestic hot water systems improve the operational comfort by a new centralized and automatically controlled system



Different steps of the building renovation process: installation of the building services, assembling of the prefabricated façade modules, almost finished building envelope (f.l.t.r.)

Indoor climate technical improvements

The indoor climate is improved due to:

- Mechanical balanced ventilation with heat recovery and a carefully adjusted supply temperature
- Less heat losses and draught through walls, windows and doors

Barriers to overcome and solutions:

- The financing of the renovation was a barrier because due to governmental regulations it was not possible to excessively increase the rental price for the apartments. Therefore other funding and financing solutions were necessary to realize the renovation.
- Additionally, the renovation works inside the building, such as the change of the layout, made a resettlement of the residents necessary. Due to the fact that there were no apartments available in Kapfenberg at the time of the renovation, this process could only be put into practice in two different construction phases in order to guarantee the residents an apartment during the renovation period.

Assembling of the prefabricated façade modules on the west facade

Summary

Summary

The existing residential building is renovated with a new façade (prefabricated active and passive elements), new windows, new roof (flat roof instead pitched roof) and new building services.

A new heating system (local district heating and solar thermal system on the south façade of the building) and a new mechanical ventilation system with heat recovery are installed.

Photovoltaic panels on the roof and on the south façade for the electric energy production were also installed.

By those measures following objectives of the renovation should be achieved:

- 80% energy reduction
- 80% ratio of renewable energy sources
- 80% reduction of CO2-emission

Left building part: finished renovation; right building part: still in renovation

Lessons Learnt

All asked tenants lived in the building before the renovation and 85% also during the renovation of the building.

The expectations of the tenants to the retrofit were generally satisfied. The tenants were also satisfied with the housing association and the different companies which carried out the renovation.

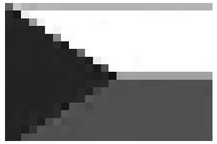
Assessing their housing situation some tenants criticized the natural lighting in the apartments, the temperatures at the beginning (too cold) and the noise because of the renovation works of the second construction phase.

The tenants were satisfied with the information they received regarding the mechanical ventilation system and the heating and domestic hot water preparation.

A few days later – building envelope of the right building part almost finished

References: all AEE INTEC

3. Kamínky 5, Brno-Nový Lískovec



Project summary

Energy concept: Renovation to low-energy standard

Background for the renovation:

Intention for the renovation:

- Modernization of aging school building
- Improvement of inner conditions
- Reduction of overall energy consumption to comply with low-energy standards

Site:	**Kamínky 368/5, 634 00 Brno-Nový Lískovec, Czech Republic**
Altitude:	312 m
Heating degree days:	3712 Kd (base temp. 13°C)
Cooling degree days:	0 Kd
Owner:	Statutory City Brno
Architect:	MENHIR projekt, s. r. o.

Street view of the school's main block before (left) and after (right) renovation. [1]

Contact Person:	**Mgr. Pavel Petr (headmaster)**
Renovation started:	2009
Renovation ended:	2010
Data collection:	Autumn 2014

Building description / typology

- Elementary school with consisting of 3 blocks (classrooms, kitchen and cafeteria, gymnasium)
- Built: 1987
- Maximum capacity: 380 students, 44 staff
- Net heated floor area: 7296 m^2

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

The buildings of Elementary School Kamínky 5 were constructed in 1987. The school consist of 3 blocks connected via multi-storey corridors. The main block (A) where the classrooms and offices are located, kitchen and cafeteria block (B) and gymnasium (C).

The maximum capacity of the school is approx. 380 students and 44 staff members. Total net heated floor area of school buildings is 7296 m².

Building envelope

The construction of the building corresponds with the period of origin – superstructure is made of prefabricated reinforced concrete frame MS-OB with basic length module 6.0 m. Walls are made mostly of 300 mm thick ceramic panels. Part of the walls is built using aerated concrete blocks.

Ground plan of the A block's 2nd floor – classrooms.

All buildings have flat roof. Superstructure of the roof is made of timber or steel trusses and reinforced concrete panels. The roof was insulated by 50 mm of EPS on a sloping layer of gravel. Bituminous sheets with mineral granules (and Ti-Zn flashing) were used as a covering and waterproofing layer of the roof.

Doors and windows were wooden, steel or aluminium, using single or double glazing.

The most heat was lost by the buildings envelope due to the low thermal resistance (U-values) of the structures and bad air tightness (especially around windows)

Heating, ventilation, cooling and lighting systems

Heating and DHW systems are supplied by district heating from a nearby (gas burning) heating plant to central (water-water) heat exchanger. No cooling system is installed in the school.

Most of the school uses natural ventilation by windows. Individual ventilators were installed in store rooms, toilets and bathrooms. Only block B had mechanical ventilation.

Bulbs and fluorescent tubes were used for lighting.

Atrium in the middle of the main block before the renovation. [1]

Element	Area m²	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade	3873	1.06	0.20
Ceiling	5325	0.97	0.15
Windows, doors	2502	1.50 - 5.65	1.05 – 1.70
Roof	5325	0.58 – 0.86	0.15 – 0.16

Energy renovation features

Energy saving concept

Main goal of the renovation was to improve the user comfort and energy performance of the school buildings.

- After a debate it was decided that the school's envelope, heating, DHW and mechanical ventilation systems will be renovated according to low-energy standards.
- During the renovation it was decided to install a photovoltaic power plant on the roof to improve the environmental impacts of the building's use.

Building

- Additional thermal insulation (ETICS) made of expanded (EPS) or extruded (XPS) polystyrene or mineral wool was installed on the walls and roof. Also new waterproofing was installed on the roof. New U-values of the building's envelope vary between ≤ 0.16 W/m2K (roof) and ≤ 0.20 W/m2K (walls).
- Most of the doors and windows in the building's envelope were replaced. New doors and windows have plastic or aluminium frames with double and triple glazing, with U-value ≤ 1.70 W/m^2K. Also a new exterior shading system was installed on classrooms' windows to improve the user's (students and staff) comfort during sunny weather.

Technical systems

Heating: New compact heat exchanger station is located in the basement of block B. The school is heated using 276 (112 original) cast-iron radiators and 8 steel-stone heating desks. The radiators are fitted with thermostatic valves and heads. Steel pipes with equithermal regulation are used to supply the radiators. The temperature gradient in the heating system is 75/55°C. Heating system's efficiency is 95 %.

Ventilation: During the renovation the original mechanical ventilation system in block B was removed and replaced by new one (with heat recovery). System's maximum output is 15000 m^3/h of fresh air. Ventilation of storerooms in the basement of block B uses separate ventilation (500 m^3/h). The boiler room in block A is ventilated by an overpressure system (500 m^3/h). All toilets and bathrooms are ventilated using manually operated ventilators with timers. Storage rooms in the school (except block B) can be ventilated naturally by windows or by new manually operated supplementary ventilators (also manually operated with timers). All ducts are made of galvanized steel and have rubber silencers to reduce the noise (< 50 dB).

Photovoltaics: A photovoltaic power plant was built on the part of the A block's roof during the renovation. 324 PV panels (415.53 m^2) with output of 205 Wp per panel were installed. The calculated peak output is 66.42 kWp. The panels are installed at optimum 30°incline and are oriented to the south. The municipality didn't have enough funds to build the power plant themselves, therefore they agreed to a proposal from a private company – the company rents the roof (where the power plants stands) for a yearly fee. This income is subsequently re/invested in the school. The power plant is connected to the public network, therefore its has only indirect impacts on the school itself.

Achieved energy savings, CO_2 reductions and Costs

Before renovation	Energy consumption		
Heating:	107.22	kWh/m²a	
DHW:	14.76	kWh/m²a	
Heating+DHW:	121.98	kWh/m²a	
After renovation	**Energy consumption**		**Savings**
Heating:	35.37	kWh/m²a	67.0 %
DHW:	13.95	kWh/m²a	5.5 %
Heating+DHW:	49.32	kWh/m²a	59.6 %

Energy savings and CO_2 reduction

Thanks to improved thermal properties of the school buildings' envelope and renovation of the heating system the heating energy consumption was reduced by 67 %.

Retrofitting of heating and DHW system lead to 5.5 % savings of energy required for DHW production and distribution. This little decrease in energy consumption can be questioned, because it does not truly describe the efficiency of the renovation. As a part of the renovation of the DHW system the original DHW circulation circuit (previously out of order – clogged with scale) was repaired. This caused increase in the DHW consumption. Despite this the overall DHW energy consumption still decreased, which proves the efficiency of the renovation.

Note: All the data about energy and CO_2 reductions are related to the net floor area.

Calculated CO_2 production before renovation	58.9	kg CO_2Eq./m²a
Calculated CO_2 production after renovation	34.9	kg CO_2Eq./m²a
Reduction:	40.7 %	

Renovation costs

Total	**1.43**	**Million €**

This amount includes all the costs related to the renovation – the renovation of the building, renovation of the outdoor sport facilities and restoration of the surroundings to the original state.

Photovoltaic panels installed on the roof of the A block. [2]

Energy production

Photovoltaic power plant installed on the roof of the school's block A has maximum calculated output 66.42 kWp. The PV is owned by the school and the generated electricity is used to cover its own electricity demand.

Between September 2009 (installation) and February 2014 (this report) the power plant produced 334.39 kWh of electricity.

The power plant is owned by a private company and supplies electricity to the public network. The municipality receives a payment of 2.200 € annually for renting the school's roof to this purpose.

Aerial view of the school's A block with photovoltaic power plant on the roof. [2]

Overall improvements

Energy benefits

Energy savings: 72.51 kWh/m^{2}a
(heating, DHW, ventilation, lighting)

Energy from PV: ~ 72.48 MWh/a (and owned by the school)

Indoor climate technical improvements

The indoor climate was improved due to:

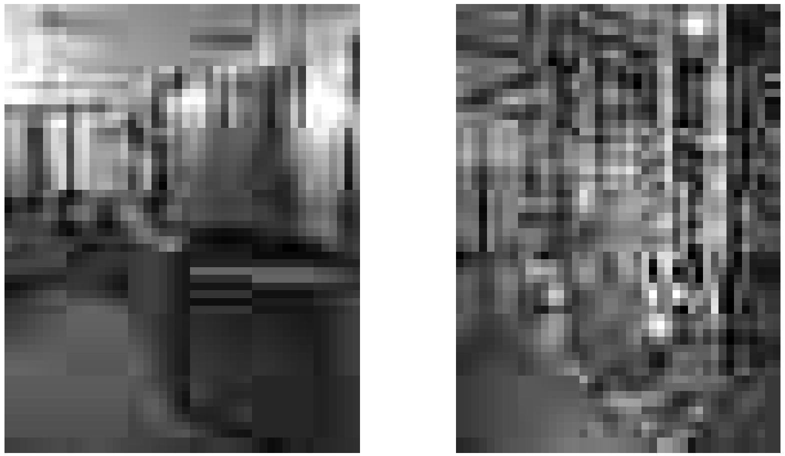
- Renovation of the school‘s envelope. This reduced the heat losses and improved thermal stability of the rooms. Thanks to the better air tightness the previously common drafts (through the original windows) disappeared.
- Partial replacement and re-regulation of the heating and DHW systems improved their efficiency and ease of use.
- Installation of exterior shading sunblind's on the windows improved problems related to overheating in summer.

Co-benefits

Overall the renovation of the school buildings and grounds improved:

- Comfort of the users (students and staff). E. g. the new equipment is easier to use and maintain.
- New possibilities for active spending of leisure time for students and general public are open thanks to the new sport facilities
- Overall improvement of people‘s perception of the building and surroundings

Aerial view of the renovated school and its surroundings. [3]



New ventilation unit (left) and heating system (right).

New bouldering wall.

New ventilation unit (left) and heating system (right).

Summary

Three blocks of Elementary School Kamínky 5 in Brno – Nový Lískovec were renovated. The building envelope (walls, roofs, ceilings and floors) was insulated using EPS, XPS and mineral wool. New waterproofing was installed on the roof.
Heating, DHW and lighting systems were partially replaced and reconstructed.
To decrease the negative environmental impacts of the operation of the school a photovoltaic power plant was installed on the roof of the school‘s main block.
Above mentioned measures decreased heating and DHW energy consumption by 59.6 %. Also the renovation has positive socio-cultural impacts – the aesthetic value of the school had risen due to the renovation. Also the surroundings of the school (playgrounds, park, etc) were renovated and refurbished during the construction.

Main entrance to the school after renovation.

Acknowledgements

Special thanks belong to:

- **Staff of Borough Office Brno - Nový Lískovec** for interest in collaboration on this project
- **Staff and students of Kamínky 5 elementary school** for cooperation during in-situ inspections and interviews
- **MENHIR projekt s. r. o.** for sharing the necessary data about the renovation
- Grant No. 2112 of **Brno University of Technology** for support

References

[1] Borough office Brno – Nový Lískovec

[2] Kučera, J., *Pronájem střechy školy na fotovoltaickou elektrárnu*, Praha: Stavitel, 2009, accessible at http://stavitel.ihned.cz/c1-39143520-pronajem-strechy-skoly-na-fotovoltaickou-elektrarnu (last access 14 Feb. 2014)

[3] http://mapy.cz/ (last access 14 Feb. 2014)

4. Koniklecová 4, Brno-Nový Lískovec

Project summary

Energy concept: Renovation to low-energy / passive house standard

Background for the renovation:

Intention for the renovation:

- Overall modernization of the aging building
- Improvement of inner conditions
- Significant reduction of energy consumption

Street (western) view of the Koniklecová 4 block-of-flats before (left) and after (right) renovation. [1]

Site:	**Koniklecová 467/4, 634 00 Brno-Nový Lískovec, Czech Republic**
Altitude:	325 m
Heating degree days:	3712 (base temp. 13°C)
Cooling degree days:	0
Owner:	Statutory City Brno
Architect:	MENHIR projekt, s. r. o.

Contact Person:	Martina Kašparová (Borough Office Brno-Nový Lískovec)
Renovation started:	2009
Renovation ended:	2010
Data collection:	Autumn 2014

Building description / typology

- Block-of-flats
- Built: 1983
- Capacity: 60 flats (47.21 to 75.17 m^2)
- Net heated floor area: 5412 m^2

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

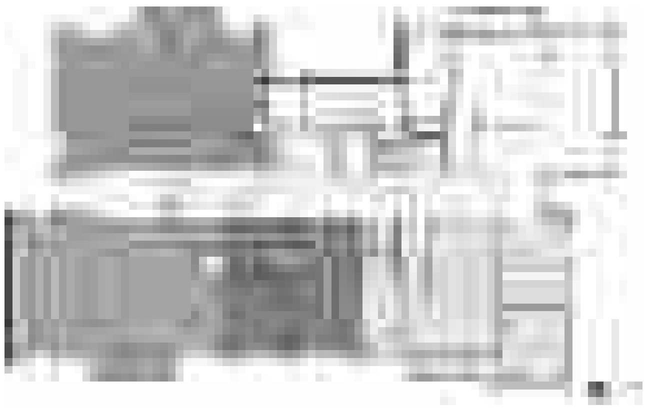
Described block-of-flats was built during the 80s‘, using B 70 R/K structural system.

The building has 12 floors and a basement. There are 60 flats in the building (5 flats/floor). Total net heated area of building is 5412 m^2. The building is owned by municipality and serves as a housing for socially disadvantaged.

Building envelope

External walls are made of reinforced concrete panels (200 and 270 mm) with in-built EPS thermal insulation (approx. 60 mm).

The building has flat cold roof (with ventilated air cavity). The superstructure of the roof is made of reinforced concrete panels. It was originally thermally insulated using 120 mm of mineral wool. The roof was covered by bituminous sheets with mineral granules. The attic wall was covered by Ti-Zn flashing.



Ground plan of the A block‘s 2nd floor – classrooms.

Doors and windows in the building were wooden, steel or plastic (result of previous renovations and maintenance), using single or double glazing.

The most heat was lost through the building envelope due to low thermal resistance (U-values) of the structures and problems with air tightness - especially in and around window and door openings, where the sealing (even though repeatedly replaced) was in bad condition.

Heating, ventilation, cooling and lighting systems

Heat energy for heating and DHW systems are supplied by district heating from a nearby (gas burning) heating plant to central (water-water) heat exchanger.

No cooling is installed in the building.

The building is mostly naturally ventilated Small ventilators are installed only in kitchens, toilets and bathrooms of individual flats to suck off odours and vapours into central ventilation shafts. These ventilation shafts are running through the whole height of the building. Exhaust air outlets are located on the roof.

Manually operated bulbs and fluorescent tubes (with timers in common areas) were used for lighting.

Eastern view of Koniklecová 4 block-of-flats before the renovation. [2]

Element	Area m^2	U-Value before renovation W/m^2K	U-Value after renovation W/m^2K
Façade	3048	0.78 – 0.80	0.17 – 0.24
Ceiling	407	1.13	0.33
Windows, doors	881	1.20 – 5.65	1.05 – 1.70
Roof	441	0.50	0.15

Energy renovation features

Energy saving concept

Similarly to the other Czech shining example, Elementary School Kamínky 5, main goal of this renovation was to improve the energy performance of the building:

- The building‘s envelope was to be renovated according to low–energy and passive house standards
- Renovation of heating and DHW to reduce the energy loses of their respective distribution systems. Renovation of ventilation systems in individual flats to improve its efficiency and reduce noise.
- Replacement of lighting in common areas of the building using energy-saving components

Building

- All wooden and metal doors and windows in the building‘s envelope were replaced. New doors and windows have aluminium or plastic frames with triple glazing.
- Additional thermal insulation (ETICS) made of expanded (EPS) or extruded (XPS) polystyrene or mineral wool was installed on the external walls, ceiling of the ground floor and roof.
- The concept of the roof was changed by the renovation from a cold roof (with ventilated air cavity) to a warm roof (air cavity not ventilated) – all the ventilation openings were sealed . This simplified the energy concept and reduced heat losses through the roof. New bituminous waterproofing was installed on the roof.
- Open balconies were converted to closed loggias with sliding windows. This reduced the heat losses through the balcony doors and windows and improved year-long use of the space.

Systems

Heating: Energy for heating and DHW is supplied by two horizontal counter-flow heat exchangers in a boiler room on the ground floor of the building. The heating system has two main sections (East and West) representing east- and west-oriented flats. Both sections have equithermal regulation. There are gilled radiators installed in the whole building. All the radiators have thermostatic heads (since 2002). During the renovation the measuring and regulation equipment was replaced. Electronic sensors of exterior temperature were installed. Old circulation pumps were replaced by new ones with electronic regulation. Old damaged valves and heads were replaced.

Ventilation: Original ventilation equipment was both morally and technically outdated, damaged and partially inoperable. It was decided to leave original ducts in central shafts in place. Only the noise silencers and outlets on the roof were replaced. Individual ventilators (kitchens, bathrooms, toilets) as well as the ducts connecting them with the central ducts were replaced. They are operated manually (with timers) by the users.

Designs for installation of a modern HVAC system is currently being prepared and borough office will submit a government subsidy application to finance this system. After installation of this system the building will reach passive house standard.

Achieved Energy Savings, CO_2 reductions and Costs

Before renovation	**Energy consumption**		
Heating:	97.23	kWh/m²a	
DHW:	32.35	kWh/m²a	
Total:	129.58	kWh/m²a	
After renovation	**Energy consumption**		**Savings**
Heating:	24.89	kWh/m²a	74.40 %
DHW:	25.82	kWh/m²a	20.20 %
Total:	50.71	kWh/m²a	60.87 %

Energy savings

Improvements in thermal properties and air tightness of the building's envelope and renovation (including re-regulation) of the heating system reduces the heating energy consumption by almost ¾. Thanks to this the renovated building easily meets Czech low-energy standards (22,95 kWh/m²a < 50 kWh/m²a).

Renovation of DHW system brought above 20 % savings of energy required for DHW production and distribution.

Calculated CO_2 production before renovation	77.9	kg CO_2Eq./m²a
Calculated CO_2 production after renovation	49.3	kg CO_2Eq./m²a
Reduction:	36.7 %	

CO_2 reduction

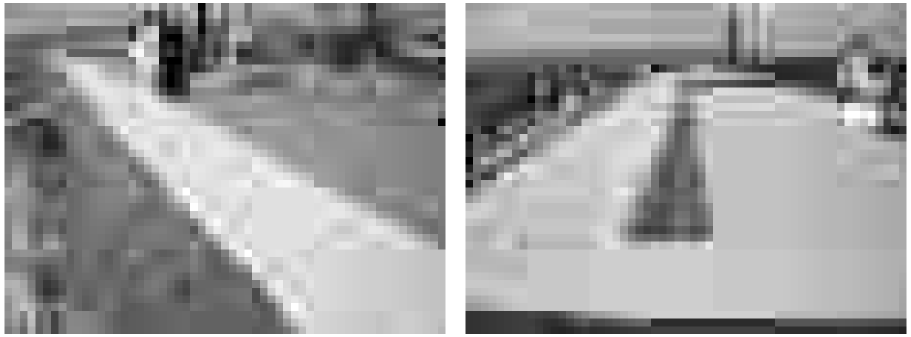
The renovation reduced the CO_2 production of the building by approximately ⅓. The largest savings were achieved by reducing the heating energy consumption. Before renovation heating of the building produced 35.0 kg CO_2Eq./m²a, while after renovation this was reduced to only 11.6 kg CO_2Eq./m²a (66.8 % reduction).

Note: All the data about e energy and CO_2 reductions on this page are related to the net floor area.

Renovation costs

Total	**770.000 €**

Original heat exchangers in the boiler room (before renovation). [2]



The attic during the renovation - installation of additional thermal insulation over the attic to reduce the thermal bridge (left) and a view of the new waterproofing/covering layer made of mPVC sheets (right). Precise design and construction of structural details are crucial for proper function of any energy efficient building. [1]

Overall improvements

Energy benefits

Energy savings: 81.06 kWh/m^{2}a

(heating, DHW, ventilation, lighting)

Indoor climate technical improvements

The indoor climate was improved due to:

- Reduction of heat losses and draught through the buildings‘ envelope.
- Renovation and re-regulation of the heating, DHW and lighting systems

According to survey among the tenants, the renovation significantly reduced overall energy consumption of the building which lead to lower the operating costs. Also the indoor climate has improved. Installation of thermal insulation and new airtight windows and doors improved the thermal comfort and stability in the individual flats – e.g. there are no more drafts around the windows, which had a negative influence on the indoor climate, especially in winter.

Co-benefits

The overall renovation of the building also improved:

- User comfort of the tenants. New equipment, windows, doors, etc. are easier to use and maintain than original ones.
- Aesthetic perception of the building and its surroundings has improved after the renovation. The renovation of the building was related to other works - renovation of surrounding pavements, playgrounds, etc. – which also had positive impact on the living conditions.

Main entrance before (left) and after (right) renovation. [2]

Aerial view of the Koniklecová 4 block-of-flats. [3]

Summary

Koniklecová 4 block-of-flats was renovated. The building envelope (walls, roofs, ceilings and floors) was insulated using EPS, XPS and mineral wool. Doors and windows in the building‘s envelope were replaced by new ones. New waterproofing was installed on the roof.

Heating, DHW, ventilation and lighting systems were partially replaced and modern measuring and regulation equipment was installed.

Above mentioned measures decreased heating and DHW energy consumption by 60.9 % - tenants survey confirmed that there are significant savings in energy consumption since the renovation.

The renovation also had positive impact on the aesthetic perception of the building and its surroundings.

Acknowledgments

Special thanks belong to:

- **Staff of Borough Office Brno - Nový Lískovec** for interest in collaboration on this project and for cooperation with the researchers
- **MENHIR projekt s. r. o.** for sharing the necessary data about the renovation
- Grant No. 2112 of **Brno University of Technology** for support

References

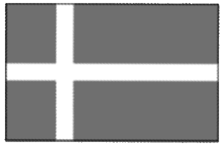
[1] MENHIR project s. r. o.

[2] Stavoprojekta, spol. s r. o., *Energetický audit – Bytový dům, Koniklecová 4, Brno-Nový Lískovec*, Brno, 2009

[3] http://mapy.cz/ (last access 24 Feb. 2014)

Western view of renovated Koniklecová 4 block-of flats.

5. Sems Have, Roskilde



Project summary

Energy concept: Insulation, ventilation, PV system, heating system

Background for the renovation:

Renovation and conversion of a dormitory/day-care centre into 30 low energy apartments:

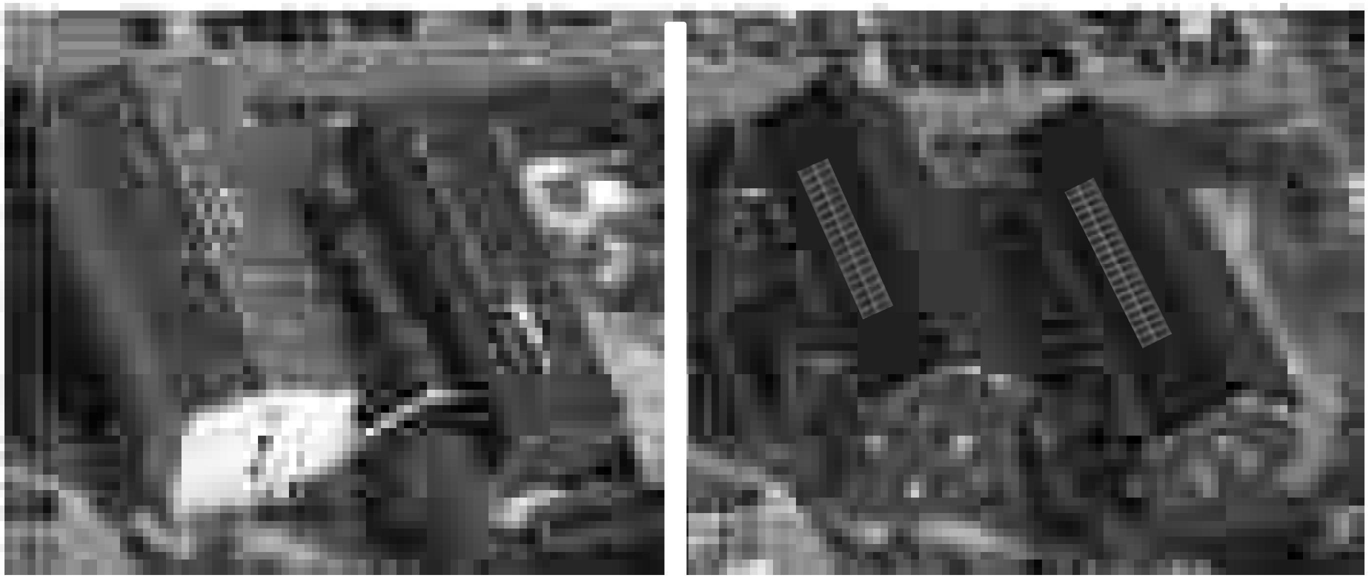
- Conversion as the buildings could no longer be let out for the original purpose
- Improved thermal envelope – walls, roof and windows
- Balanced mechanical ventilation with heat recovery
- New (district) heating system
- PV system for reaching nearly-zero energy (Danish Building Class 2020)
- Improved architecture

Site:	**Parkvej 3-5, DK-4000 Roskilde**
Altitude:	35 m
Heating degree days:	2906 (base temp. 17°C)
Cooling degree days:	0
Owner:	Housing Association Zealand
Architect: Engineer: Contractor	Kullegaard Arkitekter Terkel Pedersen Daurehøj Erhvervsbyg A/S

Contact Person:	Charlotte Szøts Housing Association Zealand
Renovation started:	2012
Renovation ended:	2013
Data collection:	Summer 2014

Building description / typology

- 2 blocks
- Built: 1973 – new windows and additional insulation in 1995
- General information: Energy label C before renovation
- Gross heated floor area: 3,626 m² after renovation



The two blocks of Sems Have before the renovation (to the left) and after the renovation (to the right).

Building envelope, heating and ventilation system before the energy renovation

Description of building

Sems Have originally consisted of:

- block A containing a day-care centre at the ground floor and a dormitory at 1st to 3rd floor.
- block B containing a day-care centre at the ground floor and a hall for e.g. music at the 1st floor.

The buildings were rented by the municipality, however, when the municipality terminated the lease, the housing association was left with buildings which could not be rented out.

Energy demand

Before the renovation, the buildings were rated at energy class C buildings. So the energy demand was not the reason for the renovation. The buildings were renovated since they could not be rented out due to their layout and because they were worn down.

Building envelope

Both blocks had a loadbearing internal concrete construction with panel walls containing 125 mm mineral wool + in 1995 extra 100 mm mineral wool was added. The U-value before the renovation was thus quite good, but the walls were worn down and needed replacement. The U-value before and after the renovation is, therefore, identical.

The windows were double glazed with a U-value of 2.8 W/m²K.

The roof of block A was insulated with 200 mm mineral wool. The horizontal part of the roof of block B was insulated with 150 mm mineral wool while the mansard part of the roof was insulated with 125 mm mineral wool.

Basement: walls against soil had no insulation, the rest had 50 mm mineral wool. Floor slap in basement consisted of 200 mm expanded clay aggregate below the 100 mm concrete slap.

Heating and ventilation systems

The buildings were heated by district heating with an indirect two-line radiator circuit. Domestic hot water via a 2,500 litre tank insulated with 100 mm mineral wool.

The day-care centre and the halls (in block B) were ventilated by balanced mechanical ventilation with heat recovery below 60 %. The dormitory and the basements were naturally ventilated.

Block A before renovation

Block B before renovation.

Element	Area after retrofit m²	U-Value before retrofit W/m²K	U-Value after retrofit W/m²K
Panel walls	1.497	0.2	0.2
Gable walls	224	0.3	0.3
Windows, doors	568	2.8	1.0
Roof	1.043	0.2-0.32	0.09
Floor over basement	970	2.3	1.1

Energy renovation features

Energy saving concept

The building had to be renovated since they could not be let out due to their layout and because they were worn down:

- Conversion from day-care centre and small dormitory flats to 30 up-to-date and affordable apartments of 67-145 m^2.
- Nearly-zero buildings (Danish Building Class 2020).
- Large PV system.

Building

- Everything except for the internal concrete construction and the roof insulation of block A was removed.
- The mansard part of the roof of the 1st floor (hall) of block B was re-placed with vertical walls identical to the other walls of the buildings.
- New pitched roofs in order to allow for 400 mm insulation.
- The hall at the 1st floor of block B was divided into 7 apartments with an extra floor in part of the apartments leading to an increase of the total gross floor area of the buildings of approx. 10 %. The living rooms are of double height.

Systems

Heating: New district heating substation, radiator circuit, two new domestic hot water tanks of each 1,000 litre with a heat loss coefficient of 3.7 W/m^{2}K, new domestic hot and cold water pipes.

Ventilation: The flats are ventilated by balanced mechanical ventilation with heat recovery. SFP factor: 2 kJ/m^3 and efficiency of heat recovery: 84.

Lighting: New lighting – LED and low energy fluorescent tubes - in the staircases.

Element	After renovation
Exterior walls	Prefabricated elements: Internal: 2x12.5 mm gypsum plates 240 mm mineral wool 9 mm fibre cement board External: 63 mm air gap behind slate tiles
Windows, doors	Triple glazed low-energy windows with 2 layers of low-E coating and Argon between the glasses.
Roof	Block A: originally 200 mm mineral wool + added 200 mm extra insulation: total 400 mm Block B: new insulation: 400 mm

Renewable energy systems

Two PV system of totally 117 m^2 with a performance of 17.3 kW$_p$.

Cross section of block A (to the left) and block B (to the right) after the renovation.

Achieved Energy Savings and Costs

Energy consumption for space heating and hot water before and after renovation:

Annual district heating consumption for both buildings incl. basement:
before renovation - measured: 508 MWh/year *
after renovation - calculated: 179 MWh/year *
Energy savings – district heating: 329 MWh/year = 65 %
* incl. heat losses from the basements i.e. equal to the numbers on the energy bill from the district heating company. This can thus not be compared with the below calculations. The savings of district heating lead to the following annual savings: 38.8 tCO_2, 5.6 tSO_2 and 44.4 tNO_x.

Energy consumption after renovation – calculated using the Danish calculation tool Be10:
Net mean space heating demand : 9.4 kWh/m²gross area **
Net mean domestic hot water demand: 13.7 kWh/m²gross area
Building related electricity demand: 6.0 kWh/m²gross area
Electricity production from PV panels: 3.6 kWh/m²gross area
Primary energy demand minus PV production: 16.2 kWh/m²gross area
Danish Building Class 2020 *** (nearly-zero energy) is 20 kWh/m²gross area
** not including the basements. The calculation is based on standard demands not on real demands
*** primary energy factors in 2020: district heating 0,6 and electricity 1.8

Calculated energy savings and PV production

Annual saving of district heating: 329 MWh/year = 214000 DKK/year.

Before the renovation the electricity demand for ventilation was 57 MWh/year. This demand is after the renovation calculated to 20 MWh/year. Savings: 37 MWh/year = 81000 DKK/year

PV electricity production:

13 MWh/year = 29000 DKK/year.

Estimated total annual savings valued to be:

89 DKK/m² = 12 EUR/m².

The two buildings after renovation.

Renovation Costs

Expence	million DKK / million EUR	kDKK/m² / kEUR/m²
Craftsmen	44.31 / 5.91	12.2 / 1.63
Consultants	5.19 / 0.69	1.43 / 0.19
Various building project costs *	22.89 / 3.05	6.3 / 0.84
From 2015 to 2020	0.23 / 0.03	0.06 / 0.01
Total	72.62 / 9.68	20 / 2.67

New balconies

* Repayment of old loans, building owner fee, municipality and state charges and fees, stamp duty for a new mortgage etc.

Overall improvements including non-energy benefits

Energy

Savings: heating 329 MWh/year
electricity 37 MWh/year
PV production: 13 MWh/year

Indoor climate technical improvements

The indoor climate was improved due to:

- Balanced mechanical ventilation with heat recovery
- Less heat loss and draught through windows and doors

Economics

The buildings had to be severely renovated or demolished as they could no longer be used for the original purpose.

The Housing Association wanted at first to renovate (not including the basement) according to Low Energy Class 2015 (30.5 kWh/m²). However, as Building Class 2020 (20 kWh/m²) would only cost 232.000 DKK (31,000 EUR) or 0.3 % extra - for the PV systems, better windows and extra 60 mm insulation on the roof - it was chosen to go for the Building Class 2020 instead.

Decision making process – barriers that were overcome

- Difficult to get the approval from the municipality to change the status of the buildings from dormitory/day-care centre to residential.
- Difficult to comply with modern acoustic requirements.
- Removal of PCB, asbestos and paint containing lead.

Economic consequences for the tenants

Due to the change in the status of the building there is no point in comparing the rent before and after the renovation.

Rent after: 897 DKK/m²/year = 120 EUR/m²/year (excl. energy)

The rent is comparable with the rent of other apartments of similar quality in Roskilde. But the annual expenses for energy use is lower than in similar buildings.

Co-benefits

The renovation has resulted in:

- Up-to-date affordable apartments which can be rented out
- Improved architecture
- Improved indoor climate
- New sewer system, new- cold and hot-water system and new electrical system
- New lighting in the staircases
- New kitchens and bathrooms
- Balconies for some apartments
- Elevator to apartments in block A
- Improved surroundings
- Saved CO_2 due to the conservation of the concrete structure
- Prestige: nominated to a renovation award

User evaluation

The users are very content with:
- The quality and layout of the apartments
- The indoor climate
- The improved architecture and surroundings

However, the best indicator of the users opinion of the new apartments is that there is a waiting list to get an apartment.

One of the gables.

Summary

Summary of project

Two buildings containing a dormitory, day-care centre and a hall were successfully transformed to up-to-date nearly-zero energy residential apartments.

Only the concrete structure and the insulation of the roof (the latter in one building) were preserved. The preservation saved money and CO_2.

The renovation was financed like new social housing (not subsidized). The rent of the apartments is comparable with other apartments of the same quality in the area. The new apartments are very popular.

New internal walls and inserted deck at the first floor of block B.

Experiences/lessons learned

The experience of Housing Association Zealand is that it is a good idea when performing deep energy renovation to strip the building down to the loadbearing constructions and add a new thermal envelope instead of trying to improve the original thermal envelope.

It is a challenge to upgrade existing buildings to contemporary and future-proof apartments especially if the new design uses other module lines etc. than the original design.

The concrete structures (including decks) were maintained, however, this made it difficult to comply with modern requirements regarding acoustics.

PCB, asbestos and paint containing lead had to be removed from the building and safely deposited.

The Housing Association experienced difficulties in obtaining approval from the municipality to change the status of the buildings from dormitory/day-care centre to residential.

The new improved apartments and architecture has been well received by the tenants. There is at the moment a waiting list for persons who would like to rent an apartment in the buildings.

Sems Have has been nominated to the renovation award Renover 2014.

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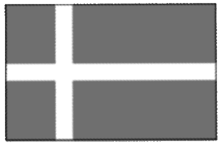
[2] Family homes in the Youth House – Energy calculations (in Danish). Terkel Pedersen Rådgivende Ingeniører Aps.

[3] Energy certificate (in Danish). September 3, 2009. Danakon A/S

[4] http://renover.dk/project/sems-have/ (in Danish)

6. Skodsborgvej, Virum



Project summary

Energy concept: Total renovation to reduce energy consumption and improve indoor climate

Background for the renovation:

- The double-storey detached house from 1927 is situated in Virum, 20 km north of Copenhagen. In December 2011, a small family bought the house. The family wanted to renovate the house in order to enjoy the house more in the future. Therefore, the family contacted an energy adviser who audited the house, and together they made a plan for the energy renovation of the house.
- They wanted an energy renovation because it was difficult to heat the house to a satisfactory temperature, and the house had a bad indoor climate and also they wanted a bigger bathroom in the basement. Therefore, they borrowed money to finance these renovation measures.
- As a result of the cooperation with the energy adviser, the energy renovation was given high priority, both because it would save money and provide comfort and improve the indoor air quality.

Figure: House seen from the road – before renovation and from the garden after renovation

Site:	**Skodsborgvej, Virum, Denmark**
Altitude:	27 m
Heating degree days:	2906 (base temp. 17º C)
Owner:	Thomas Brørup & Susanne Krøgh Rasmussen
Architect:	-
Engineer:	Susie M. Frederiksen

Contact Person:	Susie M. Frederiksen, Danish Knowledge Centre for Energy savings in buildings
Previous renovations:	1941, 1951, 1954
Renovation started:	2012
Renovation ended:	2012
Data collection:	January 2014

Building description /typology

- Two-storey villa with red bricks and red tiled roof, built in 1927
- Energy label G
- Gross heated floor area: 121 m^2

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Building envelope

The first floor had a very low level of insulation and suffered from draught, which made it quite uncomfortable during winter. For the same reasons it was almost impossible to heat the first floor to a satisfactory temperature. The mansard walls were partially insulated (ranging from 0 to 100 mm) and the roof spaces were completely uninsulated. The collar beam ceiling was insulated with 200 mm of insulation except the pediment towards the road which was insulated with only 100 mm. None of the roof spaces were insulated - neither on the wall towards the rooms nor on the floor towards the rooms of the ground floor. The front tip towards the road consisted of an uninsulated solid brick-wall. The rooms on the first floor beyond the above mentioned were insulated with cellotex.

The bathroom in the attic was insulated with 25 mm of insulation

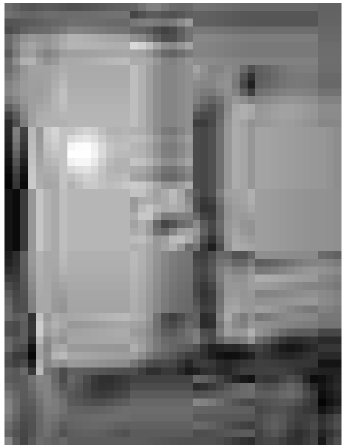
The ground floor and gable cavity walls were already insulated with injected foam, which was often used during the 1960-70s. The insulation was surprisingly found to be intact.

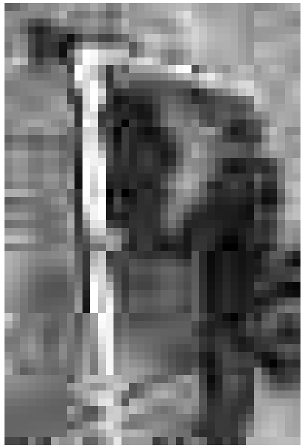
The windows were replaced by a first generation of double glazing during the 80s.

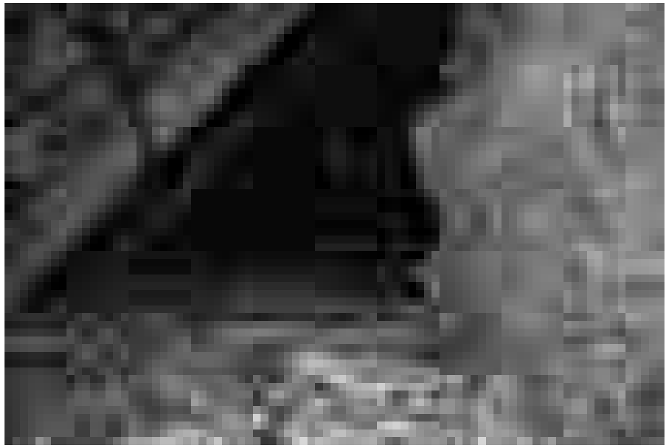
Heating, ventilation, cooling and lighting systems

The house was heated with central heating from 1954 supplied from a gas boiler from the 80s. The house had no ventilation system, i.e. natural ventilation was used.

Seen from the garden before renovation







From left to right: 1. The old gas boiler and hot water tank. 2. Installation of the new B-labbeled balcony door 3. Existing insulation in the loft

The new vapour barrier on the loft

Energy renovation features

Energy saving concept

Overall renovation in order to reduce the energy consumption and improve the indoor environment

Technologies

- Insulation of envelope
- New glazing in windows
- Solar heating plant
- Condensing gas boiler
- New valves
- New insulation of pipes
- Balanced ventilation with heat recovery

Building

U-values for constructions before/after renovation can be seen in the table.

- Ceiling - from 100 to 400 mm
- Sloping wall – from 0/25/100 mm to 200 mm
- Roof spaces in attic - from 0/25/50 mm to 300 mm
- Solid brick walls – from 0 mm to 100 mm (inside)
- Light walls and flat roof – from 25 mm to 150 mm
- Double glazed windows/doors - replaced by low energy windows/doors
- Balcony door – replaced by low energy balcony door

Systems

- Gas boiler – replaced by modern condensing boiler
- Radiator valves – replaced by thermostatic valves w. electronic control
- Installed weather compensation and night setback
- Insulation of hot water, heating system and other pipes from existing 0/20 mm old insulation to 40 mm new insulation

Construction	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Collar beam ceiling	0.30	0.14
Sloping walls (manzard walls)	1.00	0.16
Roof spaces in attic	0.90	0.11
Solid brick walls	1.65	0.29
Light walls and flat roof	1.00	0.20
Windows and balcony door	2.80	1.40

Figure: U-values before/after renovation

Renewable energy systems

- Solar heated water - 4.7 m² solar panels and 300 litre solar tank

Pediment in the bedroom with new balcony door - almost ready to move in.

Calculated Energy Savings, CO_2 reductions and Costs

Energy consumption, calculated	Before renovation	After renovation
Energy consumption	39941 kWh (3631 m^3 gas)	21087 kWh (1917 m^3 gas)
Energy consumption pr. m^2	327 kWh/m^2	172 kWh/m^2
Useful m^2	121 (but very cold)	121 (now 1. floor is comfortable)
Energy label	G	D

Costs	DKK/EUR	DKK/m^2 / EUR/m^2
Craftsmen incl. consultants	330.000 / 44.236	2705 / 363
Subsidies (Craftsmen-deduction and from energy-utilities)	48.000 / 6.434	393 / 53
Total renovation price (after subsidies)	282.000 / 37.801	2330 / 312
Increased value of the house (due to better energy label)	306.000 / 41.018	

Calculated:

The calculated savings are approx. 18.000 kWh – which means that the energy bill is cut by approx. 47%.

User evaluation:

In the first heating season the energy bill was cut by 25% and the heated area in reality increased by 100%.

Investment and savings:

Total investment (DKK/EUR): 282.000 / 37.802

Savings pr. year (DKK/EUR): 15.000 / 2.010

Simple payback (years): 19

Energy renovation	Savings kWh/a	Reduction ton CO_2	Savings DKK/EUR pr. year
Insulation of roof spaces in attic (space under the roof slope)	1850	0.4	1450/194
Insulation of mansard walls (sloping walls) 1st floor	1800	0.4	1400/188
Replacement of glazing in windows and balcony door in the pediment	2000	0.4	1600/214
Solar heating plant for domestic hot water	2350	0.5	1850/248
Ventilation with heat recovery	4700	1.0	3700/496
Old gas boiler replaced by new condensing gas boiler	5300	1.1	4200/563
Replacement of thermostatic radiator valves to new ones with electronic control			
Insulation of domestic hot water pipes and valves	2000	0.4	1600/214
Weather compensation and night setting and balancing/ controlling of the system	2200	0.5	1750/235

Overall improvements, experiences and lessons learned

Energy

Annual savings: 18.000 kWh

Indoor environment

- No draught - no cold walls - no moisture - no mould
- No condensation on the glazing of the windows
- The air is being changed without opening the windows
- Before renovation it was not possible to heat the first floor
- Now, the house is often heated only by the passive solar energy – even in winter
- Thermostatic valves ensure that the temperature is right

. **Co-benefits**

- The useable space (first floor) has increased, i.e. the family will use the rooms upstairs far more
- The family can place furniture etc. close to the wall without risking damages (mould) and draught
- Improvement of energy label leads to increased house price
- This investment ensures that the family can afford other investments in the future
- The roof-construction has been checked, and it is clear that it is a good construction which will last for the next 20 – 30 years.
- Space better used (first floor)
- No draught, no cold wall, no moisture or mould
- Improvement of energy label leads to a higher possible price of the house.

Decision process – barriers that were overcome

As soon as the family bought the house, they realised that the house was not very healthy to live in – and heating it was expensive. It was so cold upstairs, that they had to wear outdoor clothing. The cold walls also meant moisture and mould. So it was an easy and quick decision, that the first floor had to be renovated with more insulation. The process started in December 2011, where the energy adviser made the first audit and made a plan for a total energy renovation; the family chose to carry out almost the entire plan.

The energy renovation was filmed to be used as a ”good example” and the energy savings were calculated by the Danish Energy authorities. In June 2012 the family could move into their new first floor – after having done the decorating themselves. The family is really happy that they chose to spend money on the energy renovation: “The new comfort is really great value for us – and we can only advise other house owners to do the same”. It was a relatively easy process for the family. They hired an energy adviser who had knowledge about both the building envelope and the technical installations and could plan the renovation and control the work process with various craftsmen. “We are really happy that we made initiated the renovation immediately – and that we took the whole energy renovation package. We no longer have doubts that this is a good house and we really enjoy living in it!”, says Thomas Baarup.

Insulation of mansard walls and lost space walls in attic incl. vapour barrier and internal insulation of the pediment

Summary

Thomas and Susanne's new house spent a lot of energy, and they could not use the first floor as it was very cold and humid. Therefore, they contacted an energy adviser, who made a plan for the energy renovation of the house, which included as well the building envelope, heating system, ventilation and renewable energy. Susanne and Thomas chose to implement insulation of the mansard walls, and replacement of glazing in the windows and of the balcony-door. Furthermore they replaced the existing gas boiler with a new condensing boiler. A solar heating plant produces domestic hot water. A new ventilation plant with heat recovery is installed, and the pipes are insulated. Thermostatic valves are renewed, and the heating system is optimized. The family has thereby reduced the energy bill by approx. 50%, and improved indoor climate, so they can now use the entire house. The savings actually pay the loan for the renovation and the price of the house is estimated to increase just as much as the cost of the energy renovation.

Installation of the new heating system.

The dog Emil, Susanne, the daughter Elisabeth and Thomas enjoy their new home.

Acknowledgements

Carpentry work was done by:

Thomas Guld, energy adviser, thatcher and carpenter

www.thomasguld.dk

Plumbing work was done by:

Energy Adviser Morten Kühlmann

Triton Plumbing aps

www.tritonvvs.dk

The masonry work was done by:

Energy Adviser Ib Larsen

www.murerbiksen.dk

Electrical work was done by:

Electrician Kim Roy Kronkvist-Hansen

Roy Construction

Ventilation Work was done By:

PRO Ventilation

www.proventilation.dk

HMN Natural Gas A / S

www.hmn.naturgas.dk/kunde/sparenergi/

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7. Traneparken, Hvalsø

Project summary

Energy concept: Insulation, ventilation, control, PV-system

Background for the renovation:

The buildings had to be renovated because they were worn down. The overall intentions were to:

- Renovate buildings because it was needed – especially the concrete external walls
- Improve energy conditions (insulation – windows – doors)
- Improve indoor climate
- Improve flats by adding and external balcony
- Improve the outdoor areas

Site:	**Traneparken 2-20 | 4330 Hvalsø**
Altitude:	47 m
Heating degree days:	2906 (base temp. 17º C)
Cooling degree days:	0
Owner:	Hvalsø Boligselskab
Architect:	ARKIPLUS 1969
Engineer	Sigfried Lorentzen Rådgivende Ingeniørfirma

Contact Person:	Flemming Østergaard, Building Association Zealand
Renovation started:	2011
Renovation ended:	2012
Data collection:	Winter 2013

Building description /typology

- 3 blocks of prefabricated concrete sandwich element buildings
- Built: 1969
- General information: Energy label E
- Gross heated floor area: 5293 m²

2 of the 3 blocks at Traneparken. The one on the left not yet renovated – the other after renovation.

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

Traneparken consists of 3 multi-storey blocks of flats situated in the village Hvalsø, 55 km west of Copenhagen. Each block has 3 storeys and altogether 66 flats. The residents are an average part of the Danish population – except for 48 % being singles (rather small apartments). However – there is a rather big change of residents every year in Traneparken.

Building envelope

The buildings are typical 1960- buildings made of prefabricated enforced sandwich concrete elements with approx. 50 mm insulation.

Between the windows are panel walls which were insulated with approx. 6 mm insulation.

Floor insulation to basement was approx. 45 mm. The roof was insulated with approx. 190 mm. Windows were double glazed with U-value 1.8.

Heating, ventilation, cooling and lighting systems

The buildings are heated by district heating let into the basement of block A to a 200 kW plate heat-exchanger. From there it is distributed to the 3 blocks.

There are pre-insulated domestic hot water tanks in each block. Altogether there are eight 300 litre tanks.

The flats are ventilated by a mechanical exhaust air system from bathroom, toilets and kitchens.

Light: There are energy-saving-bulbs in all indoor lights on the staircases. It is equipped with automatic switch-off controls based on presence detectors. Outdoor light has automatic daylight switch-off.

The buildings seem rather "grey and boring" with problems from facades, windows, roofs, etc. The indoor climate was bad and the energy consumption was unacceptable large.

It was the intention that the renovation will make Traneparken more attractive for existing and new residents.

Facades – before and after

Facades – before and after

Element	Area m^2	U-Value before renovation W/m^2K	U-Value after renovation W/m^2K
Exterior walls	486	0.66	0.15
Floor over basement	361	0.66	0.66
Panel Wall	106	0.7	0.11
Windows, doors	205	2.4	0.8
Roof	333	0.2	0.09

Energy renovation features

Energy saving concept

The goal was to renovate the buildings because they were worn down, so the overall intention was to:

- Renovate buildings because it was needed - the concrete external walls were weakened by deterioration. At the same time external balconies should be added to improve the flats.
- Reduce the energy consumption
- Improve indoor climate

Building

- The exterior walls have been renovated: Supplementary thermal insulation is added to the outside of the exterior walls. The external insulation is continued to the base of the house to reduce thermal bridges. Cost: 12.5 million DKK = 1.67 million € (incl. VAT)
- The roofs are renovated and insulated. Cost: 4.2 million DKK = 0.56 million € (incl. VAT)
- The windows and doors are replaced with 3 layers low-energy windows. Cost: 0.85 million DKK = 114094 € (incl. VAT, excl. installation).

Systems

Heating: Nothing changed

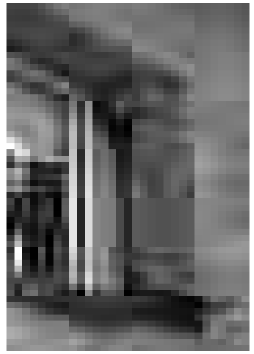
Ventilation: The flats are now ventilated by a balanced mechanical ventilation system with heat recovery. Exhaust air from bathroom, toilets and kitchens and supply air to the living rooms.

Lighting: No changes of the lighting - it is already up to date.

Renewable energy systems

Solar panels are installed for electricity production, with a performance of 33 kW_p facing south

Element (only block A)	After renovation
Exterior walls	Plus 190 mm insulation plus exterior solid standard bricks Now: 240 mm
Filling panels between windows	Plus 285 mm insulation plus exterior solid standard bricks Now: 330 mm
Windows, doors	3-layer low-energy windows with aluminium – wood frame
Roof	Plus 250 mm Now: 435 mm



Facades – during works in upper floors

Facades – during works in base floor

Achieved Energy Savings, CO_2 reductions and Costs

Calculated energy consumption:		
before renovation:		**728 MWh/year**
after renovation:		**502 MWh/year**
calculated savings:		**226 MWh/year**
Actual energy consumption measured over a 12 months period:		
before renovation	**2011 - 2012**	**736 MWh**
after renovation	**2012 - 2013**	**506 MWh**
actual savings:		**230 MWh**

Renovation Costs

	Total value	Price / m²
Craftsmen	38 M DKK	7525 DKK/m²
	5.1 M€	1010 €/m²
Consultants	11.3 M DKK	2238 DKK/m²
	1.51 M€	300.4 €/m²
Total	49.3 M DKK	9762 DKK/m²
	6.61 M€	1310 €/m²

Calculated energy savings and PV production

Energy savings by reduced heat loss from the building envelope is 120 MWh/year.
Energy savings by reduced ventilation loss is 106 MWh/year.

Total annual energy savings :
226 MWh/year.

Increased running costs for the ventilation system:
100.000 DKK/year = 13400 €/year.

PV electricity production:
30000 kWh/year = 60000 DKK/year / 8054 €/year
(~ electricity consumption in the common laundry).

Actual production from PV:
1st year of operation: 38159 kWh.

Aerial view

Non energy benefits: More beautiful buildings – better ventilation and balconies

Overall improvements, experiences and lessons learned

Energy

Savings: 226 MWh/year.

PV production: 30 MWh/year

Indoor climate technical improvements

The indoor climate was improved due to:

- mechanical balanced ventilation with heat recovery and a carefully adjusted supply temperature
- Less heat loss and draught through walls, windows and doors

Economics

It was important for the economy that the buildings needed renovation because of beginning deterioration. Therefore a large part of the renovation could be financed from funding available for improving the present situation – a Danish fund for social housing was used for this purpose: “Landsbyggefonden”.

Decision process

In social housing projects in Denmark a majority of the tenants has to agree on the decision. This means very much information, many meetings etc.

Co-benefits

The renovation has resulted in:

- New balconies
- New green surroundings
- Ventilation – better indoor climate

Facades – after

Indoor climate

Practical experiences of interest for a broader audience:

The tenants are satisfied with the improved indoor environment. For example: The benefits of the ventilation system: “now we don’t have to care about opening windows to change the air” - and the costs for heating has been considerably reduced, while the thermal comfort in the dwellings has improved considerably.

A few tenants claim that the air is now too dry – during the winter season.

It is expected that the former problems with mould will not re-occur with the improved ventilation.

Economic consequences for the tenants

Rent before: 698 DKK/m$^{2/}$year
= 93.7 €/m^2/year

Rent after: 786 DKK/m^2/year
= 105.5 €/m^2/year

Increase: 88 DKK/m^2/year = 11.8 €/m^2/year

Energy savings: 226 MWh/year

Energy price: 700 DKK/MWh = 94 €/MWh

Savings: 226 x 700=158.200 DKK = 31 DKK/m^2/year = 4.2 €/m^2/year

Users evaluation

The users are very content with:

- The new balconies – they increase the useful area of the flats
- “The buildings are more beautiful now so, we take better care”
- The air quality
- The renovation process

Summary

Summary of project

Three existing building blocks have been renovated with new facades, new windows, additional insulation on the roof, mechanical ventilation with heat recovery and a PV installation on the roof. The consultants succeeded in informing the tenants and presenting the project in detail to them well before the construction started. During the renovation process they were also good at informing and just talking with the tenants. The tenants showed great patience; probably because of the good information they had been given.

Traneparken has become a more attractive place to live and thus it will be easier to find tenants for the apartments. It is also expected that the tenants will take better care of their homes and the surroundings.

Experiences/lessons learned

It is important that the tenants get what they expect, so from the beginning it is necessary to spend a great deal of effort on making sure that the expectations are adjusted to what can be met in practice.

It takes longer time to plan and carry out a renovation than a new construction, mainly because the apartments are inhabited. The inhabitants/tenants have to be part of the decision process (tenants democracy is given by law in Denmark). The time schedule is important –the tenants need to know when something is going to happen in their dwelling.

It is cumbersome to carry out work in apartments, where people live – the individual craftsman need to be considerate. There are sometimes conditions in the individual dwellings, which are not known beforehand, so the project has to be adapted to these – and there has to be money enough for this flexibility. In this case there were sufficient financial room for particular considerations in the individual dwellings and to solve unexpected problems, what always occur in a renovation project.

The security at the building site has to be the very best – it has to take into account the tenants and especially children living at the building site. The consultants and the contractor succeeded at this in the Traneparken project.

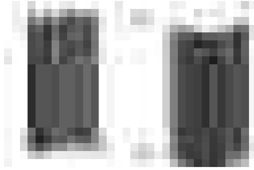
190 mm insulation plus exterior solid standard bricks. Energy windows – aluminium – wood, 3-layer energy glass. In the panel walls: 285 mm insulation plus exterior solid standard bricks.

References

[1] Notat, Martin Nørmarkve

[2] Helhedsplan for Traneparken, Hvalsø Boligselskab

8. Ca' S. Orsola, Treviso



Project summary

Energy concept: Insulation, mechanical ventilation, solar thermal and PV-system

Background for the renovation:

The building was partly inhabited and used as a guesthouse of the convent of Order of St. Ursula and it was abandoned from 2000; It reached a serious state of degradation and a high renovation was needed, but there was a heritage architectural restriction about the external envelope.

Specific goal of project were:

- to achieve A class energy classification according to Italian regulations;
- to consolidate and to reinforce the building structure;
- to improve the indoor thermal and acoustic quality;
- to transform it in a prestigious residence with all comforts.

Site:	**Treviso, Italy**
Altitude:	15 m
Heating degree days:	2378
Cooling degree days:	0
Owner:	Cazzaro Costruzioni S.r.l.
Architect:	Imago Design - Domenico Rocco
Engineer:	Systems - Vincenzo Conte Structures - Giovanni Crozzolin

General view of the building before (left) and after (right) the intervention

Contact Person:	**Mauro Cazzaro**
Previous renovations:	1923 and 1950
Renovation started:	2008
Renovation ended:	2012
Data collection:	October 2014

Building description / typology

Listed building located in Treviso, It was the old seat of a Polish Institute

Total site area: 4500 m^2

Gross heated area: 1800 m^2

Gross volume: 6300 m^3

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

Ca' S. Orsola is located in the historic centre of Treviso, in North East of Italy, very close to the Cathedral. The building was the old seat of Polish Institute and now it is a listed building by Historical and Architectural Heritage Superintendence of Veneto.

Originally it was a convent and it was inhabited until 2000 and during the time it keep intact the original structure and architectural distribution. Then it was bought in 2007 for acting a deeply renovation and converting it in a prestigious residential building. At the beginning of construction phase the structure revealed a quite ruined state of conservation: walls are crooked and presented different solutions, moisture affected wooden elements in the floors and in the roof.

Building envelope

The construction system was based on bearing masonry with covered solid bricks. The floor had a wooden structure, while the ground floor leaned directly on soil. The roof is made of hollow tiles sheets with a wooden structure and a lightweight ceiling slab. The windows frames were made of wood and the windows used to have a single glass. There is no insulation in the external walls, roof and floors.

Heating, ventilation, cooling and lighting systems

In the building heating or cooling system was not installed. Heating was provided by a fireplace, also used for cooking, occasionally an electric heater or portable fan coils was placed in any room.

The domestic hot water was supplied by electric heaters with storage tank; there wasn't a ventilation system, so ventilation was made by natural means.

Element	Area m²	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade	1300	0.90	0.18
Ceiling	508	1.65	0.79
Windows doors	140	2.70	1.95-2.04
Roof	508	1.09	0.16

Crooked walls, before renovation

Demolished partition walls left and used as a substrate

Energy renovation features

Energy saving concept

The restructuring aims not only to heal a property that was under the limit of sustainability from the structural point of view, but especially to retrain in terms of energy and acoustic complex.

Technologies

The A energy class has been achieved by means of several design topics among which:

- high insulated windows
- high level of opaque walls insulation
- mechanical ventilation system with heat recovery
- solar thermal panels and PV systems
- water to water heat pumps and chillers

Building

The first step has been the measures taken to consolidate the building structure. Subsequently a detailed study on thermal and acoustic bridges has been developed with the aim to improve the indoor thermal and acoustic quality.

- Walls: the insulation is placed on the inner part of the wall and this solution meet the requirements of the Superintendent preserving the existing materials and the external architectural identity of the building. Specifically, two types of insulating are used: an expanded polystyrene (EPS) foam, placed directly on masonry, and a rigid Rockwool panel with a plasterboard cover;
- Roof: it was replaced with a new wooden structure and it was insulated with wood fibber and water tight covering;
- Windows: all existing windows are replaced with a low-energy double layer ones within wooden frames.

Technical systems

The HVAC generation system is a water to water centralized heat pump/chiller. The underlying well is the hot/cold water source and internal comfort is achieved exploiting a radiant system installed in the floor together with a dehumidification system for the summer period.

Systems

- Heating and Cooling: 32 kW heat pump and distribution with radiant floor system;
- DHW: 20 kW heat pump;
- Ventilation: mechanical ventilation system with heat recovery box with 95% efficiency.

Renewable energy systems

- Thermal solar panels for DHW production (20 m^2) installed in vertical;
- Photovoltaic power plant producing 3230 kWh of total annual energy. The panels are installed on the roof and oriented to the south.

Radiant system

Achieved energy savings, CO_2 reductions and Costs

Energy need		Before renovation	After renovation	Saving
Heating	*kWh/m²a*	342.7	42.3	88%
DHW	*kWh/m²a*	44.4	33.6	24%
Total	*kWh/m²a*	387.1	75.9	80%
Energy label		G	A+	
Carbon emissions	*kg CO_2Eq/m^2a*	29.8	5.8	81%

Energy savings and CO_2 reduction

Before renovation there wasn't non-renewable energy consumption, so values for calculated energy needs are presented and provide comparable thermal comfort conditions.

Value for DHW needs already includes the solar thermal contribution.

Photovoltaic system - TNT under flooring above systems

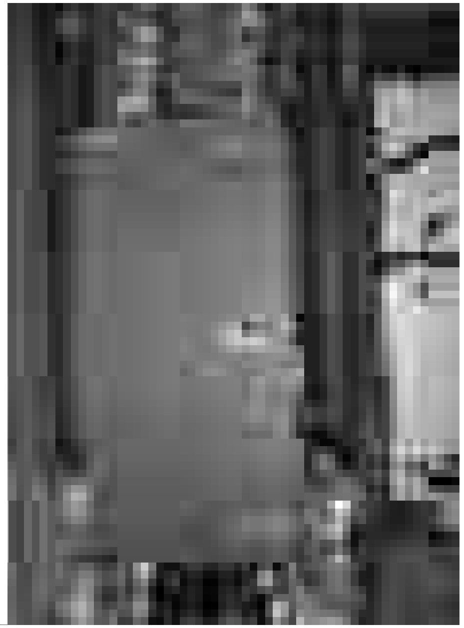
Costs	EUR	EUR/m2
Craftsmen	2.94 M€	1463.41 €/m²
Consultants	130000 €	64.71 €/m²
Electrical and Plumbing	700000 €	348.43 €/m²
Total construction	3.77 M€	1876.56 €/m²
Thermal solar and PV system	32000 €	15.92€/m²
NPV	13 Years	

Renovation costs

Construction cost excludes the costs for heating and DHW, the costs related to the purchase of the area, charges, interest, taxes.

RES contribution

PV energy contribution: *3680 kWh a*



Mechanical ventilation system

Overall improvements

Energy benefits

Energy savings: 311.2 kWh/m^{2}a (heating, DHW, ventilation)

Indoor climate technical improvements

The indoor climate was improved due to:

– Mechanical balanced ventilation with heat recovery and a carefully adjusted supply temperature;

– Reduction of losses through walls, roof and windows;

– Reduction of the thermal bridges allowing to eliminate related condensation problems;

– Upgrade of the building energy performance. The standard energy performance for new buildings in Italy has been achieved;

– Control of indoor temperature and humidity without relevant energy costs.

Economics

Renovation of existing buildings, especially if listed, is too much expensive than standard, because it need specialized operations and the preliminary count evaluation is upset during the construction phase. After intervention, however, market value increased for this property and also for the surrounding area: all apartments have been sold by the end of the construction phase.

Decision process – barriers overcome

The investment costs were incurred by the contractor, that is also the owner: in this particular situation themes such as sustainability and energy retrofitting were understood and applied; the major barrier was essentially related with the bureaucracy for obtaining the permission by Historical and Architectural Heritage Superintendence of Veneto.

Co-benefits

– Radical renovation that transformed a historic building in a prestigious and comfortable residence;

– Better living conditions with more qualified living spaces;

– Improved structural conditions in an uninhabited and listed building by implementing a seismic consolidation;

– Reached acoustic first class according to national standard UNI 11367 that ensures privacy to the occupants;

– Aesthetical improvement returning the identity of the original building and increasing the market value;

Typical living room in a dwelling

Summary

In Treviso, Ca' S.Orsola is a listed building completely renovated and converted into a residential building, with offices and shops at floor plan and dwellings above.
Renovation aimed not only to restore the structure, but also to redevelop the energetic and acoustic situation. The building is equipped with a seismic structure, and each unit is certified in Class A: using low energy glasses, creating a thermal insulation of important thickness and a mechanical ventilation system with heat recovery, integrating solar panels for DHW and heating are main themes for achieving the certification. Living comfort is assured through the use of interior materials with low harmfulness, underfloor heating and cooling with humidity control. Renovation measures decreased global energy consumption, reducing up to 90%; solar and photovoltaic system contributed to minimized energy consumption.
A prestigious location, a renovated historic building with the most innovative technical solutions made a safe and long-lasting investment.

Courtyard from west perspective

Acknowledgements

Special thanks belong to:

– ***Cazzaro Costruzioni Staff*** *for interest in collaboration on this project*

– ***Ing. Vincenzo Conte*** *for sharing the necessary data about heating system*

– ***Apartament inhabitants*** *for cooperation during in-situ inspections and interviews*

Main entrance to the building from via Riccati.

References

[1] http://www.cazzarocostruzioni.it/

[2] CASA&CLIMA, n.47, "Storico, antisismico e in Classe A", pg. 36-44, Quine Business Publisher Edition

9. Ranica, Bergamo

Project summary

Energy concept: envelope insulation, shading devices, heating systems, mechanical ventilation, renewable energy

Background for the renovation:

The intention of the owner, which was also the designer, was to refurbish his house, also addressing energy efficiency measures in order to drastically reduce energy consumptions. The provided ones have concerned:

- envelope improvement;
- new heating and DHW systems;
- mechanical ventilation system with heat recovery and geothermal pre-heat;
- renewables.

Site:	**Via Trento, 12 - 240200 Ranica, BG, Italy**
Altitude:	290 m
Heating degree days:	2486 October 15th-April 15th
Cooling degree days:	-
Owner:	Giuseppe Tebaldi
Architect:	none
Engineer	Giuseppe Tebaldi

View of the building before (small picture) and after renovation (large picture).

Building description / typology:

— Detached single family house

— One floor over a basement (+ 2nd floor after renovation)

— Initial energy class: G (the worst based on Italian regulation)

— Gross heated floor area (after): 329 m^2

— Gross heated volume (after): 1153 m^3

Contact Person:	Giuseppe Tebaldi
Renovation started:	2006
Renovation ended:	2008
Data collection:	2014

Building envelope and HVAC before the energy renovation

The house, is located in Ranica, a small village in the northern area of Italy. It has been built in Sixties. Before renovation, it consisted of only one heated floor over the basement (with garage, cellars etc.).

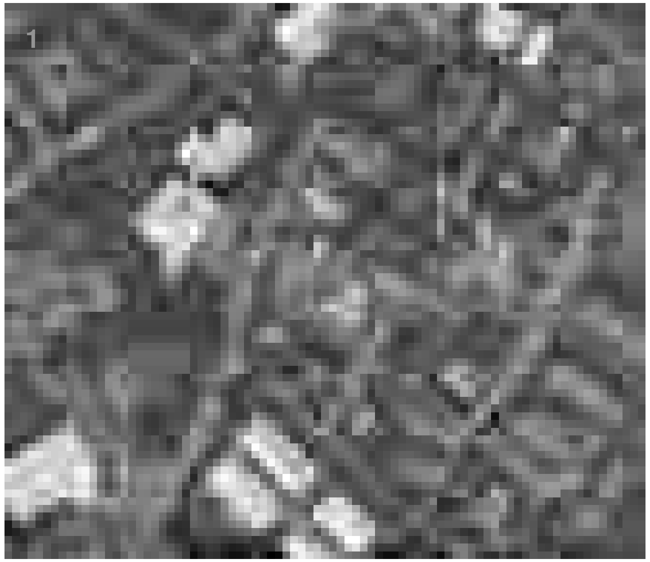
Building envelope

The vertical envelope was uninsulated, made of hollow bricks and plaster. Pitched roof with tiles was placed over a slightly insulated horizontal clay concrete slab creating an unheated loft. Windows were double glazing with aluminium frame.

HVAC before retrofit

Conventional gas heating system with radiators were installed. No mechanical ventilation and cooling system were.

Element	Area after renovation m²	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade	330	1.1	0.16-0.17
1st heated floor	160	1.25	0.17-0.28
Windows	40	3.7	1.1
Roof	160	0.7 (pitched + horiz. slabs)	0.14-0.18

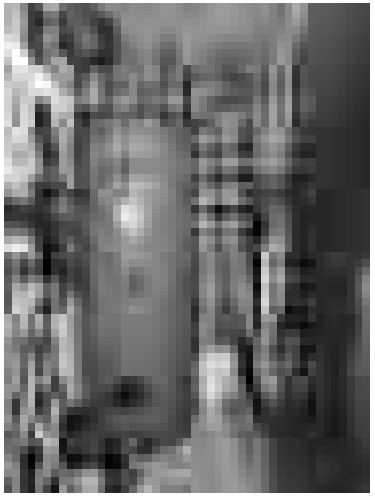


1.Satellite image of the building context;
2.View of the building before renovation;
3.External walls insulation for renovation;
4.New three-glazed windows after renovation.

Energy renovation measures

Building
In order to reduce the house energy demand, the following measures have been provided:

- external insulation of walls;
- insulation of new roof and terrace;
- insulation of first heated floor;
- insulation of dumpsters;
- thermal bridge correction;
- installation of three-glazed low emissivity windows, with argon, having a PVC frame.



Storage tank.

Distribution section of mechanical ventilation system.

Plants
Building systems, after renovation, are:
- a wood stove for both space heating and DHW;
- a condensing boiler (as back-up for the wood stove);
- radiant floor panels water-based;
- mechanical ventilation system with heat recovery and geothermal pre-heat.

Energy from renewable sources
The following systems have been installed:
- solar thermal system with flat plate collectors,
- photovoltaic system.

Solar and photovoltaic panels.

System	Characteristics
Wood stove	21 kW
Condensing boiler	18 kW
Mechanical ventilation system	320 W – 85% nominal efficiency
Solar system	7.5 m^2 – 600 l tank
Photovoltaic system	4.2 kWp

Calculated Energy Savings and Costs

Calculated energy demand and savings for space heating:

Demand before renovation:	275.0 kWh/m^2_{year}
Demand after renovation:	13.3 kWh/m^2_{year}
Saving after renovation:	261.7 kWh/m^2_{year}

Cost of energy efficiency measures:

Envelope improvement	k€ 53
New thermal systems	k€ 18
Total	**k€ 71**

Energy demand for space heating reduction

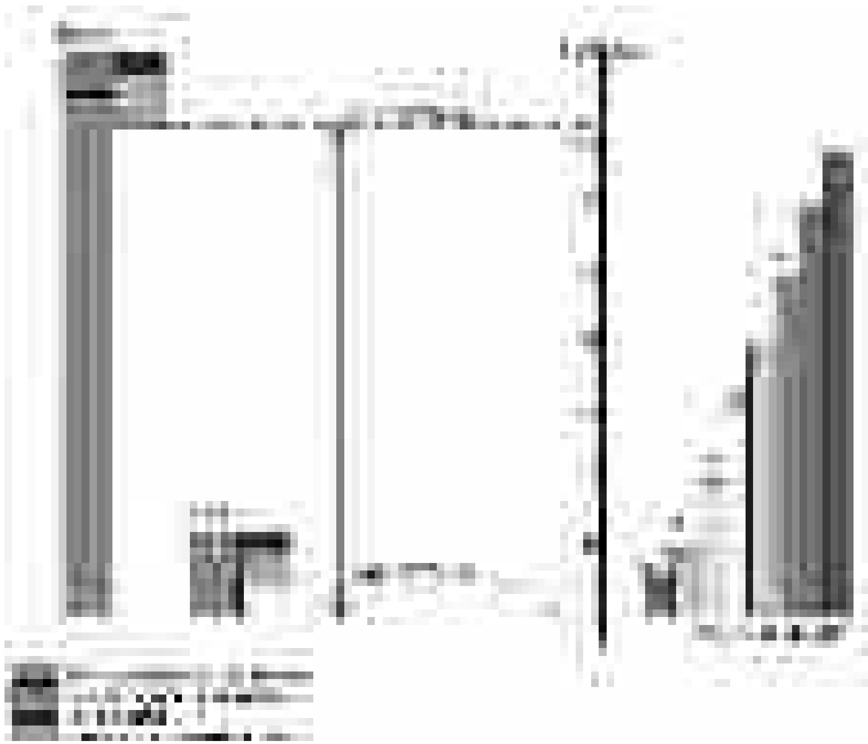
Thanks to the retrofit measures, the energy demand reduction exceeds 90% and the National energy classification passed from the worst one G to the best one A+.

Solar energy production

The solar thermal contribution is 6.5 kWh/m^2_{year} while the photovoltaic one is 14.0 kWh/m^2_{year}.

NPV

The renovation cost has benefitted from National tax deductions (equal to 55% of investment) and the resulting payback time is 7 years (without incentive 15 years).



Energy demand before and after the renovation [kWh/m^2_{year}]

View of the building after renovation.

Overall improvements

Energy

- Annual thermal energy saving equals 261.7 kWh/m^2_{year} so the percentage of heating demand reduction is about 95%; the National energy classification passed by G class to A+ class;
- renewable energy sources widely provide DHW and electric need, contributing also to the space heating.

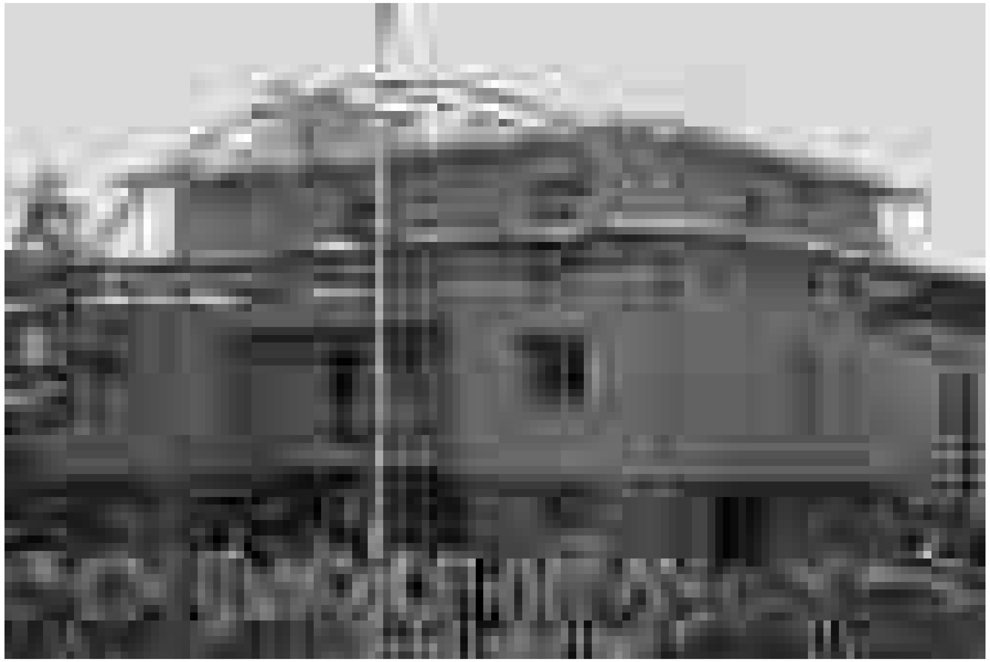
Economics

The refurbishment has purposed ambitious energy measures which have overdone the National minimum requirements with a resulting extra-cost. Nevertheless, reduction in thermal energy demand due to overall interventions (envelope and systems) would have allowed returning the investment cost within 15 years while benefitting from tax deductions has broadly shorten the pay-back time to 7 years. Moreover, thanks to the renovation, the estate value has increased with evident advantages in building market possibilities.

Co-benefits

The redesign of the house, implying the addition of a floor for providing also a professional office for the owner, has been the opportunity to overall renovate the building. Beside the improvement of the energy performances, several benefits have been provided: improved Mean Radiant Temperature, due to the radiant floor and the highly insulated envelope (which also influences the acoustic features), improved IAQ, due to the mechanical ventilation system, improved control of delight and of comfort mitigation in summer, due to the new shading devices, and achieved water savings, due to the installation of a rainwater recovery system for garden irrigation .

New shading devices.



View of the building during renovation.

Summary

Summary of project

The described building is a detached single family house located in a small village in northern Italy (2486 heating degree days). Before retrofitting, it was built with an uninsulated envelope and had old thermal systems. Starting from an overall architectural building renovation, the owner/designer intended to address also energy efficiency measures in order to reduce energy consumptions and related costs. Adopted energy efficiency measures regarded: envelope insulation, windows replacement, installation of wood stove, condensing boiler, radiant floor, solar thermal and photovoltaic systems.

Experience/lessons learned

Interesting results are provided by the overall building refurbishment, which involves envelope improvement, new thermal systems and renewable energy use. High energy and costs annual savings have been reached through this intervention, allowing profitable pay-back time despite the quite relevant investment cost. Furthermore, the approach adopted for this refurbishment, based on the owner will, implied that any barriers to the process could not be observed, also considering that owner and designer coincide.

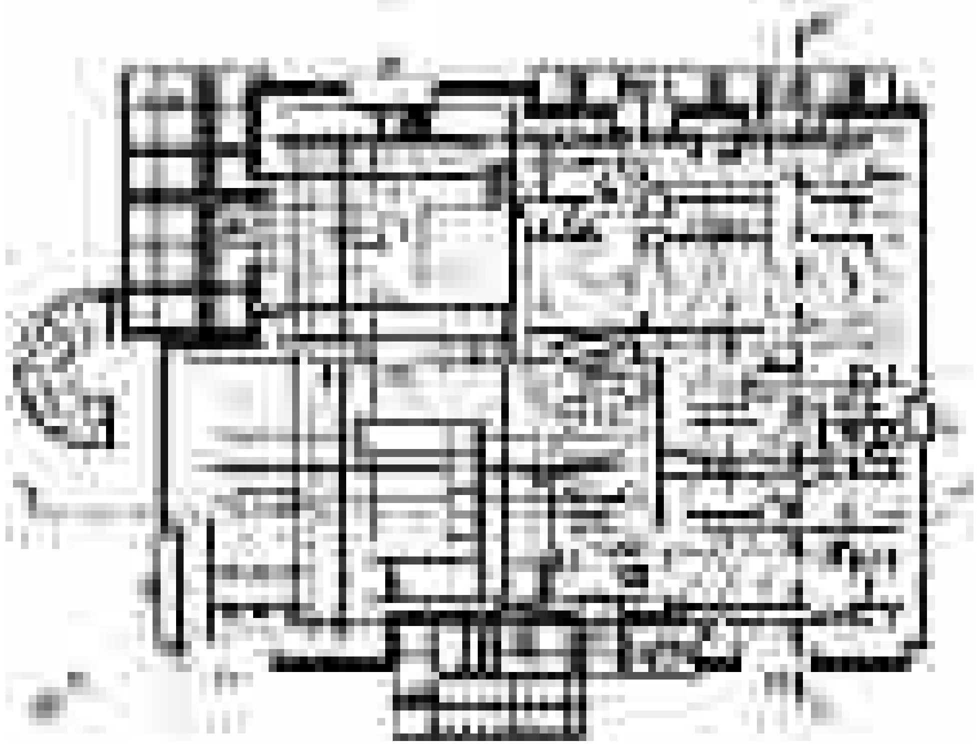
Acknowledgments

- A. Galante, Politecnico di Milano, for having shared the information on the case study.
- G. Tebaldi, owner and designer, for having provided calculated data and images.

Reference:

http://www.studiotebaldi.eu

Facade of the building.



Plan of the first floor of the building.

10. Wijk van Morgen, Kerkrade

Project summary

Energy concept: Passive House standard, balanced mechanical ventilation with high efficiency heat recovery, high efficiency condensing boiler, roof integrated PV and solar thermal collector.

Background for the renovation:

The project consists of 153 social-rental dwellings, built in 1974, that have been renovated to Passive House standard. As a precondition the renovation has taken a mere 8 working days per house, due to replacement of the facades and roof by complete, pre-manufactured elements.

Solar energy plays an important role, in particular photovoltaics and solar thermal energy

Site:	Wijk van Morgen, Kerkrade Hagendorenstraat 2 NL 6460 AC Kerkrade
Owner:	HEEMwonen Erpostraat 1 NL 6460 AC Kerkrade
Architect:	Teeken Beckers Architecten bv Hagendorenstraat 2 NL 6436 CS Amstenrade
Engineer	WSM Heythuysen

Contact Person:	Maurice Vincken, HEEMwonen
Renovation started:	2012
Renovation ended:	2013
Data collection:	Autumn 2013

Building description /typology

- Built 1974
- 70 apartments (two storeys)
- 83 single-family houses

Renovated dwellings

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

The houses are located in Kerkrade, a city at the Dutch-German border near Maastricht. They were built in 1974 as social rental houses, of which 70 apartments and 83 one-family houses. The party walls are load-bearing brickwork, the floors are concrete slab floors.

The houses during renovation – roof instalation

Heating, ventilation, cooling and lighting systems

Also aspects of building technology, long-term maintenance, improvement of the living environment, and sustainability were taken into consideration when making the plans. In addition, the tenants were supposed to continue their livings in the house during the renovation. Consequently, a renovation technology was developed based on full replacement of the roof and façade elements by brand new, prefabricated elements, the roof elements having the solar photovoltaic and thermal systems integrated.

The houses during renovation – facade instalation

Building envelope

In the not renovated situation, the building envelope consists of two façade elements made of wood. The windows have single panes; there is no insulation and the houses have an individual gas fired central heating system. As the energy demand was high, but the basic construction and floor plans of the houses were quite sufficient, it was decided to renovate the houses to such a level that the social, economical and technical lifetime was extended with an additional 40 years.

The houses before renovation

Energy renovation features

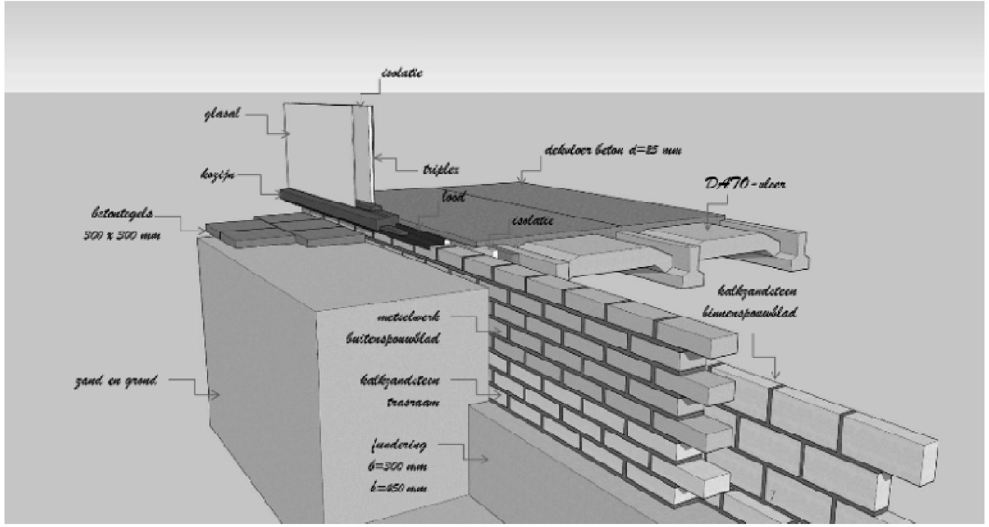
Energy saving concept

The building shell has been improved to passive house standard. The images at the right show the original construction of the walls, ground floor and foundation (before renovation) and the construction as it is after renovation.

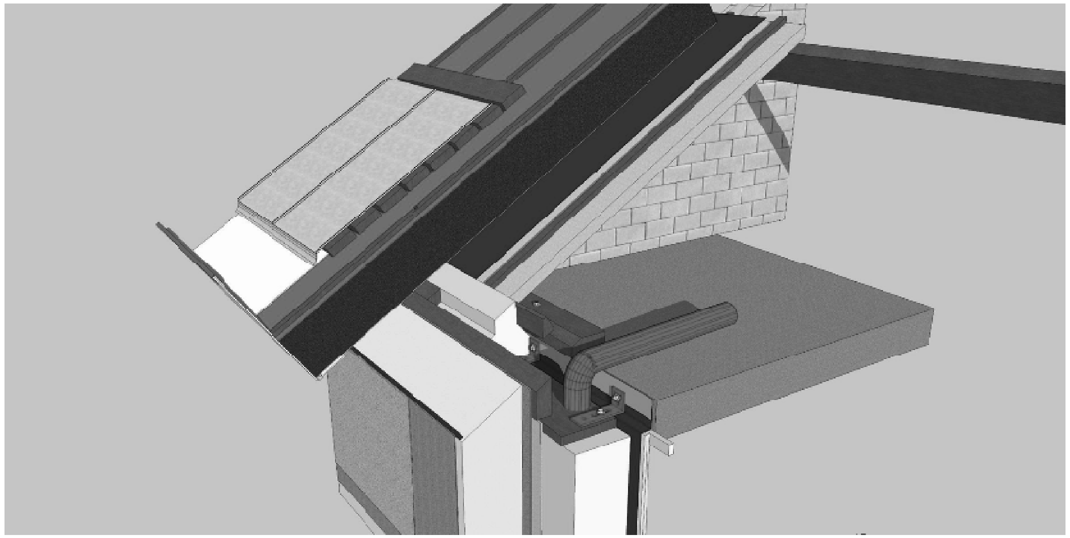
As usual with passive houses and passive house renovations, the houses have a balanced mechanical ventilation system with high efficiency heat recovery.

Space heating and domestic hot water are provided by a high efficiency condensing boiler and a solar thermal collector.

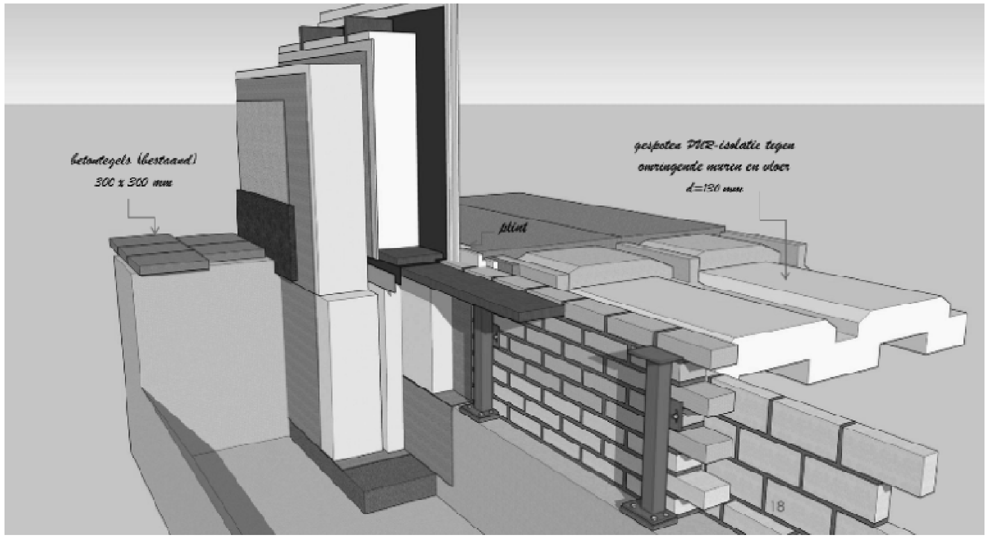
The houses have been provided with new roof elements, including prefab integrated solar collectors and photovoltaic modules.



Wall-floor construction, before renovation



Roof-upper floor construction after renovation to passive house standard



Wall-floor construction after renovation to passive house standard

Achieved Energy Savings, CO_2 reductions and Costs

Energy and cost savings from the renovation

Energy savings costs per Month:

Natural Gas:	€ 53
Electricity:	€ 48
Total savings:	€ 101

Rent increase per month:

Renovation:	€ 40
Solar system:	€ 24
Total:	€ 64

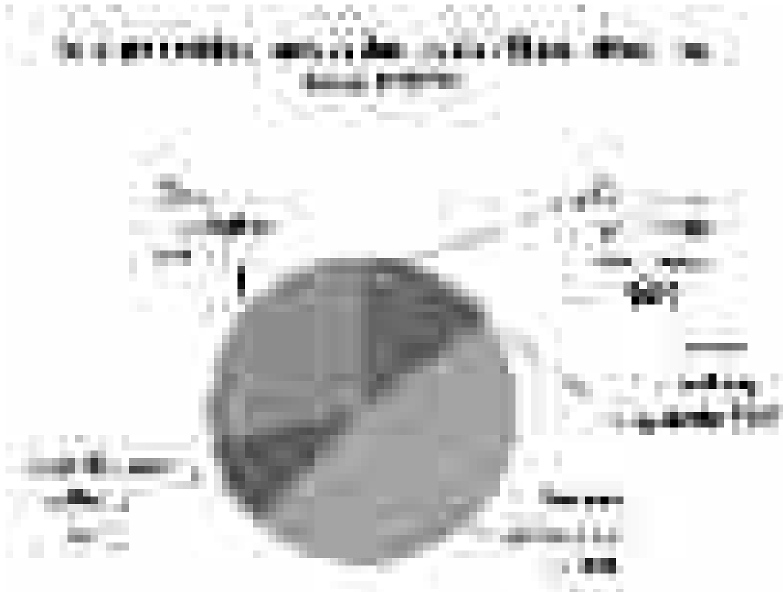
Net economical savings for the tenants per month:

Total:	€ 37

Building after renovation

Renovation costs

Energy related renovation costs per dwelling	
Ventilation with heat recovery	€ 4000
Central heating system	€ 2400
Thermal insulation	€ 20000
Solar thermal collector	€ 4200
Solar photovoltaics	€ 12100
Total	€ 42700



Overall improvements, experiences and lessons learned

The main goal of the renovation was to improve the energy standard of the house in such a way, that the living costs of the tenants do not increase, whilst the comfort and energy consumption of the house should be brought to the passive house standard, whereas the remaining "life time" of the houses should be extended to another fifty years. Furthermore, the inconveniences for the tenant during the renovation process should be as least as possible. Consequently, a concept has been developed for carrying out the renovation in a mere eight working days, with two extra days for cleaning up the building site. This concept has proven to be feasible.

Site plan

Economic consequences for the tenants

After renovation, the (calculated) net profit for the tenant should be € 37 per month (of course depending on the individual household energy consumption).

Lessons learned:

- success of the project is very much depending on the full support by the tenants and by the board of the housing association
- Participants in the process should learn to leave the common, well-known solutions and to think "out of the box" for new solutions of the problems.
- The project ambitions must be high and should not be weakened during the process.

Co-benefits

- The housing association has considerably enlarged the economical and technical “life time” of the housing complex
- The tenants have the advantage of lower living costs in a more comfortable house, as the savings on energy costs are higher than the rent increase
- The overall status of the area has improved.

Summary

Summary of project

The project consists of 153 social-rental dwellings, built in 1974, that have been renovated to Passive House standard. As a precondition the renovation has taken a mere 8 working days per house, due to replacement of the façades and roof by complete, pre-manufactured elements.
Solar energy plays an important role, in particular photovoltaics and solar thermal energy.

Figure: The houses after completion

Acknowledgements

HEEMWonen, Kerkrade
Platform31, Den Haag
EnergyGO, Alkmaar
BAM Woningbouw, Bunnik

References

[1] www.westwint.nl
[2] www.bamwoningbouw.nl
[3] www.energiesprong.nl

11. Lugar de Pontes, Melgaço

Project summary

Energy concept: The abandoned house needed to be thoroughly renovated in order to become liveable again. Taking advantage of recent growth in tourism activities all over the surroundings, the renovated building will be used for sustainable tourism activities.

Background for renovation:

During the renovation works it will be subjected to:

- Structural renovation and reinforcement (wooden and stone structures)
- Energy efficiency measures in the envelope (insulation of walls, roof, windows, doors)
- Recovery of housing conditions (present state is not habitable)
- Installation of efficient energy systems (space heating and domestic hot water)

Country house before intervention (south east and southwest facades)

Site:	**Lugar de Pontes Castro Laboreiro, Melgaço**
Altitude:	726 m
Heating degree days:	2770 (base temp. 20º C)
Owner:	Carlos Moedas
Architect:	Inês Cabral
Engineer	André Coelho Ecoperfil, Sistemas Urbanos Sustentáveis, Lda.

Contact Person:	**André Coelho**
Renovation started:	Not started
Renovation ended:	Not started
Data collection:	Winter 2014

Building description /typology

- Located in a small rural village in the hills of Peneda in the northwest of Portugal
- Individual vernacular stone (granite) wall house
- Originally built in 1940
- Currently inhabitable, almost in ruins
- Gross heated area: 180 m^2

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

The Pontes country house shares the patio with the commune stove and was bought in 2012 for sustainable tourism activities and aims at providing accommodation with sustainability principles (optimal use of environmental resources; respect and interaction with the host communities; viable, long-term economic operations, providing socio-economic benefits to all stakeholders that are fairly distributed). Its original state was almost a ruin, severely degraded in its wooden elements, lacking windows in some places, and affected by rot and moisture. Inside temperatures closely followed exterior variations, and frequent chilled air drafts. Moisture deterioration was present in wood structures, both in floors and roof, and also through seepage and/or condensation on walls.

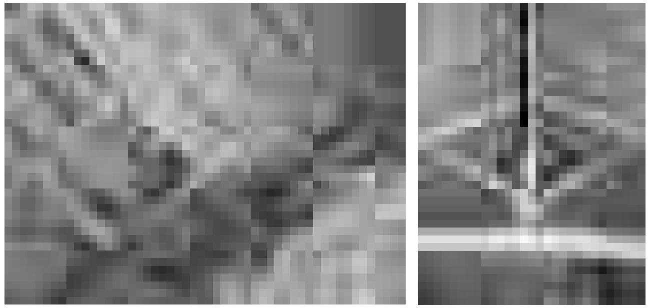
Building envelope

Uninsulated granite stone walls (without coverings), wood structure floors and roof (not insulated), ground floor in direct contact with soil (animal shelter), single glazed windows with wooden and frames (degraded). Original stone walls were massive but loosely arranged in some areas (need of structural reinforcement)

Heating, ventilation, cooling and lighting systems

The house was not serviced by running water, electricity or phone access. Heating was provided by a fireplace, also used for cooking. The house was not served by any support system, including lighting, water supply and sewerage. Renovation potential was at its maximum, in order to gain comfortable living conditions.

The building has a strong architectural image, very much linked with the region's traditional life style and architecture, but without suitable comfort conditions it will not attract visitors. The global intention of the renovation is therefore to provide that comfort, at a minimum energy and resource expenditure, according to construction sustainability principles, while maintaining the building's identity and historical features.



Roof condition and characteristics

North elevation

Element	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Exterior walls	1.82	0.45 (average)
Ground floor	Direct contact with soil	0.5 (average)
Doors	2.7	0.81
Windows	4.6	2.05
Roof	4.55	0.23

Energy renovation features

Energy saving concept

The main principles of the energy saving concept were limiting the heat losses during winter, use energy efficient heating equipment and take advantage of the sunlight to capture the thermal energy. Low embodied energy materials were preferred.

Technologies

- Building insulation
- Windows replacement
- Balanced mechanical ventilation with heat recovery and free cooling
- Geothermal heat-pump
- Efficient lighting
- Thermal solar panels for domestic hot water (DHW)

Building

- Walls: creation of an interior closed air space, placement of insulating cork boards (ICB) and light covering elements (in general MDF boards over wood support). This solution allows maintaining the existing materials and avoids new construction while preserving the external architectural identity of the building.
- Roof: wooden false ceiling, creation of closed air space, structural oriented strand board (OSB), placement of ICB , water tight covering.
- Floor: ICB under floor slab
- Windows: replacement of all existing windows and placement of new double glazed ones with low emissivity layers, within wooden frames (4+16+6 mm).

Strategy	Impact / purpose
Reinforcing structural stone walls	Maintain structural elements, avoiding new construction (less environmental impact). Maintenance of historical features.
All interior and roof structures made of wood	Use of a local, low embodied energy material. Use of waste wood (MDF and OSB). Maintenance of historical features (although with new wood elements).
Creation of closed air spaces in walls and roof	Additional free insulation (air has good thermal resistance) and use of these spaces as service ducts, avoiding waste generation in infrastructure placement.
No ceramic bricks and no cement based mortars	Use of concrete bricks, which are less energy intensive than ceramic bricks, and use of lime based mortars (eliminating the energy intensive cement in used mortars)

Systems

- Heating: 16 kW geothermal heat pump (space heating and DHW) and heat distribution with radiators
- Cooling: Natural ventilation, free cooling and wooden shutters on windows
- Ventilation: Heat recovery box with 91% efficiency. Fresh air supply and exhaustion of all spaces.
- Lighting: Up to date fluorescent and LED based lighting

Renewable energy systems

- Thermal solar panels for DHW production (6.8m^2)

Energy Savings, CO_2 reductions and Costs

Energy needs [1]	Before renovation	After renovation
Heating needs	477.9 kWh/m².y	123.8 kWh/m².y
Cooling needs	12.1 kWh/m².y	10.4 kWh/m².y
DHW needs	54.8 kWh/m².y	13.5 kWh/m².y [2]
Energy label [3]	F	A+

[1] Only values for calculated energy needs are presented once the original condition of the building didn't had non-renewable energy consumption and wasn't able to provide comparable thermal comfort conditions.

[2] Value for DHW needs already includes the solar thermal contribution

[3] Buildings energy certification scheme in Portugal ranks the energy performance of each building from level G to level A+, being the first the less efficient. The higher level A+ means that the building calculated non-renewable primary energy consumption is under 25% of the maximum allowed value for new buildings.

Calculated energy needs reductions:

Heating energy needs reduction - 74.1%

Cooling energy needs reduction - 13.7%

DHW energy needs reduction – 75.4%

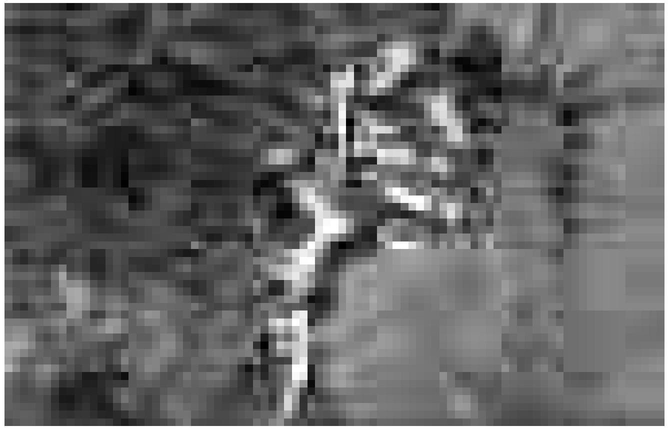
RES contribution:

Solar thermal energy contribution: 4.2 MWh/year

Overview economic efficiency and costs:

Total retrofit cost: 143 260 €

Total energy operation costs after renovation: 2160 €/year



Building context

Costs	EUR	EUR/m²
Craftsmen	135260 €	751 €/m²
Consultants	8000 €	44 €/m²
Total	143260 €	796 €/m²

Existing window sills

Overall improvements, experiences and lessons learned

Energy

Energy needs reduction for heating, cooling and DHW, compared to original state over 75%.

Energy Certification Scheme, label **A+** (less than 25% of the maximum calculated non-renewable primary energy consumption allowed for new buildings)

Indoor climate

Absence of drafts

Absence of condensation phenomena

Comfort all year round

Economics

Renovations, especially those carefully driven by sustainable construction principles, as this one, is always good for the local economy. Now, tourists enjoying nature can be housed there and enjoy comfortable conditions with minimum environmental impact. Tourism economic benefits may also be used to pursue more retrofitting of regional traditional houses.

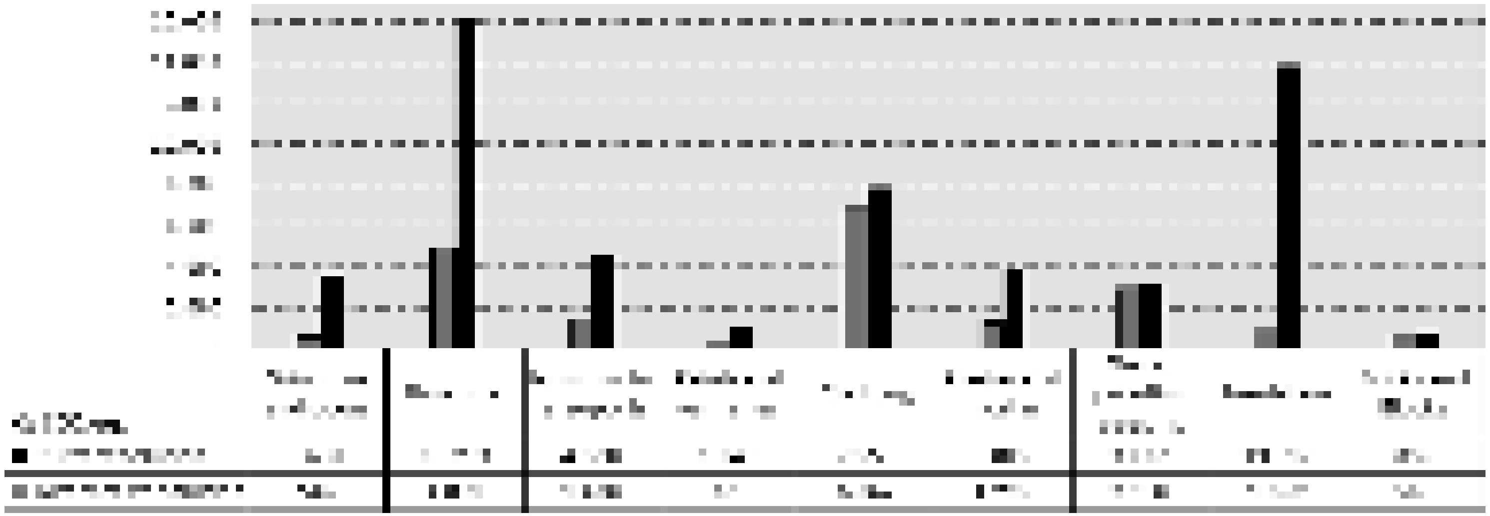
Decision process – barriers that were overcome

Barriers in this case were essentially related with the bureaucracy for obtaining the building permit and funding sources. The building permit from the municipality and national tourism entities is still a time consuming process that causes delays and doubts for the business plan. With respect to the investment costs, the building owners not always understood the unconventional nature of this renovation project, and therefore expected conventional costs as well, whether for the renovation works as for the consultants.

Co-benefits

Reuse of an abandoned traditional building, with preservation of its architectural value.

Development, in an economically depressed region, of tourism activities with sustainability principles (optimal use of environmental resources; respect and interaction with the local community; long-term economic operations providing fairly distributed socio-economic benefits to all stakeholders).



Embodied CO2 eq. amount for current and alternative material selection

Summary

An existing traditional country house, located in Pontes village, in Castro Laboreiro, Melgaço, is being renovated from a ruined condition. Its non insulated and deteriorated present condition would lead to very high energy consumption, if occupied.

The present renovation project was elaborated aiming the architectural preservation, the low environmental impact and the offer of suitable comfort conditions for tourism exploitation. Global energy consumption reduction can be as high as 94% when compared to the hypothetical use of the building at its present state, which could mean almost 6000€/year of potential savings.

The right kind of message is put forward to other possible regional initiatives as sustainability and nature protection are the core drivers of this project.

Acknowledgements

Inês Cabral – Architect and project coordinator. Deep knowledge of regional construction characteristics and sustainability in construction.

André Coelho – Civil engineer and energy in buildings specialist. Responsible for the thermal/energy analysis of the house, and its HVAC systems. Structural design and engineering disciplines coordination.

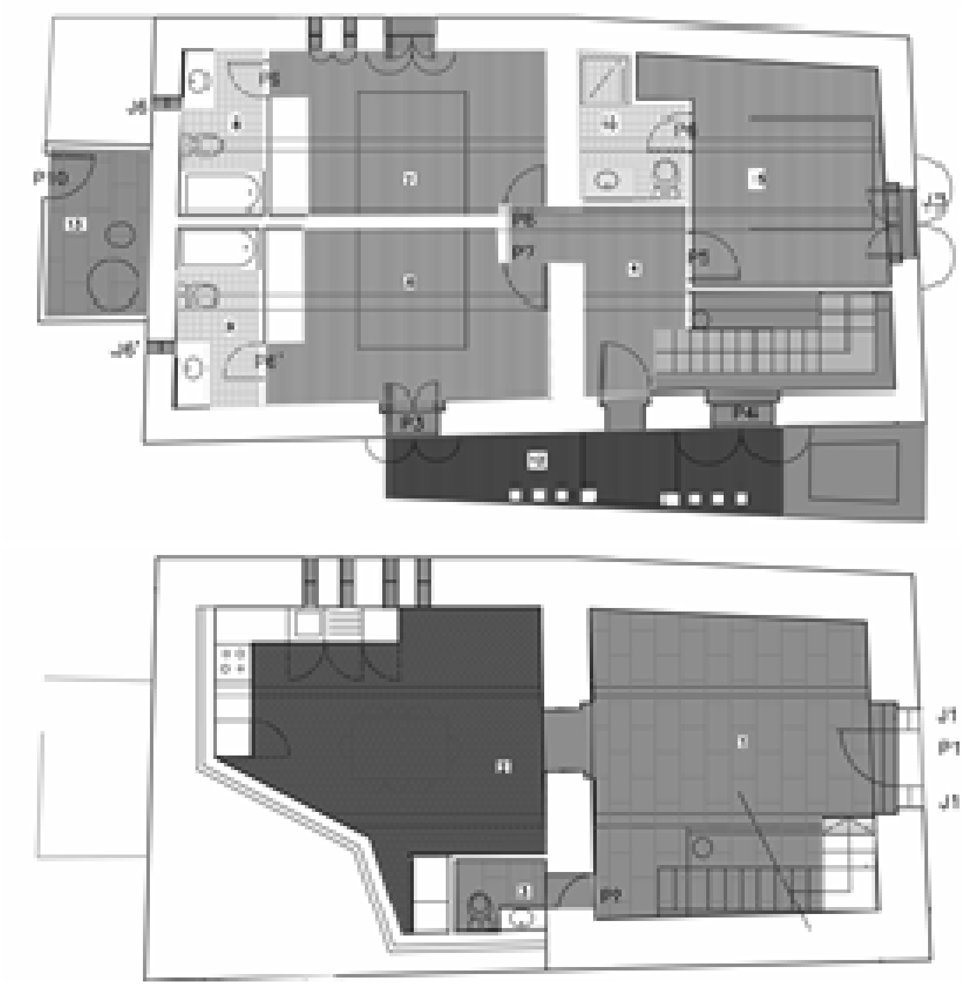
Gonçalo Machado – Architect, energy in buildings consultant and specification of materials specialist. Responsible for the materials environmental impact analysis.

Ecoperfil engineers, for this project – André Batoréu (water supply and waste water drainage), Luís Rato (electricity and telecommunications), Rodrigo Castro (acoustic design)

References

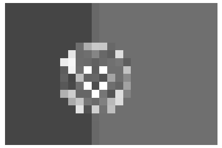
[1] – Cabral I., Coelho A., Gonçalo M., 2013. Assessing energetic self-sufficiency and low environmental impacts in protected areas with rehabilitation needs: Pontes Village case study. Proceedings of CIAV Conference 2013, Vila Nova de Cerveira

[2] – Project for Casa de Campo, municipal reference 2048/2013 (Câmara Municipal de Melgaço)



Lower and upper architecture plans of the retrofitted house

12. Travessa de Montarroio, Coimbra



Project summary:

Energy concept: This project assumes that well designed and constructed buildings were able to provide comfort to their users in a time when fossil fuels were not easily available. “Learning from Traditional Knowledge towards Engaged Inhabiting” (Brito et al., 2014), it is proposed that users and buildings are teams that must interact to better use the walls inertia and openings as “thermal wheels” to shift thermal loads. Acknowledging that contemporary occupation patterns vary, the building/user team is reunited using ICT management aid and **solar thermal panels to provide for 85%** of hot water and acclimatization needs.

A XIVth-XVIth century residential building will soon achieve the “nearly Zero Energy Building” (nZEB) standard, the minimum requirement for new buildings in 2020.

Background for the renovation:

An ancient residential building located in historical centre of Coimbra, recently recognized as UNESCO Heritage area, was studied (Brito et al., 2014) and intervention options proposed having in mind that:

- this almost derelict ancient residential building represents hundreds of similar homes in Coimbra and millions across Europe, that resisted to centuries of weather and use, and are now menaced by one-dimensional (energy efficiency) renovation perspectives;
- energy efficacy can only be achieved by multidimensional approaches based on a thorough assessment of what ancient building were designed to provide, and what is now required from them;
- renewable energy and ICT can bridge the gap between what we **have and know** / **want and expect** and uphold good comfort conditions and Quality of Life with minimum primary energy needs.

This study demonstrates that demolition /reconstruction strategies are too expensive, financially and environmentally, and that the best solutions for similar climates may also be the easiest to implement.

The collective insights from the commonly developed IEA EBC Annex 56 methodology together with findings from the ongoing Ph.D. thesis on “Upgrade Opportunities for ancient buildings in city centres” are used to visualize the options and emphasize **key topics for informed decision processes**.

Panorama view of the Montarroio case study and surroundings (source: author)

Site:	Travessa de Montarroio, 2, 3000-288 Coimbra, Portugal
Altitude:	50m
Heating degree days:	1287 Kd
Owner:	Nelson da Silva Brito
Architect:	modular, arq:i+d, lda

Contact Person:	Nelson da Silva Brito
Renovation started:	Not started
Renovation ended:	Not started
Data collection:	Winter 2015

Building description / typology

Ancient residential building located in Coimbra, Portugal, with strong restrictions imposed by its location facing “Jardim da Manga” National Monument, and the UNESCO protection area.

Total site area: 22 m^2

Useful heated area: 36 m^2, potential 46 m^2

Building envelope, heating, cooling, ventilation and lighting systems before the energy renovation

Description of building

The Montarroio street and its buildings are already reported in the XIVth century, while the higher level stone-embellished window and a chimney portray XVIth century exterior signs of comfort (Trindade, 2002). It still stands in the ancient city centre of Coimbra, within the UNESCO “University of Coimbra –Alta and Sofia” (UNESCO, 2013) and “Jardim da Manga” National Monument (Figure 2) protection areas.

Building envelope

Stacked masonry walls provide peripheral support to wooden floor levels and ceilings, under ceramic roof tiles on a wood structure.

Wood doors and simple glazing sash windows with interior shutters exist, with high infiltration due to lack of maintenance.

The walls’ thickness reduces towards the upper levels, with growing internal areas:

• 13.7m² (p00) in a semi-buried level with separate entrance,

• 15.3m² (p01) on the intermediate level and

• 20.7 m² on the top level (p02).

Only 36 m² are inhabitable, as level (p00) suffers from severe humidity issues.

Due to its location, energy efficiency improvement strategies are limited: street width and fire risk hamper exterior insulation approaches, while small useful areas make interior insulation inadequate and large size equipment's hard to conciliate.

Architectonic constraints impose limitations on solar panels and exterior heat pump units, aggravated by the noise risk from close proximity to the neighbours.

Heating, Cooling, DHW, Ventilation and Lighting systems

Like in all neighbouring buildings, heating is achieved using electric resistance heaters (erh) converting electricity into heat through Joule effect.

Due to the high inertia of the building, cooling in not needed on the original constructions, although more recent top level extensions may require cooling devices.

Domestic Hot Water (DHW) is provided by electric storage heaters or small scale gas-based devices, using bottled gas.

Incandescent lights are still around, but will progressively be changed to low consumption alternatives when replaced.

Like in all the neighbouring buildings, natural ventilation is the current solution, with occasional occurrence of bathroom extractors.

View from inside to “Jardim da Manga” National Monument

Element	Area m²	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade	56	2.04 (avg)	2.04 (avg)
Ceiling	21.1	1.57	0.44
Windows, doors	7.55	3.22	2.1
Lower floor	15.6	1.41	0.4

Energy renovation options and technologies

Energy saving options

The Montarroio Detailed Case Study (Brito, 2015a) compiles the evaluation of five alternatives for the renovation of ancient buildings in Historic Centres, including demolition and reconstruction. To compare a wide range of strategies and renovation perspectives, some of the studied options are briefly described:

- **Opt.0_*_Reference Case**: The building “as it is”, with non-energy renovation works necessary to render it inhabitable (see Anyway Measures), including the necessary equipment maintenance and/or replacement;

- **Opt.1_*_Common “rehabilitation”**: Current neighbourhood practices include double glazing windows, interior insulation under plasterboard (hiding decay), and equipment maintenance and/or replacement;

- **Opt.2_*_Demolition & Reconstruction**: Exterior shell/image kept, increased useful space and new construction techniques and compliance, and equipment maintenance and/or replacement;

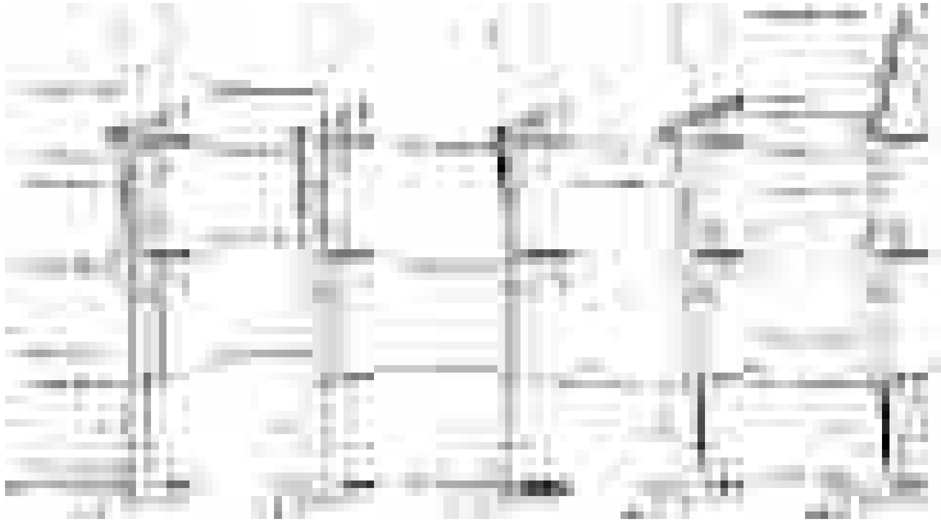
- **Opt.3_*_Upgrade without extension**: Detailed assessment to optimize the building characteristics to achieve efficacy with users. Single glazing kept, insulation only in top and bottom limits, thick walls used for thermal storage. Solar thermal heating and DHW require primary energy only for backup;

- **Opt.4_*_Upgrade with extension**: Structural seismic reinforcement of “Opt.3” made financially viable by upwards area extension (IEA-EBC Annex 50, 2011): safer users and investment, space for a small family and city centre densification.

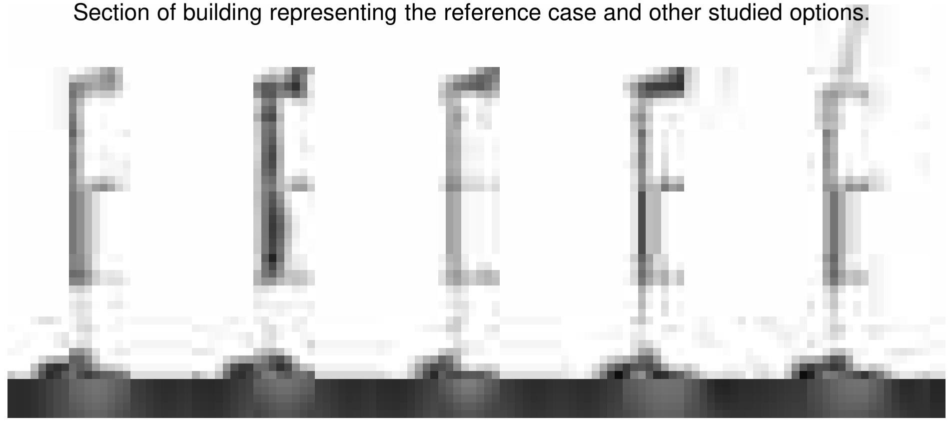
Building Integrated Technical Systems (BITS)options

A large number of equipment's and energy sources are available, but privilege was given to contrast commonly used solutions and available innovations. BITS options are denoted by suffix notations: ”**bio**” for biomass; ”**erh**” for electric resistance heater; ”**hp**” for heat pump; ”**gas**” for gas combustion; ”**st**” for solar thermal, and conjunctions like ”**st-erh**”, when backup is provided by electricity.

Graphical illustration of the presented renovation options



Section of building representing the reference case and other studied options.



Thermal behavior analysis of the intervention options above using THERM (LBNL, 2015). Notice that Opt.1 denotes severe thermal stress in the floor area and lower temperatures inside the walls that may result in frost damage in colder nights.

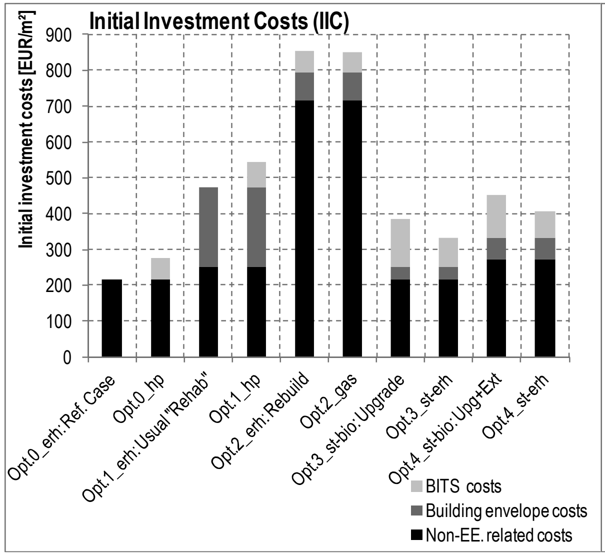
Initial investment costs and potential Energy Efficiency (EE) incentives assuming that heat pumps, solar panels and insulation investments are financed at 50% rate.

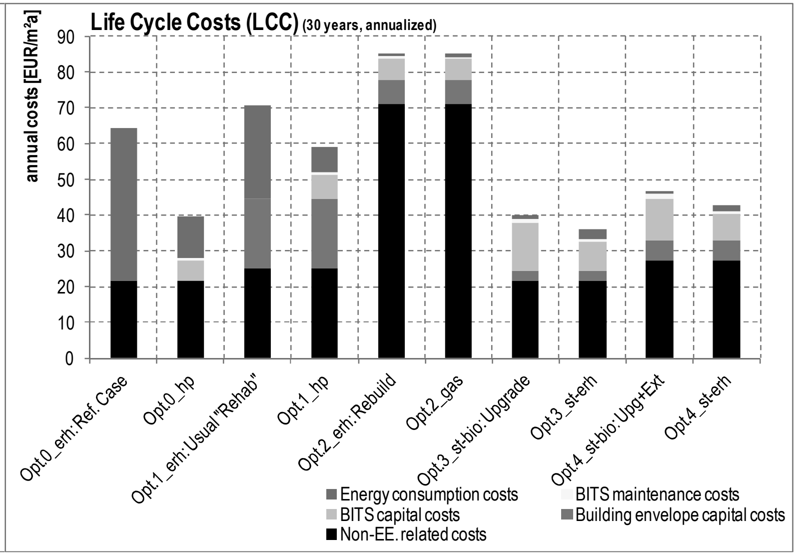
EE.Ren.Options:	**Opt.0**		**Opt.1**		**Opt.2**		**Opt.3**		**Opt.4**	
Equipment type:	_erh:	_hp:	_erh:	_hp:	_erh:	_hp:	_st-bio:	_st-erh:	_st-bio:	_st-erh:
Useful area	*36 m²*	*36 m²*	*31 m²*	*31 m²*	*63 m²*	*63 m²*	*36 m²*	*36 m²*	*46 m²*	*46 m²*
Non-EE.costs (€/y)	7 801	7 801	7 801	7 801	45 039	45 039	7 801	7 801	12 545	12 545
IIC_EE.Envel. (€/y)			6 906	6 906	4 957	4 957	1 188	1 188	2 733	2 733
IIC_EE.Equip (€/y)		2 120		2 120	1 874	3 719	4 840	2 975	5 490	3 475
%EE.OverCost/m²	**0%**	**27%**	**119%**	**150%**	**280%**	**293%**	**77%**	**53%**	**108%**	**88%**
Energy costs (€/y)	1 546	423	811	218	160	44	36	92	32	82
Yearly LCC (€/y)	2 321	1 642	2 192	2 042	5 724	5 735	1 924	1 591	2 686	2 314
EE. Payback (y)	**no ROI**	**2y**	**9y**	**7y**	**5y**	**6y**	**4y**	**3y**	**5y**	**4y**
50% EE. incentive?	no fund	1 060	3 453	4 513	3 415	4 338	3 014	2 082	4 112	3 104

Achieved energy savings, CO_2 reductions and Costs: informed choices

The graphs show the **Initial Investment Costs (IIC)** per square meter of renovation area, the value the owner pays upfront, and the **Life Cycle Costs (LCC)**, a value comprising the IIC, the equipments maintenance / replacement (each 15 years) and the energy costs during 30 years, divided by 30 to simulate as if it was paid annually: **LCC is a strong indicator of real costs of ownership and use**.

Comparing both graphs demonstrates that higher IIC in efficient equipment is, most of the times, favourable on the long term LCC. The reduction of primary energy consumption seems obvious by comparison, but other conclusions emerge when tackling the LCIA analysis, on Figure 6.





Initial Investment Costs and corresponding Life Cycle Costs for the reference case and other studied options. The "non-EE related costs" bar illustrates the investment needs that would occur anyway, even if Energy Efficiency was not considered. "Building envelope costs" quantifies all the costs on the exterior boundary, while BITS stands for Building integrated Systems to quantify ventilation and acclimatization equipments. More info in the Detailed Case Studies (IEA EBC Annex56 (Brito, 2015a).

Choosing options considering the **baseline scenario** (Ref.Case) **costs of 217 €/sqm**.

For a similar level of comfort the relevant energy-related renovation options are:

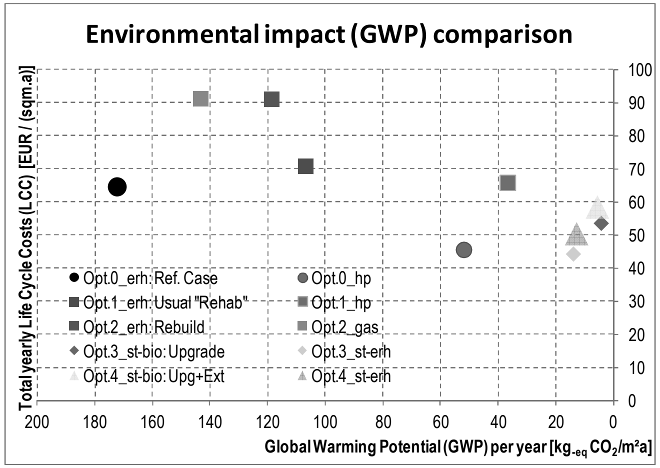
Opt.0_hp: small investment with heat pump for **relevant energy consumption reductions** (**276** €/sqm);

Opt.1_hp: higher investment with smaller energy consumption, but reduced useful areas (**474** €/sqm);

Opt.2_hp: significant energy reduction, but beyond the budget and a bad investment (**873** €/sqm);

Opt.3_st-erh: "**nearly Zero Energy Building**" (**nZEB**) level for a very low added cost (**332** €/sqm);

Opt.4_st-erh: more **useful area** and **nZEB level** are a **good investment** on that location (**408** €/sqm).



Environmental impacts comparison. The reference case (Opt.0_erh, black circle) illustrates the current situation. The less expensive solution (Opt.0_hp, grey circle) has significant impact, but does not reach nZEB levels.

Cross-comparing graphics:

It is interesting to observe each of the options in the three proposed graphs:

Initial investment Costs (IIC) gives a strong impression on the upfront investment;

Life Cycle Costs (LCC) illustrates real costs in a 30 year period that include costs like monthly bills, equipment maintenance and replacement;

Global Warming Potential (GWP) illustrates the overall long term impacts on environment.

Structural reinforcement study using Rhinoceros / Grasshopper interface (special thanks to Esteban Agüero)

Chosen option overall improvements

The owners preferred solution is "Opt.4_st-bio_Upgrade with extension", achieving "nearly Zero Energy Building" (nZEB) levels with very low energy consumption: this is not the least expensive cost-optimal choice (Opt.3_st-erh), but paying around 450 €/sqm for structural reinforcement towards increased seismic safety for users/investment and added floor area (10sqm) would make this a good investment in this location, or in other similar areas

The extension allows for a small city apartment in a central area, with the comfort of a **wooden stove for heating and cooking in the winter**.

Energy benefits: from "D" to "A+"

The winter-needs dimensioned solar thermal panels provide for the majority of heat necessary for domestic hot water and acclimatization throughout the day, stored in tanks and high inertia walls, and discharged in the night period. Excess heat production is channelled to a small adsortion unit to produce ice at night for cooling needs, or other domestic uses. Highlights are:

- **Reduced energy needs:** from (calculated) 214 to 135 kWh/m^2.a (-40%);
- **Solar thermal (7sqm) and biomass:** 95% reduction, only 13 kWh/m^2.a

Economics

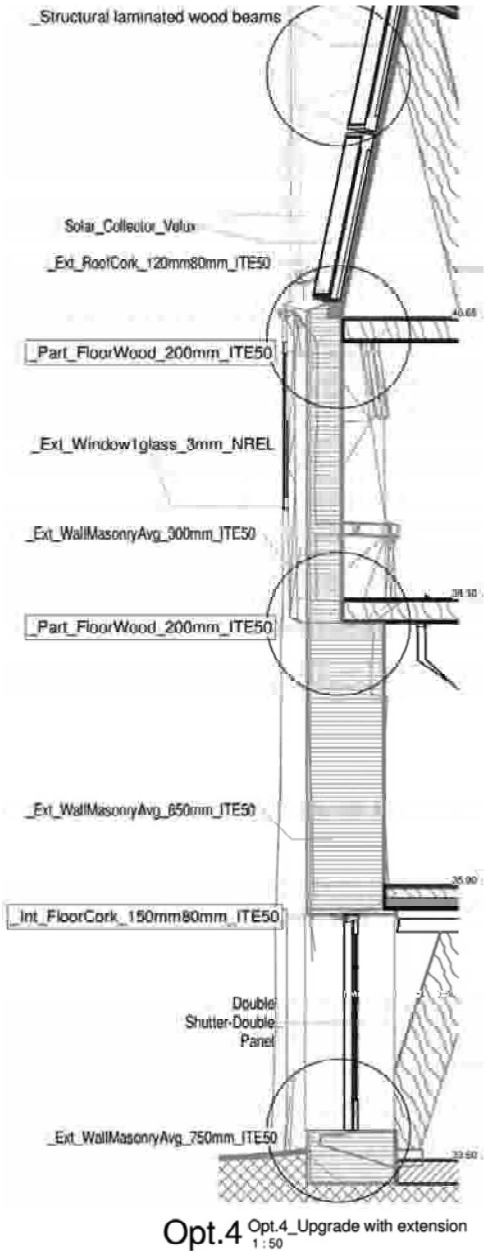
Renovation interventions for less then 450€/sqm (Opt.4) or less then 340€/sqm (Opt.3) demonstrate that significant cost reductions can be achieved if a proper assessment is made on the existing buildings characteristics, their users' habits and expected needs.

Although currently these assessment costs are high, published information (Brito et al., 2014a) shows that such costs can be lowered to feasible values.

Decision process – barriers overcome

The IEA EBC Annex 56 methodology, commonly developed during the evolution of this process, was important on two main levels:

- **Helping to evaluate parameters like IIC and LCC**, and their cross-connected implications allowed for a better planning;
- Providing means to **visualize options to municipal stakeholders**, thus helping them to understand the **individual and collective** implications.



Section of Opt.4 proposal: 450€/sqm provide for a new seismic structure and 10 sqm extension, the local maximum expansion limit.

Co-benefits

After completion, Opt.4 will be able to provide other non-energy benefits:

Material benefits

Increased seismic safety, energy performance and more area (from 36 to 46sqm) increase the value of the building, and potential rent value;

Immaterial benefits

By keeping and upholding Traditional Knowledge for a valuable cost, this strategy refrains renovations that completely demolish the buildings and keep only the outer shell: although sometimes necessary, most of the times stakeholders just don´t know better.

By fostering Traditional Knowledge maintenance habits and materials that kept this building alive for more that 700 years, this strategy preserves knowledge, professions and the resurgence of (old) new jobs.

Alternative renovation processes allow for new insights on collective energy efficacy, and Energy Service Companies (ESCO's) role to foster them (Brito 2015b).

Neighbourhood benefits

By renovating towards nZEB goals, the neighbouring owners can realize about the potential of their buildings, and engage in their renovation;

By fostering maintenance practices, local jobs are encouraged.

Summary

An ancient building located in the highly restricted UNESCO area of Coimbra city centre is used to depict several intervention options, and the IEA EBC Annex 56 methodology used to visualize their costs, economic and environmental.

This “shinning example” demonstrates that a detailed assessment of the existing conditions can help overcome generic misconceptions, and significantly reduce intervention costs.

The Traditional Knowledge embedded in ancient constructive solutions (Brito et al., 2014c), single glazing thermal behaviour enhancement strategies (Historic Scotland, 2010) and current building use patterns can be intertwined with ICT to create new opportunities for lower cost intervention alternatives.

An image of Montarroio Case Study from “Jardim da Manga National Monument, illustrating that several perspectives must be intertwined in order to achieve energy efficacy in ancient Historic Centres reuse and densification.

Acknowledgements

This investigation is being developed within the Sustainable Energy Systems theme of the University of Coimbra/MIT Portugal program, funded by the SFRH/BD/51017/2010 FCT grant and possible by the engaged commitment of stakeholders from modular, arq:i+d, lda, ISR-UC, ADAI-LAETA,WSBP, lda, to name a few. Special thanks to my colleagues in the IEA EBC Annex 56 team and in the ICOMOS International Scientific Committee for Energy and Sustainability (ISCES) for the shared knowledge, insights and diversity.

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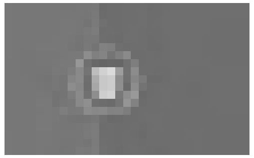
More information is available at **IEA EBC Annex 56 website** and at:

https://www.researchgate.net/profile/Nelson_Brito3/publications

13. Rainha Dona Leonor, Porto



Project summary

Energy concept: Although energy consumption were not the main concern in the engagement of the renovation process, a global intervention had to comply with current thermal regulation, thus providing a significant improvement in the energy performance of the building envelope, the installation of new heating/cooling and DHW systems and also the use of RES.

Background for renovation:

This is a social neighbourhood built in 1953 that reached a profound state of degradation. A deep renovation or demolition were the possible actions to take towards this neighbourhood. The final decision was to renovate it and the approved project aimed to:

- Renovate the buildings that have reached a profound state of physical degradation
- Improve comfort conditions of dwellings that were built 60 years ago and were never upgraded
- Recover the neighbourhood's image maintaining architectural and urban original characteristics
- Increase the dwellings area, adjusting it to todays people’s life patterns
- Refresh of the neighbourhoods surroundings taking advantage of its urban context

General view of selected building before renovation (left) and after the renovation (right)

Site:	**Porto, Portugal**
Altitude:	76 m
Heating degree days:	1610 (base temp. 20ºC)
Owner:	Domus Social
Architect:	Inês Lobo Arquitectos, Lda.

Contact Person:	**Domus Social, Porto**
Renovation started:	2009
Renovation ended:	2014
Data collection:	Spring 2014

Building description /typology

- Neighbourhood with 150 dwelling that will be reduced to 90 after complete renovation
- Multifamily building, with concrete structure, brick walls and light weight slabs
- Originally built in 1953
- Gross heated area of the selected building: 123.60 m^2 (2 dwellings)
- Gross heated of the total renovated neighbourhood: Approx.. 5000m^2

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

This neighbourhood is a social housing complex with several two floors buildings with variations in the area and the number of bedrooms. It also has 3 apartment blocks, but the renovation intervention taking place includes only the two floor multifamily buildings.

Building envelope

The building has a concrete structure with single brick walls. It did not had any insulation in the exterior wall, roof or floor. The roof is made of fibber cement sheets with a wooden structure and a lightweight ceiling slab. The windows frames were made of wood and the windows used to have a single glass with external plastic blinds. The box for the blinds was placed outside the wall.

Heating, ventilation, cooling and lighting systems

There was not a heating or cooling system installed. Occasionally it was used an electric heater or portable fan coils, that each user has acquired. The domestic hot water was supplied by individual electric heaters with storage tank and the ventilation was made by natural means.

Rainha Dona Leonor neighbourhood urban context

Building before renovation

Energy renovation features

Energy saving concept

The main purpose of the intervention was to improve the liveability of the dwellings and simultaneously restore consistency and homogeneity to the neighbourhood by subtracting the illegally constructed elements, restoring the original volumes.

The main targets were:

- Renovate the buildings due to its deep degradation state
- Adapt the living areas to modern standards once the original dwellings were very small
- Improve the comfort inside the dwellings
- Renovate the outdoor areas such as playgrounds and circulation areas

Technologies:

- Exterior walls insulation
- Roof insulation
- Introduction of double glazing windows
- Day lighting improvement with bigger windows in the living room
- Efficient heating and cooling systems
- Solar thermal system for DHW

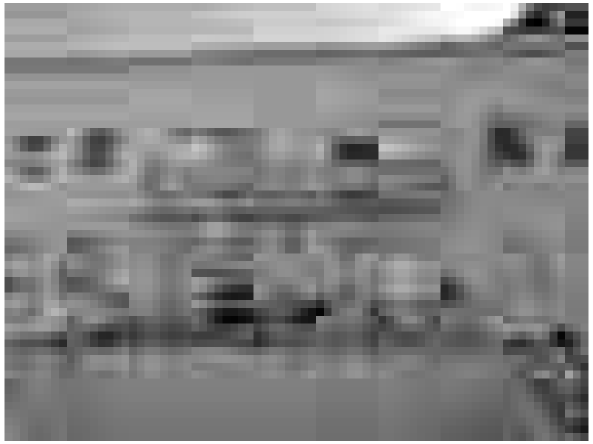
Building

- Wall: External insulation and wall renovation with 60mm of EPS covered by reinforced plaster;
- Roof: Insulation with 50mm XPS panels;
- Windows: Wooden frames + double glazing with 4mm and 6mm

Systems

- HVAC: Multi-split air conditioning system with a coefficient of performance (COP) of 4,1 for heating and energy efficiency ratio (EER) of 3,50 for cooling, on each flat.
- Lighting: Improved daylighting with larger windows.
- Renewables: 3m^2 of solar panels for DHW, per flat.
- DHW: New electric heater with storage tank

Element	U-Value before renovation W/m^{2}K	U-Value after renovation W/m^{2}K	After renovation
Exterior walls	1.38 / 1.69	0.45 / 0.48	60mm EPS insulation
Windows	3.40	2.90	Double glass and wood
Roof	2.62	0.64	50 mm XPS insulation



Above and right: Buildings after renovation

Energy Savings, CO_2 reductions and Life Cycle Costs

	Before renovation (calculated)	After renovation (calculated)	Reduction
Heating Needs (kWh/m².a)	119.70	68.55	43%
Cooling Needs (kWh/m².a)	6.49	7.86	-21%
DHW Needs (kWh/m².a) (considering the reduction from the use of solar thermal panels)	37.09	27.13	27%
Non renewable primary energy consumption for heating, cooling and DHW (kWh/m².a)	413.75	127.21	70%
Total annual electricity consumption (kWh/a)	20 456	6 289	70%
Energy Cost for calculated life time of 30 years (€)	85 580	27 221	70%
Carbon Emissions (TONeqCO²/a)	18.92	6.02	70%

Calculated energy savings:

Energy needs reduction due to the improvement of the envelope and control of infiltrations: 49.78 kWh/m².a
Solar thermal contribution: 9.96 kWh/m².a
Primary energy savings: 286.54 kWh/m².a
Total carbon emissions reduction:
12.9 ToneqCO_2.a

Global evaluation

"Within the municipality housing stock, Rainha Dona Leonor, by the deep renovation work that has been submitted, passed from Group I (very poor condition and / or low level of comfort) to Group V (good condition), becoming the best social neighbourhood of Porto, with comfort and liveability conditions superior to newly built neighbourhoods like Monte São João and Parceria e Antunes."

Rui Rio, Porto Mayor

Costs	EUR	EUR/m²
Total Life Cycle Costs (NPV)	225 609€	1825€/m²
Total Investment	165 340€	1338€/m²
Investment in renewables	6 987€	57€/m²
Investment in systems	16 092€	130€/m²
Energy costs	27 221€	220€/m²
Maintenance costs	33 048€	267€/m²

Building during the renovation process

Building after the renovation process

Overall improvements, experiences and lessons learned

Energy

Potential annual savings of 35417 kWh/a of primary energy in each building.

Indoor climate

Reduction of losses through walls, roof and windows;

Reduction of the thermal bridges allowing to eliminate related condensation problems;

Upgrade of the building energy performance. The standard energy performance for new buildings in Portugal has been achieved;

Control of indoor temperature and humidity without relevant energy costs.

Economics

These renovations were supported by the municipality, who owns and runs these neighbourhoods allowing a significant increase of the rents.

Potential energy costs for heating, cooling and DHW have been reduced by almost 70%.

Decision process – barriers that were overcome

The lack of financing to carry out the works at once;

Strong discussion whether the best solution was to renovate or to demolish and transfer tenants to other buildings;

The need to have the buildings vacant to carry out the renovation works.

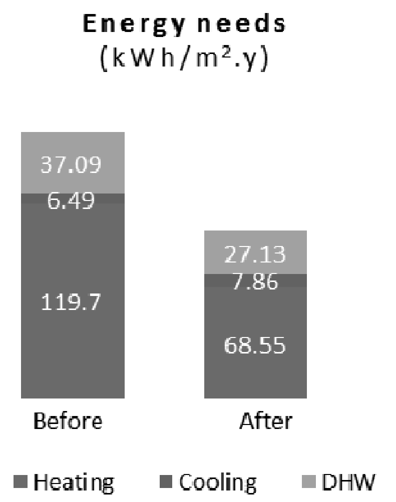
Co-benefits

Aesthetical improvement, returning the dignity and identity of the neighbourhood, reducing the social housing stigma;

Better living conditions with more space and more qualified living spaces;

Improved thermal comfort conditions with users now able to heat indoor spaces and keep the interior environment within healthy and comfortable temperatures;

Improved natural lighting with larger glazing areas in living room.



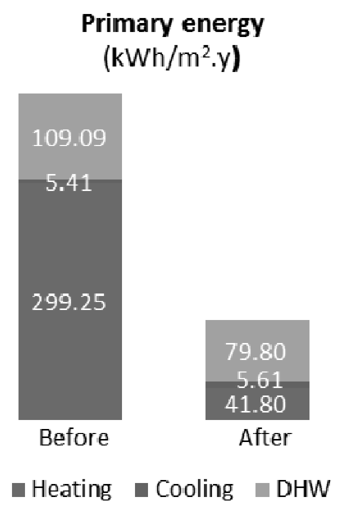
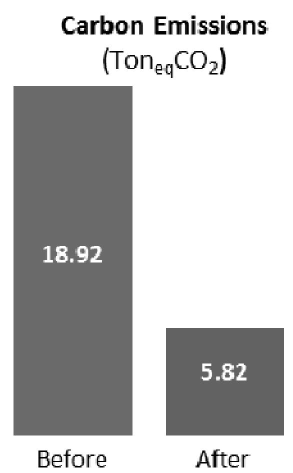


Figure above on the left shows the energy needs for heating, cooling and DHW before and after the renovation works calculated in accordance with the Portuguese thermal codes, which consider the comfort indoor temperatures of 20ºC in winter and 25ºC in summer.

Figure above on the right shows the non renewable primary energy use for heating, cooling and DHW, before and after the building renovation.

Figure on the right shows the carbon emissions before and after the building renovation related to the non renewable primary energy use.



Summary

With this renovation process, the city hall achieved two main goals: return the confidence to the neighbourhood and improve the living conditions of the local population.

Additionally, the potential reduction of the non renewable primary energy consumptions is about 70%.

The overall improvement of the neighbourhood allowed to transform this neighbourhood into the best social neighbourhood of Porto city according to the evaluation of the municipality, with comfort and liveability conditions much better than other recently built neighbourhoods.

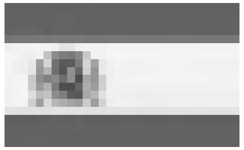
Front facade of the renovated buildings

Back facade of the renovated buildings

Acknowledgments

We want to offer our thanks to Domus Social, E.M. and Inês Lobo Arquitects, Lda. for sharing the data necessary for the development of the calculations and for the preparation of this shining example , and specially to José Ferreira from Domus Social, E.M. who kindly introduced us to the renovation process of this neighbourhood.

14. Corazón de María, Bilbao



Project summary

Energy concept: This is a social building with 111 dwellings, built in 1956 in Bilbao. The building renovation was projected under a global approach, taking advantage of economic incentives from Basque Government existing to promote building renovations. Improving the building energy performance is just one of the main targets of this project, which plans a global intervention taking into account not only energy aspects (improvement of the building envelope, updating the heating and DHW systems and evaluating the possibility of using RES) but also other issues such as accessibility or improving the urban area.

Background of renovation:

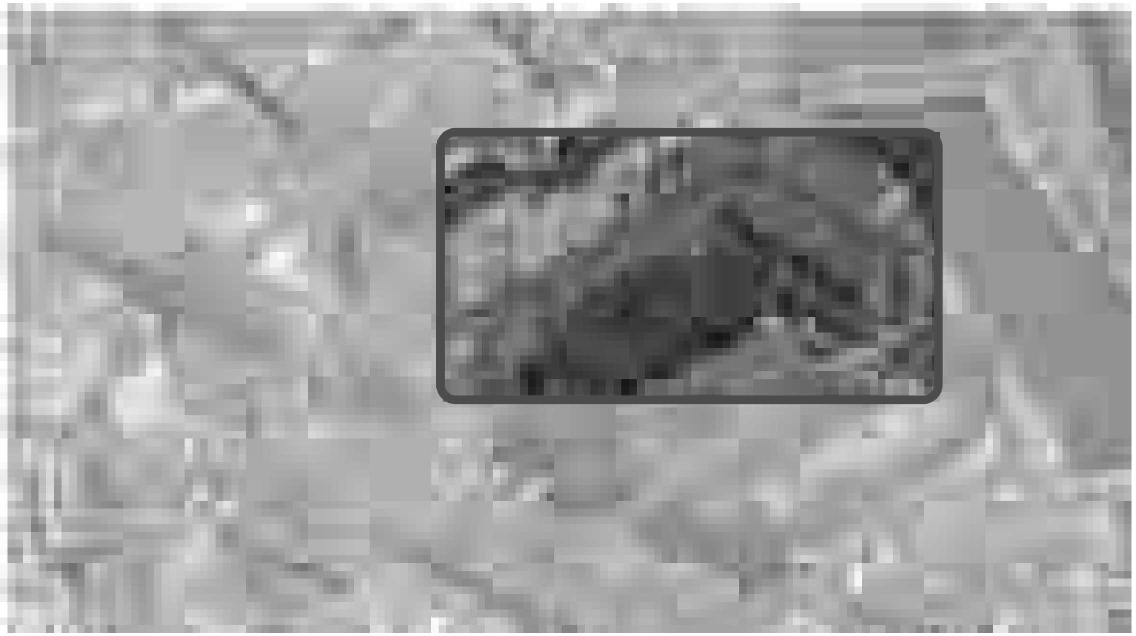
The project aims to:

-Improve the energy performance of the building

-Improve the comfort conditions of dwellings (the building was never upgraded)

-The building accessibility will be significantly enhanced (lifts are installed)

-Recovering the neighbourhood image maintaining architectural and urban original characteristics



General view of the building

Site:	**Bilbao**
Altitude:	19 m
Heating degree days:	1135
Cooling degree days:	0
Owner:	Bilbao Social Housing
Architect:	Pascual Perea

Contact Person:	**Bilbao Social Housing**
Renovation started:	2014
Renovation ended:	2015
Data collection:	Winter 2015

Building description / typology

•A complete renovation of the building has been projected, which includes improvements on building thermal performance and accessibility.

•It is a building with concrete structure, brick walls and light weight slabs. Average area of each dwelling is 75 m²

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building and its situation before renovation

The building is located in a neighbourhood that have reached certain level of degradation, and several of its buildings (many of them, inhabited by low-income-families) are needed for a deep renovation.

It is a L-shaped multi-storey block of flats. It has 5 levels and 111 flats, with an average area of 75 m^2. Some small neighbourhood stores can be found in the ground floor of the building.

The main renovation needs are to **improve the thermal performance**, some **structural repairs** and mainly, to **improve the building accessibility** (In fact, this last one was the main motivation for the residents to carry out the renovation works)

Building before renovation

Building envelope

The building has a concrete structure with single brick walls. It has no thermal insulation in exterior wall or roof.

The roof is made of ceramic tiles with a wooden structure.

The windows frames are varied, and some owners have carried out windows replacements in the last years. However, the majority of the windows are single-glazing windows with wood frames.

Heating, ventilation, cooling and lighting systems

There is no central heating/cooling system. Currently, 23 residents have installed Natural Gas Boilers (only one of them is a condensing boiler) for DHW and heating system. Occasionally, some occupants can use electric heaters and it doesn't have any cooling system (It must be highlighted that the climate in the city in summer is not too hot, and cooling is not usual for domestic uses)

In many cases, the domestic hot water is supplied by individual electric heaters with storage tank and the ventilation is made by natural means.

Building before renovation

Element	Area m^2	U-Value before renovation W/m^{2}K	U-Value after renovation W/m^{2}K
Exterior walls	7284	1.7	0.27
Windows	1279	4.8	1.4
Roof	1720	1.5	0.33

Energy renovation features

Energy saving concept

The main purpose of the intervention is to improve the comfort of the dwellings, and simultaneously, to improve the energy performance of the building, by means of a global energy renovation, The projected actions related to the thermal performance of the building are:

- Improve the building envelope, maintaining its aesthetic features
- Upgrade the energy systems
- Improve the building accessibility
- Improve the comfort inside the dwellings
- Repair the roof and the wooden structure

Moreover, residents participation has been taking into account during the project definition, by means of several information campaigns and a questionnaires collection.

Technologies:

- Building insulation and thermal bridges treatment
- Windows replacement
- Natural Gas Boilers (instead the currently installed electric heaters)
- The introduction of Solar Thermal panels and a Biomass heating system is projected

Building

• Wall: Cavity wall of the façade (12 cm) will be filled with thermal insulation (EPS). The thermal bridges will be treated

• Roof: Insulation of the roof with 10 cm of rock-wool, wooden structure will be repaired.

• Windows: PVC frames + double glazing windows

Element	Strategy - Impact/Purpose
Exterior walls	Exterior walls:10 cm de EPS (Filling the air gap) Thermal Bridge treatment
Windows	Introducing a Double glazing windows (PVC frames)
Roof	10 cm rockwool insulation
Energy Systems	Introducing condensing boilers
RES	Solar Thermal. Biomass.

Systems

Heating: condensation — Electric boilers will be replaced by individual, boilers

Ventilation: — Natural ventilation using crossed ventilation

Lighting: — No changes are projected

Renewable energy systems

Thermal solar panels for meting the 50% of DHW are projected

Central heating system based on biomass is proposed and planed to install in the future.

Centralized heating system based on biomass is planed to install in the future

Achieved Energy Savings, CO_2 reductions and Costs

Energy needs	Before renovation	After renovation
Heating needs [1]	679.350 kWh/y (81.6 kWh/m^2.y)	482.020 kWh/y (57.9 kWh/m^2.y)
Cooling needs	-	-
DHW needs [2]	207.000 kWh/y (24.9 kWh/m^2.y)	207.000 kWh/y (24.9 kWh/m^2.y) 103.500 kWh/y (12.5 kWh/m^2.y)
Electricity needs (Appliances) [3]	374.070 kWh/y (44.9kWh/m^2.y)	374.070 kWh/y (44.9kWh/m^2.y)
Energy label [4]	G	C

[1] Heating demand has been calculated using Energy Plus

[2] DHW needs has been calculated based on the requirements presented in Spanish regulation (28 l/person.day; 350 residents)

[3] Electricity needs has been defined based on statistical data published by Basque Energy Agency (3370 kWh/year per dwelling)

[4] Buildings energy certification scheme in Spain ranks the energy performance of each building from level G to level A, being the first the less efficient

Calculated energy needs reductions:

Heating energy needs reduction: 29 %
Cooling energy needs reduction: N/A
DHW energy needs reduction: 0-50 %

RES contribution

Solar thermal contribution: 0-103.500 kWh/y.

Overview economic efficiency and costs per dwelling

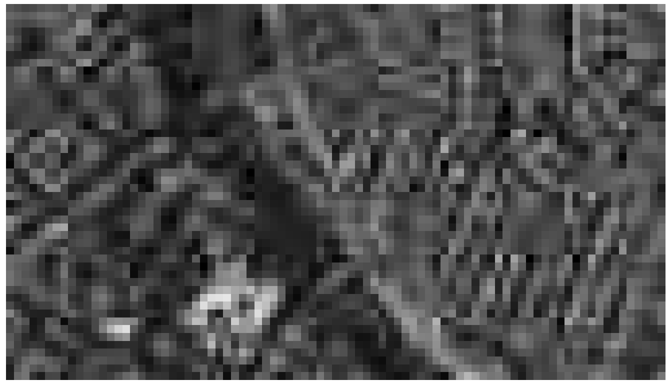
Total retrofit cost: 38.150 €
Total energy operation cost before reno:1655 €
Total energy operation cost after reno: 995 €

Scenario 2 (Including solar thermal panels)

Total energy operation cost before reno: 1655 €
Total energy operation cost after reno: 945 €

Building façade before renovation

Costs	EUR	EUR/m^2
Craftsment	4 M€	475 €
Consultants	200 000 €	23.5 €
Total	4.2 M€	498.5 €



Building context

Overall improvements, experiences and lessons learned

Energy

Energy needs reduction for heating, cooling and DHW, compared to current state over 22 % are obtained, and a reductions over 34% can be reached if the projected installation of Solar Thermal panels for DHW are finally installed.

Indoor climate

- Reduction of draughts
- Absence of condensation phenomena
- Better comfort all year round

Economics

This renovation improves the urban context of that area, doing it more attractive for the inhabitants, and that point is good mainly to the neighbourhood stores located in the area.

Economic consequences for tenants

The most direct effect consequence of renovation works is the fact that the property rise in value, due to the improvement in accessibility and thermal performance.

The enhancement on the building thermal performance also involve a theoretical energy savings around 660€. However, this value must be taken with care. Currently, many residents use no heating system, and then, renovation consequences will affect mainly on the indoor comfort in these cases.

Decision process

Funding sources were obtained from a public administration. This involved an increase of bureaucracy. However, the funding was a key factor to carry out the renovation works, taking into account the low income profile of the building residents.

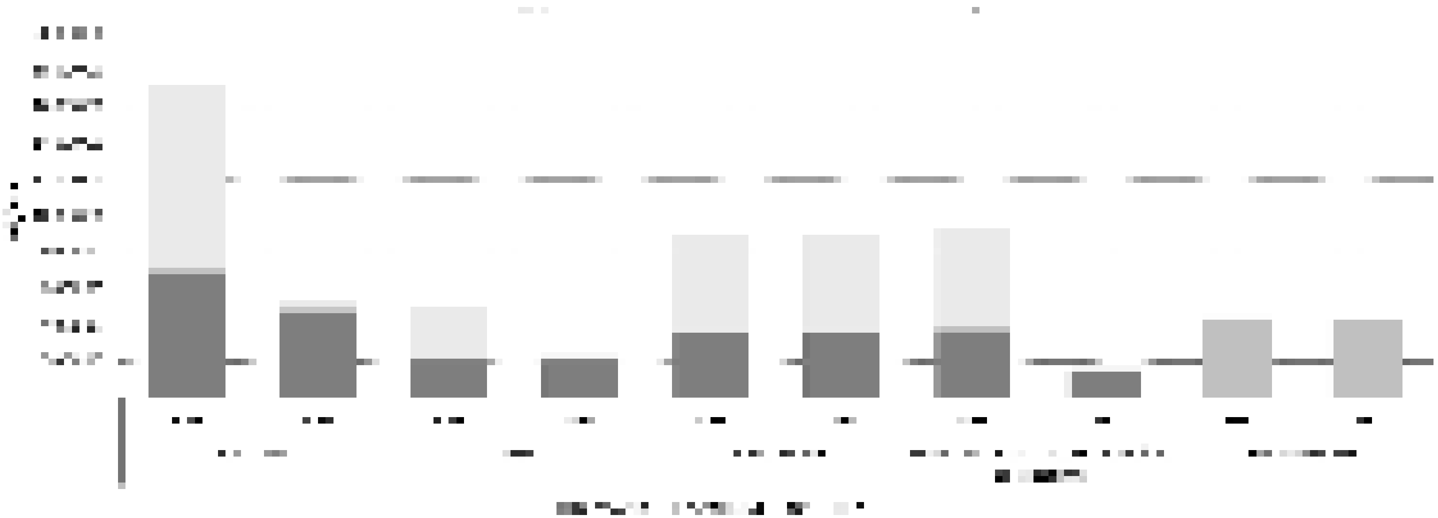
Residents participation has been promoted over the project. Residents were initially reluctant to carry out the renovation works, and, in many cases, the main motivation to carried out the renovation was not the improvement of building thermal performance, but the building accessibility.

Co-benefits

- Development in an depressed area of the city.
- Renovation makes easier delivering affordable warmth to the fuel poor households, and then, it involves reduction the risk of energy poverty and cold homes.
- Building accessibility is significantly improved.

Overview economic efficiency and costs

Even in the theoretical case presented in the study (operation costs) the payback of this renovation is not very attractive when only energy savings is considering. However, a global approach must be carried out, and taking into account the aforementioned non-energy benefits must be taken into account when the feasibility of this kind of renovation is assessed.



Building energy performance (Conversion Factors: Electricity 2,.4; Natural Gas: 1,.07; Source: IDAE // Infiltration before renovation: 0,6 ACH; Infiltration after renovation: 0.24 ACH)

Summary

Summary of the project

This is a social building with 111 dwellings, built in 1956 in Bilbao. The building is located in the core of the neighbourhood, shaping the main square in this area. The case study building, like many others in this neighbourhood, was built without taking into account thermal requirements. That point involves that many of the buildings located in this neighbourhood present a great potential of energy performance improvement.

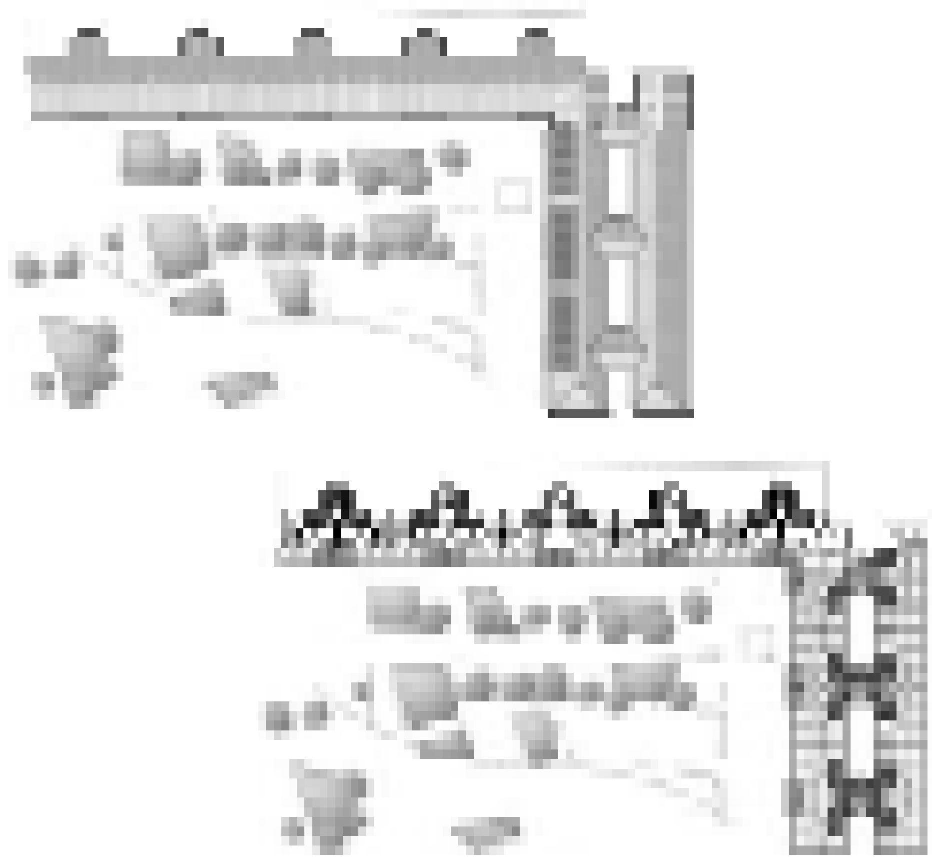
In this case, the building renovation was projected under a global approach, taking advantage of an economic incentives from Basque Government existing to promote building renovations. Three main objectives can be identified in this project: (1) improving the energy performance of the building, (2) improving comfort conditions of dwellings (the building was never upgraded), (3) the building accessibility will be significantly enhanced (lifts are installed).

Experiences and lesson learned

It is important that the tenants get what they expected, so from the beginning it is necessary to spend a great deal of effort on making sure that the expectation are adjusted to what can be met in practice. The residents also have to be part of the decision process. These points can make easier solving the possible problems that can arise over the works.

Closely linked to that point, it is important to take into account that the resident motivations are not always related to energy issues. In fact, in social dwelling at least, energy consumptions are usually lower than those theoretically expected, by lowering the indoor comfort level. For that reason, it is usually difficult to carried out a renovation when only “energy-motivation” is presented. Effects on indoor comfort and accessibility improvements were highlighted when renovation-benefits were presented to residents.

Although the consumption profiles and climatic conditions are technically quite good to propose an small PV auto-consumption, currently existing Spanish regulation makes difficult the feasibility of this kind of installations.



Roof and general architecture plans of the retrofitted building.

Acknowledgements

We would like to offer our thanks to ”Viviendas Municipales de Bilbao” (Bilbao Social Housing), for sharing the data necessary for the development of the calculations and for the preparation of this shining example, and specially to Rosario Vallejo and Koldo Ibáñez. Many thanks also to Laboratory for the Quality Control in Buildings (LCCE) of the Basque Government.

15. Backa röd, Gothenburg

Project summary

Energy concept: To achieve a substantial reduction of the energy losses

Background for the renovation:

The technical status of the building was poor due to wear and tear and the energy use was high before the renovation. The intentions were to:

- Take care of the deteriorated façade
- Improve all technical systems, which were in bad condition
- Renew the kitchens and bathrooms, which were in bad condition (original condition)
- Renew the surface finish in the apartments, as it was needed
- Improve the energy efficiency

Site:	**Gothenburg**
Altitude:	35 m
Heating degree days:	3307 (base temp 17ºC)
Owner:	Bostads AB Poseidon
Architect:	Pyramiden Arkitekter
Engineer	Structural engineering: Byggtekniska Byrån i Göteborg HVAC: Andersson & Hultmark

Contact Person:	Cathrine Gerle, project leader, Bostads AB Poseidon
Renovation started:	2009
Renovation ended:	2009
Data collection:	Spring 2014

Before renovation.

After renovation.

Building description /typology

- First 16 energy renovated apartments (of 1,564)
- Heated usable floor area 1357 m²
- Built: 1971
- Prefabricated concrete elements and balanced ventilation without heat recovery

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

Backa röd consists of 1,574 apartments in high-rise buildings, low-rise buildings and low tower blocks built during the million homes' program. The first building to be energy renovated, which is described here, is a low tower block with 16 apartments and 4 floors. The apartments have good floor plans, with generous and easily furnished rooms. However, the buildings needed to be renovated due to wear and tear.

Building envelope

The buildings are typical for the seventies with a prefabricated concrete structure of sandwich facades panels. The facades were damaged by carbonation and were in need of renovation.

The building was leaky, through the façade and between the apartments. Draught occurred from the in fill walls at the balcony and cold floor was caused by the thermal bridges from the balconies.

Heating, ventilation, cooling and lighting systems

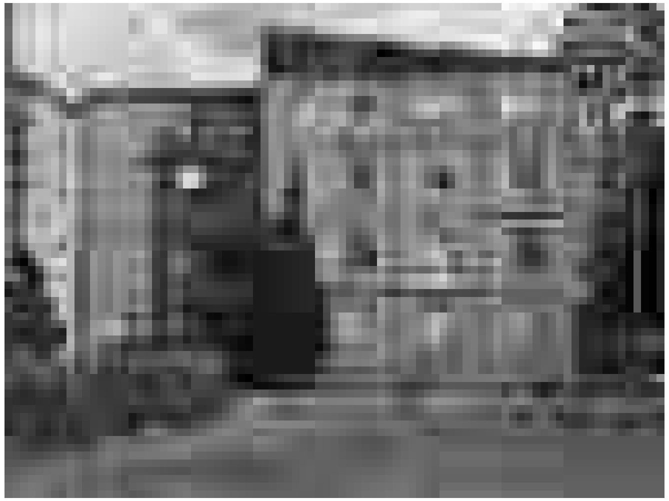
The buildings are heated by district heating. In each apartment there were radiators under the windows.

Domestic hot water is also heated by district heating. District heating is renewable to 81%.

The apartments were ventilated by mechanical exhaust and supply ventilation without heat recovery.

The intention of the renovation was upgrade the standard of the building.

Element	U-Value before renovation W/m^2K	U-Value after renovation W/m^2K
Exterior walls	0.31	0.12
Roof	0.14	0.10
Ground floor	0.40	0.10
Windows (average)	2.40	0.90



Before renovation

Energy renovation features

Energy saving concept

The aim was to combine the necessary maintenance renovation with a 65 % reduction in energy use. The overall intention was therefore to:

- Renovate the building
- Reduce the energy use
- Improve the indoor climate

Building

- Additional insulation, loft and crawl space
- Exterior additional insulation and sealing of the façades and new windows
- The joints between the apartments were rendered impermeable to air movement with floating putty on the floor
- New draught-proofed curtain wall on the balcony side
- New balconies on freestanding supports to minimise thermal bridges
- Individual metering of and invoicing for hot water

Systems

Heating: New radiator system with thermostat valves. Temperature sensors in the apartments. Individual metering of domestic hot water.

Ventilation: Change from exhaust and supply system for ventilation to an exhaust and supply system with heat recovery (rotary heat exchanger), with an efficiency of 85%. Cooker hood with separate fan and no heat recovery.

Lighting: Low energy lighting for fixed lighting.

Element	After renovation
Exterior walls	Adding 200 mm of thermal insulation
Roof	Total of 500 mm of thermal insulation
Crawl space	Additional insulation with 500 mm Leca and heat supply by supply air
Windows	Triple-glazed low energy windows

Renewable energy systems

None, apart from district heating produced to 81 % from renewable energy and the electricity is green electricity.

Other environmental design elements

Extended eaves and balcony after renovation

Overall improvements, experiences and lessons learned

Energy

Annual savings 160 MWh

Indoor climate

— Improved thermal comfort and indoor air quality

Economics

The costs have been divided into refurbishment 1.6 M€ and energy efficiency measures 0.4 M€ (total cost of 2 M€).

The investments consist of standard-raising measures 0.7 M€, operating cost reducing measures 0.2 M€, neglected maintenance 0.9 M€ and unprofitable energy measures 0.2 M€.

The payback time of the energy savings is estimated to be 25 years. However the owner only considers their yield (profitability) requirements.

Decision process – barriers that were overcome

The alternative of demolishing the buildings and building a new one was considered, but was not considered politically realistic as there is a severe lack of apartments in Göteborg. Besides it was a pilot project for energy renovation, to gain experience for future renovations.

Co-benefits

— Water and sewage systems replaced, hot water circulation installed

— New electrical installation

— New bathrooms and kitchens

— Change to parquet floor in living rooms and bedrooms

— New surface finish in the apartments

— Safety doors for the apartments

— New extended balconies, which also reduce the thermal bridges

— Façade repaired

Economic consequences for the tenants

Rent before: 76 €/m²/year íncl. space heating and dhw

Rent after: 102 €/m²/year incl. space heating

Rent increase: 26 €/m²/year

Energy savings: 160 MWh/year

Energy price (assumed): 110 €/MWh

Savings: 160 x 110=17600 € = 13 €/m²/year

Users evaluation

The tenants perceive that

— Draughts from external walls and windows, and cold floors have been completely eliminated

— The room temperature is more comfortable, although it gets warm indoors in the summer.

— Unpleasant odors and noise levels have lessened

Achieved Energy Savings, CO_2 reductions and Costs

Energy consumption for heating, hot water and facility electricity before and after renovation

Calculated energy consumption, kWh/(m²·year):	District heating	Facility electricity	Total
before renovation:	153	8	161
after renovation:	55	6	61
calculated savings:	98	2	100
Actual energy consumption measured (normalized), kWh/(m²·year):			
before renovation:	166	8	174
after renovation:	50	7	57
actual savings:	116	2	118
BBR2012 (building code requirement for new construction)			90

Calculated:
Energy savings thanks to reduced energy losses are calculated to be 136 MWh or 100 kWh/m². The measured energy reduction is 160 MWh or 118 kWh/m².

Renovation Cost and LCC (NPV)		
Total (price level of 2009)	18.05 M SEK (2 M€) of which 3.75 MSEK (0.42 M€) energy measures	14500 SEK/m² (1,625 Euro/m²) of which 3000 SEK/m² (335 Euro/m²) energy measures
NPV (sum of discounted energy savings – investments, assumptions: cost of capital 4.25 %, calculation period 50 years, energy price increase 4 %/year). The owner has the tougher profitability requirement of 6.25 % and assumes that the energy price follows the inflation.	3.75 M SEK (0.42 M€)	3000 SEK/m² (335 Euro/m²)

Summary

Summary of project

The renovation was necessary due to wear and tear. The results were substantial improvements in the standard of the building and at the same a substantial reduction in energy use, 65 %, while keeping a similar exterior architectural appearance, however a completely different colour. The energy saving measures had low profitability in this demonstration project. The standard improvements meant new installations, new bathrooms and kitchens, and new surface finish. The energy saving measures included added thermal insulation to the building envelope, low energy windows and installation of ventilation heat recovery.

The tenants have appreciated the improvements in thermal comfort, indoor air quality and noise climate.

After renovation with new facade and balconies etc.

Experiences/lessons learned

According to the owner the energy efficiency measures have not been profitable. Given the rather stringent yield requirements of the owner (profitability requirement of 6.25 %, energy price increase according to the inflation) only half of the energy investment will pay for itself.

If energy efficiency measures which result in improvements of indoor climate could be considered as standard-raising and allow a rent increase the profitability would be reasonable even with the stringent yield requirements. Major energy renovations only make sense in buildings which need a major traditional renovation. The profitability of renovations increases for bigger multi-family buildings and if many buildings can be renovated at the same time here.

The owner has therefore continued with similar energy renovations of five tower blocks of the same type in the same area. An additional feature is adding two floors on the roof. This way the profitability requirement of the owner will be met.

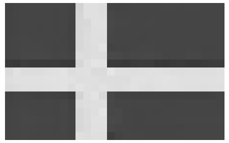
References

[1] Byman, K., Jernelius, S., 2012, Economy for reconstructions with energy investments, Energy center of environmental administration of Stockholm city.

[2] Östlund, M., 2013, Katjas Gata – Classic million program house became low energy building (in Swedish) http://www.byggtjanst.se/For-alla/Hallbar-upprustning-av-miljonprogrammet/Katjas-Gata---klassiskt-miljonprogramshus/

[3] Mjörnell, K., et.al. 2011, Milparena – Million homes program arena Innovative action proposals for renovation of the building envelope and installations (in Swedish), SP Rapport 2011:39, Technical research institute of Sweden

16. Brogården, Alingsås



Project summary

Energy concept: Renovation using passive house technologies.

Background for the renovation:

Intention for the renovation:

- Increase the accessibility
- Create a variation in apartment size
- Renovate because of wear and tear
- Improve on the poor thermal comfort
- Improve the poor energy efficiency by at least 50 %

Site:	**Alingsås, Sweden**
Altitude:	58 m
Heating degree days:	3724 (base temp. 17ºC)
Owner:	AB Alingsåshem
Architect:	Efem Arkitektkontor
Engineer:	Structural engineering: WSP HVAC: Andersson & Hultmark AB

Contact Person:	Ing-Marie Odegren, CEO, Alingsåshem
Renovation started:	2008
Renovation ended:	2013
Data collection:	Winter 2013

Building description /typology

- Built 1971-73
- First 18 renovated apartments (of 300)
- Heated usable floor area (18 apartments) 1,274 m²
- Three storey buildings
- Poorly insulated building envelope and exhaust fan ventilation without heat recovery

Before renovation.

After renovation.

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building

Brogården consists of 300 apartments in three-four storey buildings built during the million homes' program. The first building to be renovated, which is described here, has 18 apartments. The apartments have good floor plans, with generous and easily furnished rooms. However, the buildings needed to be renovated due to wear and tear, to increase the accessibility, to create a variation in apartment size and to improve the energy efficiency.

Building envelope

The buildings are typical for the seventies with a concrete structure and in fill wall. Walls consisted of gypsum boards on non loadbearing wooden studs, 95 mm insulation and façade bricks. Basement: cast-in-situ concrete walls were without any insulation. There was 300 mm insulation on roof slab and wooden rafters with props on roof slab. The windows were single pane with supplementary aluminum sash and one additional pane.

The apartments were perceived as drafty and had a poor indoor thermal comfort due to leaky facades. The balconies constituted thermal bridges. The façade bricks were partly destroyed by moisture.

Architecturally the wish was to preserve the impression of the façade e.g. the yellow brick façade.

Heating, ventilation, cooling and lighting systems

The buildings are heated by district heating. In each apartment there were radiators under the windows. The radiators were regarded as worn out.

Domestic hot water is also heated by district heating. District heating is renewable to 98%.

The apartments were ventilated by mechanical exhaust ventilation without heat recovery.

The buildings needed a deep renovation.

Before renovation

Before renovation

Element	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Exterior walls	0.30	0.11
Roof	0.22	0.13
Base plate	0.38	0.16
Windows average	2.00	0.85
Doors	2.70	0.75

Energy renovation features

Energy saving concept

The aim was to combine the necessary renovation with an upgrade to nearly passive house standard using passive house technologies.

Building

- Replacing the infill walls with well insulated new facades.
- Adding thermal insulation to the gables, the roof and the base plate.
- Improving the airtightness from 2 l/sm² to 0.2 l/sm² at 50 Pa.
- Replacing the windows with triple pane windows.
- Incorporating the balconies with the living rooms to eliminate thermal bridges and building new balconies supported by columns.
- Individual metering of household electricity.

Systems

Heating: Replacing the radiators with heating coils in the supply air of the ventilation system. Individual metering of domestic hot water.

Ventilation: Installation of decentralized balanced ventilation systems with heat recovery. The heat exchanger efficiency is 80 %.

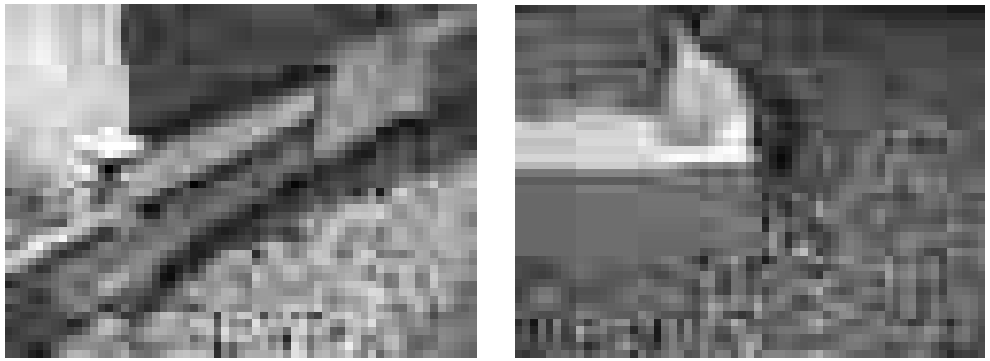
Lighting: Low energy lighting for fixed lighting.

Element	After renovation
Exterior walls	Altogether 480 mm thermal insulation. Adding 430 mm of thermal insulation to the gables
Roof	Adding 400 mm of thermal insulation to the roof
Base plate	Adding 60 mm of EPS
Windows, average	Triple pane
Doors	New doors

Renewable energy systems

None, apart from district heating based on 98 % renewable energy .

Other environmental design elements



Added insulation to the foundation

Achieved energy savings, CO2 reductions and Costs

Energy consumption for heating, hot water and facility electricity before and after renovation:

Calculated energy consumption:		
before renovation:		175 kWh/(m²·year)
after renovation:		74 kWh/(m²·year)
calculated savings:		101 kWh/(m²·year)
Actual energy consumption measured over a 12 months period:		
before renovation:	normalized	175 kWh/(m²·year)
after renovation:	normalized	77 kWh/(m²·year)
actual savings:		98 kWh/(m²·year)
BBR2012 (building code requirement for new construction)		90 kWh/(m²·year)

As 98 % of the district heating is renewable energy the reduction in CO_2 emissions is small.

Item	Total amount	Value/m²
Craftsmen	17.7 MSEK (1.87 M€)	14000 SEK/m² (1.480 €)
Total of which energy measures	25 MSEK (2.8 M€) 7.1 MSEK (0.8 M€)	19800 SEK/m² (2.225 €/m²) 5600 SEK/m² (625 €/m²)
NPV (sum of discounted energy savings – investments, assumptions: cost of capital 4.25 %, calculation period 50 years, energy price increase 4 %/year) The owner applies the profitability requirement of 5.5 %, district energy price increase of 3 % and electricity increase of 5 % above inflation.	0 MSEK	0 MSEK

During reconstruction the building was covered by a tent.

Calculated energy savings

Energy savings thanks to reduced transmission and ventilation losses are 129 MWh or 100 kWh/m²·year. Measured energy use is only slightly higher.

Nice looking buildings with new balconies

Overall improvements, experiences and lessons learned

Energy

Annual savings 100 kWh/m²·

Indoor climate

— Improved thermal comfort

— Improved indoor air quality

Economics

The client divided the costs:

1) Energy saving measures, will be paid back in 17 years.

2) Improved standard of the apartments paid for by the tenants (5 m² larger living rooms, renovated bathrooms etc.) with a 35 % average rent increase.

3) The maintenance cost for the buildings, in any case needed.

Decision process – barriers that were overcome

The planning process took long time partly due to poor project management, which was overcome by improved project management.

The preservation of the area and accessibility questions in the project took much time late in the planning process. The energy issues were almost neglected at least in the beginning of the project. Someone has to be in charge of the energy issue.

Co-benefits

— New balconies and larger living rooms

— Better indoor climate

— Increased accessibility (ground floor)

— New water/ sewage system, electrical installations, bathrooms and kitchens, surface finish inside.

Prefabricated facade elements for the next phase of renovation.

Economic consequences for the tenants

Rent before: 77 €/m²/year íncl. space heating, DHW and household electricity

Rent after: 97-118 €/m²/year incl. space heating

Rent increase: 19-40 SEK/m²/year

Energy savings: 127 MWh/year

Energy price (assumed): 105 €/MWh

Energy savings: 10.5 €/m²/year

Users evaluation

The tenants were most satisfied with the new entrance, the entry phone and the fresh indoor air.

The tenants on the ground floor perceived occasionally the indoor temperature as low during the first winter and the users on the top floor perceived the indoor summer temperatures as high.

Summary

Summary of project

The renovation was necessary due to wear and tear. The results were substantial improvements in the standard of the building and at the same a substantial reduction (60 %) in energy use, while keeping a similar architectural appearance. This was done using traditional building materials and with common contractors. The energy savings were estimated to be paid back in 17 years. The planning process was very long in this demonstration project. The energy aspect was for a long time not considered important. The conclusion is that comprehensive efficient project management is needed and that energy has to be included from the beginning. All necessary competence has to be involved from the very start of a renovation project.

Long side façade with balconies before (left and above) and after (below) renovation.

Experiences/lessons learned

The most important lesson is that passive house technology for renovation requires that all competence work together from the start. The project has shown that it is possible to renovate a million programs' home to a very low energy use using traditional materials and common contractors. Besides it is an advantage to use standard material in standard sizes.

Central ventilation heat recovery on ventilation should be used instead decentralized, to reduce maintenance work and work changing filters. The façade construction should be simplified from a four layer on-site construction to a two layer construction with insulation, to reduce investment costs and simplify the production. For the following buildings (150 apartments) prefabricated façade elements are used for renovation.

The tenants were satisfied with the renovation.

Another important conclusion is that the tenants have to be informed from the beginning. In this project they had to move out during the renovation.

References

[1] Janson, U., 2010, Passive houses in Sweden - From design to evaluation of four demonstration projects, Division of Energy and Building Design, Department of Architecture and Built Environment, Lund University, Faculty of Engineering LTH, Report EBD-T--10/12

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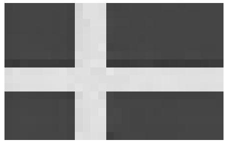
17. Maratonvägen 36, Halmstad



Project summary

Energy concept: To achieve a substantial reduction of the energy losses.

Background for the renovation:

The aim was to combine a maintenance renovation with a reduction in energy use and serve as pilot project for future renovations.

Therefore the objectives of the renovation was to:

- renovate because of wear and tear
- attend to increased radon levels
- improve on the poor thermal comfort
- improve on the poor energy efficiency by 30-50 %

Site:	**Halmstad, Sweden**
Altitude:	10 m
Heating degree days:	3325 (base temp. + 17 C°)
Cooling degree days:	0
Owner:	Halmstad Fastighets AB (HFAB)
Architect:	Krok & Tjäder
Engineer:	Ramböll, Dagsgårds VVS konsulter AB

Contact Person:	Joakim Patsonen, property engineer, HFAB
Renovation started:	2009
Renovation ended:	2011
Data collection:	Spring 2014

Before renovation

After renovation

Building description /typology

- Built 1963-65
- Three - four storey buildings
- 51 apartments (of 579 apartments)
- Heated usable floor area (51 apartments) 4,521 m²

Building envelope, heating, ventilation, cooling and lighting systems before the energy renovation

Description of building and its situation

The area of Maratonvägen is a typical "million homes program“ area with 580 apartments in 21 buildings. The buildings have undergone very few changes since the construction in the sixties and is therefore in need of maintenance actions. However, the bathrooms have been renovated previously. Besides it has been shown that the buildings contains a type of concrete which emits radon which results in increased radon levels in some apartments. The energy efficiency of the buildings also needs to be improved.

Building envelope

The buildings were typical for the sixties with a concrete structure and exterior walls of 0.20 m of light concrete and 0.12 m of bricks. Behind the balconies the walls were infill walls. There was 0.125 m of insulation on the roof slab and the roof was flat. The windows were double pane windows.

The apartments were perceived as drafty and had a poor indoor thermal comfort due to leaky infill walls. The balconies constituted thermal bridges.

The brick façade was partly destroyed by corroding reinforcement.

Architecturally the wish was to preserve the impression of the façade.

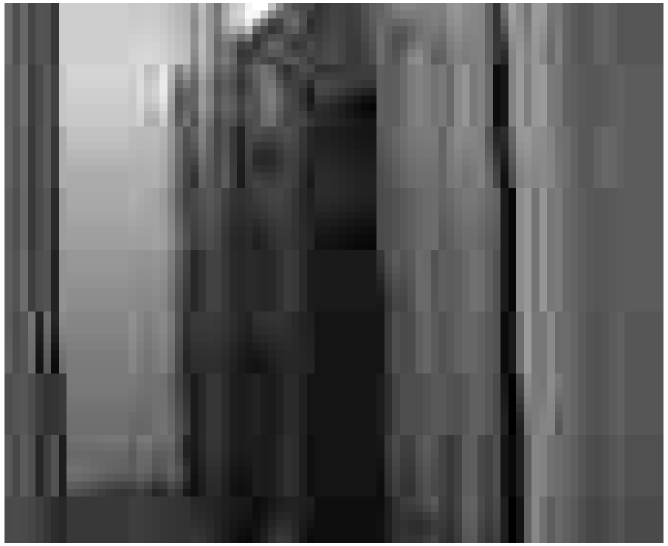
Heating, ventilation, cooling and lighting systems

The buildings are heated by district heating. In each apartment there are radiators under the windows. Domestic hot water was also heated by district heating. District heating is renewable to 95%.

The apartments were ventilated by a passive stack ventilation system, one passive stack in each bathroom and one in each kitchen.

The staircase lighting was of energy inefficient type.

Before renovation



Before renovation – basement storerooms

Element	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade, behind balcony	0.82	0.43
Roof	0.35	0.08
Windows, average	2.70	1.00
Doors	2.70	1.40

Energy renovation features

Energy saving concept

The aim was to combine a maintenance renovation with a 50 % reduction in energy use.

Building

- Adding thermal insulation to the roof and the infill walls behind the balconies.
- Raising the roof from being a flat roof to a ridged roof.
- Improving the airtightness from 1.4 l/sm² to 0.5 l/sm² at 50 Pa. All apartments were tested.
- Replacing the windows with triple pane windows.

Systems

Heating:

- Installation of new thermostatic radiator valves and adjustment of the heating system.
- New substations for district heating.
- New district heating culverts between the buildings.
- New energy efficient washing machines connected to district heating.

Ventilation.

- Installation of a centralized balanced ventilation system with counter flow heat-exchanger. The heat exchanger efficiency is 80 %.

Lighting:

- Installation of low energy lighting for fixed lighting i.e. compact fluorescent tubes.

Element	After renovation
Exterior walls	Adding 45 mm of insulation to the infill walls
Roof	Adding 400 mm of thermal insulation to the roof
Windows, average	Triple pane
Doors	New doors

Renewable energy systems

No renewable energy systems were introduced. The buildings already used district heating based on 95 % renewable energy.

Other environmental design elements

Installation of ventilation ducts in the new attic and new washing machines in the common laundry room.

Achieved energy savings, CO_2 reductions and Costs

Energy consumption for heating, hot water and property electricity before and after renovation:

Calculated energy consumption:		
before renovation:		145 kWh/(m²·year)
after renovation:		92 kWh/(m²·year)
calculated savings:		53 kWh/(m²·year)
Actual energy consumption measured over a 12 months period:		
before renovation:	normalized	145 kWh/(m²·year)
after renovation:	normalized	92 kWh/(m²·year)
actual savings:		53 kWh/(m²·year)
BBR2012 (building code requirement for new construction)		90 kWh/(m²·year)

As 95 % of the district heating is renewable energy the reduction in CO_2 emissions is small or even slightly increased due to the new ventilation system.

Renovation Costs

Craftsmen	≥ 20 mio SEK (2.25 M€)	≥ 4400 SEK/m²* (495 €)
Total incl. VAT	22.2 M SEK (2.5 M€)	4900 SEK/m²* (550 €)
NPV (assumptions: cost of capital 4.25 %, calculation period 12 years, energy price increase 3 %/year) The owner applies the profitability requirement of 5 %.	13 M SEK (1.45 M€)	2900 SEK/m²* (325 €)
NPV if no renovation * Net floor area or residential floor area.	7.35 M SEK (0.825 M€)	1.625 SEK/m²* (180 €)

New cooker hood.

Calculated energy savings

Energy savings thanks to reduced transmission losses, heat recovery and reduced use of domestic hot water are 280 MWh or 62 kWh/m²·year. However the use of electricity increased by 41 MWh or 9 kWh/m²year, caused by the new ventilation system. Measured energy use is similar to calculated.

New windows and entrance

Overall improvements, experiences and lessons learned

Energy

Annual savings 53 kWh/m^2.

Indoor climate

- Improved thermal comfort and indoor air quality

Economics

The costs can be divided:

1) Energy saving measures,
2) Improved standard of the apartments paid for by the tenants (new common laundry rooms, renewed staircases and storerooms etc.) with a 15 % average rent increase,
3) The maintenance cost for the buildings, in any case needed.

Decision process

According to information received there were no major barriers. The board of HFAB made the decisions according to the interest calculated for costing purposes. The decision paths were reasonably short.

Co- benefits

- Better indoor climate
- The old entrance doors to the apartments were replaced with new safety entrance doors
- New surface finish of staircases
- New burglar proof storerooms
- New common laundry rooms
- Glazing of balconies
- Improved surroundings
- Improved status of the area

Economic consequences for the tenants (2011)

Rent before: 77 €/m^2/year íncl. space heating and dhw

Rent after: 88 €/m^2/year incl. space heating and dhw

Rent increase: 11 €/m^2/year

Energy savings: 239 MWh/year

Energy price: 105 €/MWh

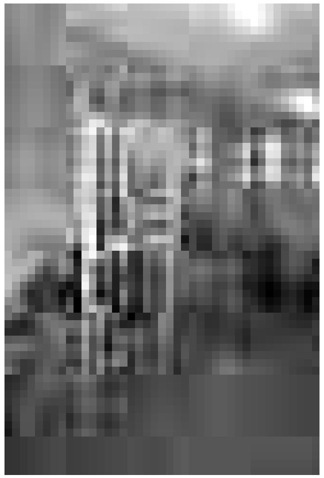
Energy savings: 5.6 €/m^2/year

Users evaluation

The tenants were most satisfied with the glazing and widening of the balconies.

The tenants perceive that:

- Draughts have been completely eliminated from external walls and windows.
- The room temperature is more comfortable.
- Less noise from outside
- The towels dry faster in the bathrooms.



After renovation – basement storerooms

Renovated staircase with new safety doors and new energy efficient lighting.

Summary

Summary of project

A maintenance renovation was needed. The results were substantial improvements in the standard of the building and at the same a reduction in energy use with 35 %, while keeping a similar architectural appearance. This was done using traditional building materials and with common contractors.

The tenants have appreciated the improvements in thermal comfort, indoor air quality and noise climate. The tenants were however most satisfied with the glazing and widening of the balconies.

The tenants were satisfied with the overall renovation, which was carried out without evacuating the tenants.

The dialogue with the tenants has to be prioritized before and during a major renovation. A questionnaire among the tenants showed that what is most important to the tenants is security and safety. Many tenants are against changes which result in a too big an increase in rent.

During the renovation it is useful to have a renovation “host”, who the tenants can address.

The contract for the building construction was a divided contract, which had some coordination problems. It might be that partnering is more suitable for major renovations. Partnering implies that the property developer, the consultants, the contractors and other key operators collaborate to complete a construction task.

Prospect for future renovations

Currently other buildings in the same area are being renovated in a similar way. This time improvements in cost efficiency have been made. Good solutions were found during the initial renovation for e.g. window details, electrical installations.

The level of renovation in this project would make technical and financial sense in many buildings built during the sixties and seventies.

Renovated building.

References

[1] Mjörnell, K., et.al. 2011, Milparena – Million homes program arena Innovative action proposals for renovation of the building envelope and installations (in Swedish), SP Rapport 2011:39, Technical research institute of Sweden

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[2] Nihlén, M., 2012, Half the energy use after step by step renovation (in Swedish), VVS Forum nr 12.2012.

18. Les Charpentiers, Morges

Project summary

Energy concept: Insulation, ventilation with heat recovery, passive solar facade

Background for the renovation:

The goal is to renovate a building aged 45 years and to reduce the heating demand by 90 % (estimation before measurements). The energy related renovation measures are:

- Improvement of the facade and roof energy efficiency (insulation – windows)
- Reduction of ventilation heat losses by adding a mechanical ventilation with heat recovery. Each apartment has its own air handling unit (AHU)
- Use of innovative system for heating and domestic hot water distribution (instantaneous water heaters with heat exchanger)
- Improvement of lighting efficiency in common areas

Site:	**Morges, Switzerland**
Altitude:	373 m
Heating degree days:	2375 (12/20 ºC)
Cooling degree days:	-
Owner:	Caisse de pension COOP
Architect:	Patrick Hellmüller (Renovation)
Engineer:	Swissrenova

South and East facades - Before renovation

After renovation

Contact Person:	**Mr. Sergio Viva** Caisse de pension de la COOP
Renovation started:	2010
Renovation ended:	2012
Data collection:	Winter 2013

Building description /typology

- 5-storey with 61 / 59 flats (before / after)
- Year of construction: 1964-65
- GHFA: 4280 /4836 m2 (before / after)

Building envelope, heating, ventilation, cooling and lighting systems before renovation

Description of the building and its situation before renovation

The five-storey building is located in the city centre of Morges (Switzerland). The ground floor is a shopping centre and has not been renovated. The remaining storeys are composed of residential apartments. The four first floors were built in 1964-65. The last attic floor was added in the 80th. On the South and East facades there were balconies (covered during the renovation) and the total number of apartments was 61.

Building envelope

Exterior walls with almost no insulation. During 45 years, no renovation work has been performed, so the building needed a complete renovation of the apartments and of the building envelope.

Heating, ventilation, cooling and lighting systems

The energy source was gas. The boiler and the DHW storage were located in a technical room. For each apartment, one water distribution system provides energy for heating and for DHW.

The flats were equipped with an exhaust ventilation from the bathroom and kitchen (simple exhaust ventilation).

No special lighting system was used and no cooling device was installed.

Kitchen before renovation

Living room before renovation

Element	Area m² before/ after	U-Value before renovation W/m²K	U-Value after renovation W/m²K
Façade	817.6 / 1235	0.36 – 3.06	0.13 - 0.34
Windows	1014 / 699	3.13	0.79
Roof (atic)	728.8 / 802.2	0.38 - 0.61	0.20
Roof (terrace)	150.7 / 296.5	1.28	0.13
Floor against exterior	32 / 168.5	1.18	0.15

Energy renovation features

Energy saving concept

- Pre-fabrication of passive solar facade (system gap-solution: www.gap-solution.at)
- A mechanical ventilation system with heat recovery has been installed in each apartment and an individual controller to allow tenants to reduce the electrical demand of the AHU
- Individual heat meter to make tenants more responsible of their heat consumption
- LED for common areas

Building

The renovation of the building thermal envelope was obtained by adding a pre-fabricated module on the existing facades and balconies. This solution increases by 14% the total heated gross floor area while the apartment size is increased by 22%. In addition, the heat losses through thermal bridges are dramatically reduced.

In each apartment, heat is distributed through a single system. In the bathroom, this heat is primarily used for the heating system (single radiator). If DHW is required, the heat is redirected to a heat exchanger to heat the domestic cold water (Swiss frame system).

The kitchen and bathroom facilities were completely renovated

Systems

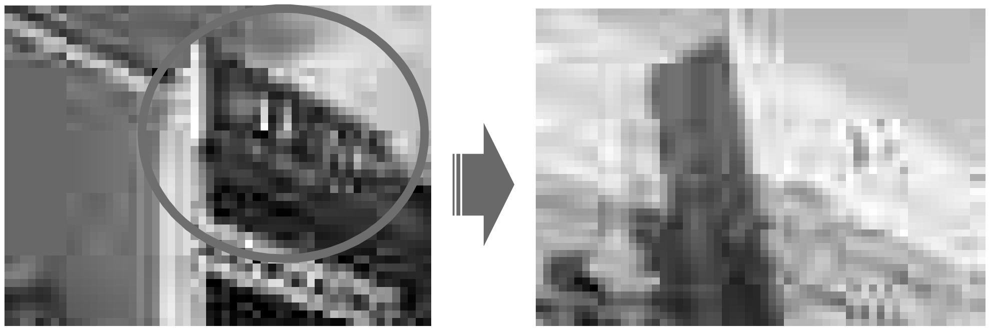
Heating: Gas cogeneration (12 kW_{th} and 5 kW_{el})

Cooling: -

Ventilation: AHU with a heat recovery system

Lighting: LED (for common areas like corridors)

Element (only Block A)	After renovation
Façade	Concrete 200 mm / Mineral wool 180 mm / GAP module
Windows	2-layer low-energy windows + 1 external glass with PVC frame
Roof (attic)	Mineral wool 160 mm / Mineral wool 300 mm
Roof (terrace)	Concrete 200 mm / Mineral wool 300 mm / Bitumen sheet 5 mm
Floor (above heating zone)	Plaster 50 mm / Mineral wool 20mm / Concrete



Pre-fabricated solar facade system from gap-solution

Achieved Energy Savings, CO_2 reductions and Costs

Energy consumption for heating before and after renovation:

Total gas consumption (heating)

Before renovation (mean value 2008 to 2009):	424 MWh/year
After renovation (First heating season 2011-2012):	43 MWh/year
Energy savings (heating):	381 MWh/year

Electricity consumption (corridor lightning, lift, laundry, pumps, ventilation):

Before renovation *	19.2 MWh/year
After renovation †	32.4 MWh/year
Energy savings:	-13.2 MWh/year

* No ventilation

† Ventilation with heat recovery

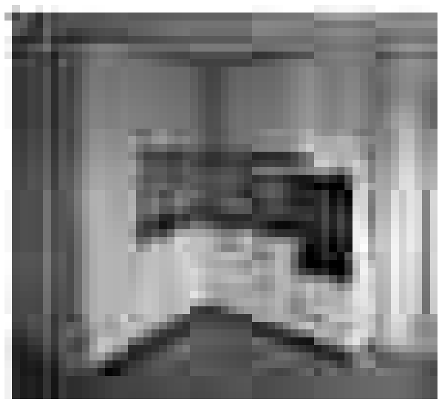
New prefabricated modules during the renovation

Energy savings

The ratio of the heating demand before and after renovation is more than 10. Thus, the annual energy saving is around 380 MWh (117 tCO_2-eq).

The increase of electricity demand is mainly due to AHU added.

Renovation costs and LCC (NPV)		
Craftsmen	7.67 million €	1585 €/m^2
Consultants	0.73 million €	150 €/m2
Total	8.40 million €	1735 €/m2
NPV	21 Years	5%



Kitchen after renovation

Renovated facade

Overall improvements, experience and lessons learned

Energy

Annual savings: 381 MWh, 79 kWh/m²

Heating demand reduction: ≈90%

Indoor climate

- Better external noise insulation
- Improved IAQ (No discomfort about ventilation noise)
- Improved thermal comfort during the heating season
- No thermal discomfort during summer

Economics

In terms of investment cost, about 40% are due to improvements of the thermal building efficiency. The remaining amount concerns the replacement of the sanitary facilities, kitchen, lift and the change in the configuration of the apartments.

Rents have increased (+ 16%/m²) but remain within current market value.

Decision process – barriers that were overcome

The challenge was to perform the renovation keeping the largest possible number of tenants. Some tenants have been moved several times.

Co-benefits

- Better comfort (noise, thermal)
- New apartment, new sanitary and kitchen facilities
- Larger living floor area

Indoor climate

Practical experiences of interest for a broader audience:

The tenants are satisfied with the improved of facilities, kitchen, bathroom and the refurbish of the apartments.

There are no more balconies but on the other hand they were used only as a storage place.

The fan speed of AHU could be selected by each tenant to fit the desired comfort.

Improved sound insulation is so good that the inhabitants have become accustomed to silence.

Users evaluation

A survey of occupant satisfaction has been sent to all tenants. Regarding thermal comfort, results are as follows:

- 76% comfortable to very comfortable
- 21% moderately comfortable
- 3% uncomfortable

Economic consequences for the tenants

Rent before: 187 €/m²/year

Rent after: 223 €/m²/year

Increase: **36 €/m²/year**

Energy savings: 381 MWh/year

Energy price: 73 €/MWh

Savings: 381 x 73=27.813 € = **7,3 €/m²/year**

Summary

Summary of project

Different aspects were analysed and measured:

- U-value of the renovated facade
- Energy consumption for heating and domestic hot water production
- Thermal comfort during several representative periods
- Efficiency of the ventilation heat recovery
- Ventilation's noise distribution in apartments
- Air quality (CO_2 and VOC)
- General feeling and behaviour of tenants (opinion survey)

The combination of the thermal envelope renovation and the addition of the individual ventilation system has led to a reduction by a factor of 10 in the energy consumption while providing an excellent comfort.

Aerial view of the building

Experiences / lessons learned

This project was able to show:

- Only one radiator per apartment can be considered
- Reductions by a factor of 10 in the heating energy demand can be achieved
- For the building owner, it is essential to renovate with tenants into the building in order to keep as many as possible. Thus, a great attention is given to communication with tenants and management of successive removals. After renovation, half of the initial number of tenants remained in the apartments.
- The role of caretaker is important for inform tenants regarding the use of the ventilation system and the concept of low consumption building. It is always possible to open the windows contrary to popular belief.

References

[1] S. Citherlet, J. Bony, O. George: Projet Reno-HP, Installation technique décentralisée pour la rénovation à haute performance de bâtiments, OFEN, final report: November 2011, additional report: Dec. 2012.

Co-benefits

Several terms are used in the literature for side-effects that arise from building renovation such as co-benefits, non-energy benefits (NEBs) and multiple benefits. The term co-benefits is used in this Annex 56 report to represent the benefits of energy related renovation measures beyond the impacts of energy, energy price, CO2 emissions and renovation costs. These co-benefits can have a significantly value and are most often disregarded and that is why the full value of renovation work is often underestimated.

In Annex 56 the following co-benefits are considered: 1) Thermal comfort, 2) Natural lighting and contact with the outside environment, 3) Improved air quality, 4) Reduction of problems with building physics, 5) Noise reduction, 6) Operational comfort, 7) Reduced exposure to energy price fluctuations, 8) Aesthetics and architectural integration, 9) Useful building areas, 10) Safety (intrusion and accidents), 11) Pride, prestige, reputation and 12) Ease of installation.

An analysis for the valuation and integration of co-benefits in the decision making process is performed from the private perspective (user/promoter/owner). It is therefore relevant to identify and evaluate all the effects that arise from different renovation measures. Furthermore, survey on existing and ongoing studies about the co-benefits from the societal perspective are made, in order to deliver a report targeted for policy makers to provide these with knowledge and tools to develop a more comprehensive rationale for energy efficiency policies and programmes.

It is one of Annex 56 goals to evaluate possible forms of integrating co-benefits on the methodology for cost effective energy and CO2 emissions optimization. However, these benefits are often difficult and nearly impossible to quantify and measure accurately, which makes it much more difficult to add their contribution into a traditional cost-benefit analysis. Some of the co-benefits occur as a consequence of reduction of energy consumption, CO2 emissions and costs respectively while others occur as a side effect of the renovation measures (e.g. less noise if change of windows).

Many issues determine whether occupants find energy retrofitting to be successful. The co-benefits in the case studies include a big variety of issues e.g. better indoor climate, comfort and architecture.

All of the renovation projects discussed in the following table have been initiated mainly because of other reasons than the reduction of the energy demand. The energy renovation was most often an addition to an anyway renovation of the buildings.

Positive experiences might, if communicated to building owners or tenants help to overcome some of the barriers that homeowners and housing associations are experiencing.

Country	Designation	Co-benefits from energy related measures	Benefits from non-energy related measures
Austria	Kapfenberg	— Improved thermal quality by reduction of thermal bridges — Better indoor climate by mechanical ventilation sys-tem with heat recovery — Renewal of old heating and domestic hot water systems improve the operational comfort by a new centralized and automatically controlled system	— Barrier-free access to all flats by the installation of an elevator and an arcade — Changed layout of the flats enables new modern living with operable windows to both, east and west, sides — New and larger balconies for all flats: — Improvement of the reputation of the building — New functional area for the residents
Austria	Bruck an der Mur	— High thermal comfort in summer — High thermal comfort in winter — Acoustic comfort — High ratio of daylight — Possibility of natural ventilation	— Barrier free access to all parts of the building
Czech Republic	Kaminsky	— Comfort of the users (students and staff) e. g. the new equipment is easier to use and maintain	— New possibilities for active spending of leisure time for students and general public are open thanks to the new sport facilities — Overall improvement of people‘s perception of the building and surroundings
Czech Republic	Koniklecova	— Improved user comfort of the tenants as new equipment, windows, doors, etc. are easier to use and maintain than original ones.	— Aesthetic perception of the building and its surroundings has improved — Renovation of the building was related to other works - renovation of surrounding pavements, playgrounds, etc. – which also had positive impact on the living conditions

Country	Designation	Co-benefits from energy related measures	Benefits from non-energy related measures
Denmark	Skodsborgvej, Virum	— The family can place furniture etc. close to the wall without risking damages (mould) and draught — This investment ensures that the family can afford other investments in the future	— The roof-construction has been checked, and it is clear that it is a good construction which will last for the next 20 – 30 years — The useable space (first floor) has increased, i.e. the family will use the rooms upstairs far more
Denmark	Traneparken Hvalsø	— New ventilation system and better indoor climate	— New green surroundings — New balconies
Denmark	Sems Have, Roskilde	— Improved architecture — Improved indoor climate — New lighting in the staircases — Saved CO2 due to the conservation of the concrete structure — New sewer system, new- cold and hot-water system and new electrical system	— Up-to-date affordable apartments which can be rented out — New kitchens and bath-rooms — Improved surroundings — Prestige: nominated to a renovation award — Elevator to apartments in block A — Balconies for some apartments
Italy	Ca' S. Orsola, Treviso	— Radical renovation that transformed a historic building in a prestigious and comfortable residence — Better living conditions with more qualified living spaces — Reached acoustic first class according to national standard	— Aesthetical improvement returning the identity of the original building and increasing the market value — Improved structural conditions in an uninhabited and listed building by implementing a seismic consolidation
Italy	Via Trento, Ranica	— Improved mean radiant temperature, due to the radiant floor and the highly insulated envelope — Improved acoustic features — Improved IAQ due to the mechanical ventilation system — Improved control of light and of comfort mitigation in summer due to the new shading devices	— Addition of a floor providing a professional office for the owner — Achieved water savings due to the installation of a rainwater recovery system for garden irrigation

Country	Designation	Co-benefits from energy related measures	Benefits from non-energy related measures
The Netherlands	Wijk van Morgen, Kerkrade	— Reduced exposure to energy price fluctuation — The housing association has considerably enlarged the economic and technical "life time" of the housing complex	— Overall status of the area has improved
Portugal	Pontes Country House, Melgaço	— Renovation measures returned the building living conditions, with levels of thermal and acoustic comfort and air quality consistent with current requirements — Focus on energy consumption minimization and usage of low embodied environmental impact materials is to be used for marketing purposes, as a sign of pride, prestige and reputation	— Reuse of an abandoned traditional building, with preservation of its architectural value — Development, in an economically depressed region, of tourism activities with sustainability principles
Portugal	Neighbourhood Rainha Dona Leonor, Porto	— Improved thermal comfort conditions with users now able to heat indoor spaces and keep the interior environment within healthy and comfortable temperatures — Improved natural lighting with larger glazing areas in living room	— Aesthetical improvement, returning the dignity and identity of the neighbourhood, reducing the social housing stigma — Better living conditions with more space and more qualified living spaces
Portugal	Montarroio, Coimbra	— Benefits from seismic safety, energy performance and increased floor area that increased: the value of the building and the rent value — Alternative renovation processes allow for new insights on collective energy efficiency	— By renovating towards nZEB goals, the neighbouring owners can realize the potential of their buildings, and be engaged in their renovation — By fostering maintenance practices, local jobs are encouraged
Spain	Viviendas de Corazón de María, Bilbao	— Renovation makes delivering affordable warmth to the poor households easier, and it reduces the risk of energy poverty and cold homes	— Development in a depressed area of the city — Building accessibility is significantly improved

Country	Designation	Co-benefits from energy related measures	Benefits from non-energy related measures
Sweden	Backa röd, Gothenburg	— Repaired façade — Water and sewage systems replaced, hot water circulation installed	— New electrical installation — New bathrooms and kitchens — Change to parquet floor in living rooms and bedrooms — New surface finish in the apartments — Safety doors for the apartments — New extended balconies
Sweden	Brogården, Alingsås	— Better indoor climate — New water and sewage system	— Improved accessibility (ground floor) — New electrical installation — New bathrooms and kitchens — New surface finish in the apartments — New balconies — Larger living rooms
Sweden	Maratonvägen, Halmstad	— Better indoor climate — Glazing of balconies — The old entrance doors to the apartments were replaced with new safety entrance doors	— New burglar proof storerooms — New common laundry rooms — Improved surroundings — Improved status of the area — New surface finish of staircases
Switzerland	Les Charpentiers, Morges	— Better comfort (noise, thermal) — To avoid thermal bridges, the new thermal envelope wraps balconies. So the living floor area increases	— New sanitary and kitchen facilities

Anyway measures

Buildings require maintenance, repair or updates to keep fully functional or in line with the evolving contexts, needs and expectations of the people who inhabit them.

The “shinning examples” portrayed demonstrate that the fulfilment of these needs and expectations, of these actions that would be carried out anyway, often trigger energy efficiency oriented interventions.

In IEA EBC Annex 56 the reference scenario and the energy-related cost-effective renovation options are compared to demonstrate that improvements are easy to reach, and viable in a mid-term scenarios.
For visualizing this potential, several milestones were defined:

1. A reference scenario, the “business as usual” baseline for comparison;
2. The definition of the included / excluded energy related items;
3. The comparison and validation of the process.

Anyway measures, here defined as “a set of actions, products and services necessary to guarantee the regular, safe and legal functioning of buildings, as well as aesthetics, technological and contemporization evolutions that societal changes require of them” are thus essential on defining the baseline – the items accounted in the reference scenario and their costs –, making options comparison possible.

Having in mind that the energy-related optimization costs include all expenses regarding the optimization and related procedures (soft costs), it is fair to deduct from the energy optimization options the “anyway measures” costs that such options do replace, or render unnecessary.

The scope of the “anyway measures” tag includes all the costs that would naturally occur during the expected lifetime of the building, and without which failure would occur. Well performed “anyway measures” increase or maintain the existing building value, and the same can be achieved by well performed optimization interventions.

The “anyway measures” considered in this publication include all the costs that the proposed optimization measures are able to substitute or defer in the existing building. The optimization of the external envelope, applied in all the "Shining Examples" of this brochure, is helpful to explain this approach:

a. Existing buildings’ external envelopes require “anyway measures” that range from regular condition verifications to periodic maintenance or substitution due to wear and tear. These “anyway measures” costs account for scaffolding or other lifting methods to execute the work, workmanship, materials and soft costs. In the end the aesthetics is improved or maintained, and the value of the building increases, or at least does not decrease.

b. An optimization measure using insulation will require similar scaffolding or other lifting methods to execute the work and some of the workmanship and materials that, although eventually different, contribute to the same purpose. Having in mind that these similar goals are achieved, it is fair for the energetic optimization costs to account all the expenses directly related to the optimization measure, subtracted by the values that would happen in the “anyway measures” described in a).

A brief analysis of the examples in this publication is provided to illustrate the accounted “anyway measures” in the following table.

Optimization measure with deductible "anyway measures"	Deductible "anyway measures"	Shining example	Comments
Exterior envelope improvement	— "Wear and tear" are good starting reasons for energy efficiency renovations. Exterior painting, rendering, and scaffolding can be deducted	All "Shining Examples"	— Materials in the end of their useful life expectancy, so the costs of fixing or replacing would occur soon; — The refit of existing accessories (antennas, cables, and other) should be accounted, not deducted.
New radiator system with thermostat valves, Heat Recovery Ventilation; District heating connection; Other new (more efficient) equipment	— Existing radiators, systems and mechanical ventilation ducts that were to be maintained or replaced anyway — The current price of a normal boiler, that would be replace "anyway" where the existing boiler is deductible	All "Shining Examples"	— Maintenance and/or replacement would happen anyway, even if no optimization was performed. — Replacing existing Domestic Hot Water equipment's (gas boilers, electric storage, others) in the end of their lifetime expectancy has a cost that can be deducted from the new (more efficient) equipment.
Low energy fixed lighting	— Low energy lighting evolution, lowering cost and current regulations make it mandatory or unavoidable	All "Shining Examples"	— As incandescent lights are being taken off the market, lighting will be an efficient "anyway measure" when replacement occurs. Lighting fixtures introduced by users choice can´t be controlled.
Measures without relevant energetic optimization impact, thus deductible (performed "anyway" during renovations)	— Water and electrical networks, new kitchens and bathrooms, other aesthetic enhancements	All "Shining Examples"	— Costs related with water and electricity networks, would occur even without energy optimization, as they are frequently replaced for aesthetic reasons or in the end of their useful life expectancy;
Accessibility (barriers reduction to widen the range of building users)	— As accessibilities are mandatory in many regulations, the installation of lifts / other accessibility improvements would have to happen anyway to keep the buildings legal.	Les Charpentiers , Brogården, Bruck an der Mur, Kapfenberg, Montarroio (level p01)	— Lifts are very expensive and energy consuming equipment, but progressively assumed as necessary to guarantee the usability of the building by people of all ages and physical conditions; — Architectural solutions for accessibilities are also considered "anyway measures".

Optimization measure with deductible “anyway measures”	Deductible “anyway measures”	Shining example	Comments
Renewable energy and energy conservation measures (“Factor Four “ savings)	— By reducing the energy losses and improving efficiency, the savings that result from smaller and generally less expensive equipment's are deductible: a solar thermal system reduces DHW heating needs, and the size and type of heating backup equipment	All "Shining Examples". “Montarroio“ details the impact of solar thermal on DHW backup choices	— Solar thermal for DHW reduces the hot water backup needs, making air-water heat pumps a non cost-effective investment; — See “Factor Four: Doubling Wealth, Halving Resource Use” from Weizsacker, Lovins and Lovins, 1998)
Collectively shared services like washing machines	— The costs of the original less efficient solutions would occur “anyway” in the end of their lifetime	Maratonvagen	— In this example hot water is provided from an efficient source (heat pump), relegating the use of electric heating resistances only for backup
Almost “non-deductible” as energy related measures: - Structural strengthening; - additional levels / balconies;	— On extra level expansions, the price of the roof maintenance intervention can be deduced, as it would happen “anyway”	PT_Montarroio, DN_Sems Have, IT_Casola)	— Although not happening “anyway”, these measures are ”added value” that can make the optimization more attractive, or improve financial return; — Prices vary from around 2000€ (DN_Sems Have, IT_Casola) to 450€ (PT_Montarroio), closely related to strategies as the depth of intervention, demolition or reinforcement options and workforce costs.

<u>“Anyway measures” as triggers for optimization opportunities:</u>

- Building materials, equipment and systems affected by: normal ageing, adverse conditions or simple misuse.
- To avoid degraded buildings, a set of maintenance operations are required, ranging from the response to slow decline - **chronic occurrences** - to the emergency resolution of failures - **acute occurrences**.
- Cultural and social expectations also play a role on the users´ decision to change, with potential impacts on the energy consumption, briefly analysed in the subsection “Users expectations and compromise”.

As disruptions to an existing status, “**anyway measures**” are **opportunities towards optimized energy related renovations**.

<u>Chronic occurrences</u>:

- The predictability of the materials natural decay can be used to plan and anticipate interventions.
- Although regular maintenance can extend the useful life of materials, the performance of systems and extend the durability of buildings, this publication demonstrates that cost-effective alternatives for energy related optimization exist beyond simple replacement: **these are opportunities for enhancement**.
- In programmed change situations “anyway measures” assume solutions that are either more recent or represent local trends: if a renewable-based district heating system is available, a system renovation would use this solution.

<u>Acute occurrences:</u>

- In rupture related situations, fast-paced interventions to control further damage consist frequently in exchanging the existing system by an equivalent one, usually more efficient due to technical evolution of equipment's, regulations and certification.
- Imagining a gas based water heater failure, its probable replacement would raise efficiency values from 65% to new standards of at least 80% efficiency. “Anyway measures” would hardly include a gas condensing boiler due to the extra space, cost and works that its installation implies; and an air to water heat pump would hardly be recommended by the gas technician.

In this context it is fair to assume that a water heating related optimization measure would deduct the 80% efficiency gas water heater as the “anyway renovation” cost:, thus deductible from the optimization cost.

The surprise of **acute occurrences** does not leave much space for **optimization measures** unless a significant information effort is made with owners, **highlighting and anticipating** replacement alternatives.

<u>Users expectations and compromise:</u>

The relation between the best solution and the users’ choice is not linear, as most of the decisions are influenced by factors as status, availability or simple preference.

To simplify the evaluation, non-energy related “anyway measures” are only accounted if they need to be deduced from bulk final prices of investment.

For instance, the introduction of efficient kitchen equipment is assumed to occur anyway, independently of optimization efforts, but this assumption is not valid when home appliances and personal energy uses are accounted in the buildings’ total energy consumption.

<u>Added-value interventions (extensions, balconies, structural safety)</u>

Some of the “shinning examples” include measures that range from demolition and reconstruction (IT_Casorsola), to simple structural reinforcement (PT_Montarroio), interior space rearrangement (DN_Sems Have) and added balconies in several examples.

These are not common “anyway measures” but they are not energy-efficiency measures, and so they should not be included in the final energy-related intervention costs.
Nevertheless these interventions increase the attractiveness of the buildings, the co-benefits for its users and their market value.

Which measures (RUE/RES balance)

When tackling energy consumption reduction in existing building renovation, two major approaches describe most of the options: those that reduce energy consumption, associated to a Rational Use of Energy (RUE), and those related to supplying the existing needs with Renewable Energy Sources (RES). Many of the Rational Use of Energy (RUE) measures are currently less expensive while including the advantage of reducing the energy that has to be supplied by Renewable Energy Sources (RES), although further evolution in the existing or innovative technologies may alter this cost relation.

This brochure illustrates several examples where energy consumption reductions (RUE) were achieved by improving the performance of the building envelope and recovering heat from the ventilation losses, and others where significant use of solar panels or renewable-based district heating (RES) was used to complement the remaining needs. What both show is that each combination is a direct result from the existing context, the available solutions and sources, and significant integration efforts. Depending on the climate severity, period and quality of construction, and many other factors (see topic Barriers) the buildings behave differently, create different baselines and require different intervention strategies.

Summary table for building envelope improvement

	Wall (U-value W/m².ºC)			Roof (U-value W/m².ºC)			Window (U-value W/m².ºC)		
Location	**Before**	**After**	**Improved by**	**Before**	**After**	**Improved by**	**Before**	**After**	**Improved by**
Bruck, AT	1.32	0.15	89%	0.50	0.11	78%	3.00	1.38	54%
Kapfenberg, AT	0.87	0.17	80%	0.74	0.10	86%	2.50	0.90	64%
Morges, CH	1.20	0.11	91%	1.28	0.13	90%	2.90	0.70	76%
Kaminky, CZ	1.06	0.20	81%	0.72	0.15	79%	3.58	1.90	47%
Konikecova, CZ	0.78	0.17	78%	0.50	0.15	70%	3.43	1.38	60%
Sems Have, DK	0.25	0.25	-	0.26	0.09	65%	2.80	1.00	64%
Skodsborgvej, DK	1.65	0.29	82%	0.90	0.11	88%	2.80	1.40	50%
Traneparken, DK	0.66	0.15	77%	0.20	0.09	55%	2.40	0.80	67%
Bilbao, ES	1.70	0.27	84%	1.50	0.33	78%	4.80	1.40	71%
Casorsola, IT	0.90	0.18	80%	1.09	0.16	85%	2.70	1.95	28%
Ranica, IT	1.10	0.16	85%	0.70	0.14	80%	3.70	1.10	70%
Melgaço, PT	1.82	0.45	75%	4.55	0.23	95%	4.60	2.05	55%
Montarroio, PT	2.04	2.04	-	1.57	0.44	72%	3.22	2.10	35%
Porto, PT	1.38	0.45	67%	2.62	0.64	76%	3.40	2.90	15%
Backa röd, SE	0.31	0.12	61%	0.14	0.10	29%	2.40	0.90	63%
Brogården, SE	0.30	0.11	63%	0.22	0.13	41%	2.00	0.85	58%
Maratonvagen, SE	0.82	0.43	48%	0.35	0.08	77%	2.70	1.00	63%

Many of the RUE measures included the renovation of the boundaries with poor thermal performance (roofs, ceilings, walls, windows and floors with insufficient or no insulation), with particular focus on those in need of renovation due to wear and tear (see topic “Anyway measures”). The improvement of energy conservation noticed in roofs mostly ranged from 65% to 95%, while the ones with smaller improvement are buildings with initial U-values relatively low (~0,20 W/m²ºC). Nevertheless, after renovation, roof performance varies from 0.08 W/m²ºC in more severe climates to 0.64 W/m²ºC in warmer areas.

When looking at wall renovation, improvements ranged from 50% to 90%. It is important to notice that in walls the U-values after renovation vary from 0.11 W/m²ºC to 0.45 W/m²ºC in similar conditions. It was identified 2 cases where no energy renovation occurred in their walls.

In the particular case of windows, the improvements ranged from 15% to 75%, where countries and specific locations with higher demands for heating demonstrate the use of a wider range of high performance windows (triple glazing is rather common).

In most of the examples, the Rational Use of Energy (RUE) measures were taken as a first step to reduce the energy demand while improving the occupants' comfort (see topic “Co-Benefits”), while reducing the amount needed from RES production.

The Renewable Energy Sources approach was implemented in most of the buildings in this brochure either by connecting to existing district heating structures fuelled by biomass or garbage combustion, or using biomass based heating systems. Many also included solar thermal panels for domestic hot water and/or heating, or solar photovoltaic (PV) panels for consumption or connection to the grid.

Summary table for RES installed

Location	RES measure	Size
Bruck, AT	Photovoltaic	225 MWh
	RES via DH	√
Kapfenberg, AT	Solar Thermal	40 MWh
	Photovoltaic	80 MWh
Kaminky, CZ	Photovoltaic	72.5 MWh
Sems Have, DK	Photovoltaic	13 MWh
Skodsborgvej, DK	Solar Thermal	~ 5 sqm
Traneparken, DK	Photovoltaic	38 MWh
Bilbao, ES	Solar Thermal	103 MWh
Casorsola, IT	Photovoltaic	3.7 MWh
	Solar Thermal	~ 20 sqm
	Heat Pump	√
Ranica, IT	Photovoltaic	4.6 MWh
	Solar Thermal	~ 7.5 sqm
Melgaço, PT	Solar Thermal	4 MWh
	Heat Pump	√
Porto, PT	Solar Thermal	50 MWh
	Heat Pump	√
Backa röd, SE	RES via DH	√
Brogården, SE	RES via DH	√
Maratonvagen, SE	RES via DH	√

Country / climate specific measures

The tables on pages 19 and 20 provides an overview of the energy renovation technologies implemented in the 18 Shining Examples.
All cases have had insulation added, most of them on façades and roofs. 17 cases have included new energy efficient windows in the renovation.
Solar heating is exploited either in an active or passive way in 10 of the cases. In most of the cases the heating system was renovated and/or supplemented with renewable energy systems.

Summary of the energy renovation features
Envelope

- All examples increased insulation thicknesses of the building envelope in one way or another. Two Austrian and one Swiss example have changed the facade with new facade elements including active and passive elements or added an extra module for passive solar use;
- 17 cases have new windows or glazing:
  - Southern European countries typically use double layer-glazing, where central and northern Europe use triple layer glazing.

Ventilation, heating system and renewable energy

- 14 cases have added ventilation with heat recovery
- Half (9) of the cases have added solar thermal features mainly for the heating of domestic hot water;
- 7 cases have installed PV-plants – only one of them in southern Europe
- Half (9) of the cases have improved their lighting by LED technology or other efficient lighting systems;
- Half (9) of the cases have new or improved heating distribution systems such as thermostatic valves, insulation of pipes, new circulation pumps, weather compensation or implemented individual meters;
- 13 of the 18 examples have changed or improved their heat supply:
  - Three of the examples have solar heating as supplement for space heating
- Four heat pumps have been installed:
  - Two have installed water-to-water (ground coupled) heat pumps
  - One example has a reversible heat pump with boreholes for cooling in the summer and heating in the winter
  - One example has air-to-air heat pump (also working as air conditioning system)
- Four new gas boilers were installed - and one example has a gas driven CHP system.
- Two have installed wooden stoves for heating and either cooking or domestic hot water, and one has biomass district heating.
- One has installed a new district heating substation.

Country and climate specific cooling and exploitation of solar energy
Three examples have implemented some kind of cooling system: One of them is a “classic” air conditioning system. This is one of the South European examples (Portugal), where the summer is quite hot. In this case the window area has been increased, improving the use of daylight and increasing heat gains, which are useful during winter. On the other hand, the increase in window area also led to higher heat gains during summer and the necessity of dealing with cooling needs. Also, in this example heat recovery of the ventilation air is not applied due to the low savings potential because of the relative mild winter in this region of Portugal.
A cooling/heating system in Austria consists of a ground source heat pump with deep drillings.

All 6 examples in Southern Europe have solar thermal systems for domestic hot water, whereas only 3 central- and northern cases have hot water supply from solar thermal systems.

One Austrian, one Dutch, one Portuguese case have solar thermal system for space heating. All 3 cases in Austria and Switzerland have active or passive façade elements to collect passive solar heating.

The relatively extensive use of solar heating systems for space heating in the central European countries may be explained by a comparatively better coincidence of heating demand and available solar radiation.

Surprisingly only one of the 7 cases with PV-plants is in southern Europe. Maybe this is due to low electricity prices and/or low feed-in prices: In Spain it is explained by the existing regulation.

Types of features installed in the project buildings

Energy renovation features		**Insulation**	**Windows (and/or doors) glazing**	**Mechanical ventilation**	**Solar thermal**	**PV**	**Efficient lighting**	**Air condition/ cooling**	**New/improved heat distribution system or DHW system**	**New heat supply**
Rainha Dona Leonor, PT	A	1, 2	6		9			√		14
Pontes Country House, PT	A	1, 2	6	22	9		√		23	15
Montarroio, PT	A	32, 33			9, 10			Ice-production		31
Viviendas de Corazón de Maria, Bilbao, ES	A	1, 2	6		9		√			19
Ca`S. Orsola, Treviso, IT	A	1, 2	6	21	9	√				34
Ranica, IT	A	1, 2	7,37	36	9					35,19
Kapfenberg, AT	B	1, 2, 3, 4, 5	7	21	8,9	√				16
Bruck an der Mur, AT	B	1, 2, 3, 5	7,37	22		√		39		38,39
Les Charpentiers, CH	B	1, 2, 5	7	21			√		20	17
Wijk van Morgen, Kerkrade, NL	B	1, 2, 3	7	21	9, 10	√				18
Koniklecová 4, CZ	B	1, 2	7	28			√		24, 25, 26, 27	
Kaminky 5, CZ	B	1, 2	6, 7	21, 29		√	√		30	
Backa röd, SE	C	1, 2, 3	7	21			√		11	
Brogården, SE	C	1, 2, 3	7	21			√		12	
Maratonägen, SE	C	1, 2	7	21			√		40, 41, 42, 43	44
Skodsborgvej, Virum, DK	C	1, 2	7	21	9				13	19
Traneparken, Hvalsø, DK	C	1, 2, 3	7	21		√				
Sems have, Roskilde, DK	C	2, 3	7	21		√	√		46, 41	45

(1) Exterior walls insulation
(2) Roof insulation
(3) Ground floor/basement ceiling/basement wall insulation
(4) Active facade elements
(5) Passive facade elements
(6) Windows with double glazing
(7) Windows with triple glazing
(8) Solar thermal
(9) Solar thermal for DHW
(10) Solar thermal building integrated
(11) New radiators and thermostat valves – individual metering of DHW. Already district heating based on 80 % renewable energy.
(12) Individual metering of DHW and electricity. Replacing radiators with heating coils in the supply air. Already district heating based on renewable energy.
(13) New thermostat valves – insulation of pipes Weather compensation and night set back
(14) Air to air heat pump
(15) Ground coupled heat pump
(16) Local district heating and solar thermal panels
(17) Gas driven CHP system
(18) Solar thermal system coupled with condensing gas boiler
(19) New condensing gas boiler
(20) Individual meter
(21) Mechanical ventilation with heat recovery
(22) Mechanical ventilation with heat recovery and free cooling
(23) New wall radiators
(24) New circulation pumps with electronic regulation
(25) New valves
(26) Weather compensation set with electronic sensors
(27) New measuring and regulation equipment
(28) Partly renovation of ventilation system
(29) Individual ventilators installed
(30) Retrofitting heating and DHW system
(31) Wooden stove for heating and cooking
(32) Insulation only in top- and bottom limits
(33) Thick walls used for thermal storage
(34) Water to water heat pumps and chillers
(35) Wood stove for space heating and DHW
(36) Mechanical ventilation system with heat recovery and geothermal preheat
(37) Shading
(38) Biomass district heating
(39) Refrigerator/heat pump with deep drillings to cool in summer and heat in winter
(40) New thermostatic valves and adjustment of heating system
(41) New substations for district heating
(42) New district heating culverts between the buildings
(43) New energy efficient washing machines connected to district heating
(44) Already district heating based on 95% renewable energy
(45) New district heating substation
(46) New radiator circuit and DHW tanks

South Europe	A
The Alps and Central Europe	B
North Europe	C

Barriers & Solutions

The implementation of energy renovation projects in the building sector is not just a technical and/or economical matter. It involves the users/inhabitants/owners of the buildings, who, in some cases, have to vacate the buildings for the renovation for a shorter or longer period of time. Additionally, those who pay for the energy renovation are not always those who benefit from it. Therefore, energy renovation projects often run into barriers that may hold up the project. It is then a must that owners, technical consultants and policy makers find solutions to overcome these barriers. In a pre-study on barriers and solutions carried out in the context of this work, four different categories of barriers were identified:

- Information issues
- Technical issues
- Ownership issues
- Economic issues

The "information issues" can include either confusing information, i.e. different opinions expressed by different professionals, or incomplete information. It can also be lack of clear requirements, lack of inspiration or lack of knowledge about possibilities, potential benefits and added values.

The "technical issues" are mainly related to lack of well proven systems and lack of complete solutions consisting of packages of technologies.

The "ownership issues" generally have to do with who has to pay for the investment in energy renovations and who saves the money – not always the same person(s).

The "economic issues" can be as simple as too high investments needed, which often are also coupled with lack of incentives. Additionally, there may be uncertainty as to how much money can be saved from the energy renovation (sometimes just the comfort is improved) and finally, lack of economic understanding or knowledge.

Barriers and solutions observed in the 18 Shining Examples

The barriers met in the energy renovation process of the 18 Shining Examples and the solutions to overcome them. They include a combination of different barriers such as: information, economic and ownership/user issues. Tenants in rented apartments are often in focus as critical elements in the renewal process as for example in the Swiss case, where it was important to keep the largest possible number of tenants in their apartments during the renovation. In Denmark, tenants came into play in a different way as the democratic requirements in the Danish housing rent laws demand that tenants vote for the energy renovation before it can be initiated.

Designation	Barriers	Solutions
Bruck an der Mur	— Originally it was planned to renovate the pilot project with prefabricated timber elements with solar comb for passive solar gains. But due to the demands in fire protection no timber façade was possible.	— New metal façade elements with integrated solar comb had to be developed. This development required a close cooperation of all involved which increased the planning effort and also the costs of the renovation.
Kapfenberg	— The financing of the renovation was a barrier because, due to governmental regulations, it was not possible to excessively increase the rental prices for the apartments;	— Other funding and financing solutions were necessary to realise the renovation;
	— Additionally, the renovation works inside the building, such as the change of the layout, made a temporary resettlement of the residents necessary.	— Due to the fact that there were no apartments available in Kapfenberg at the time of the renovation, this process could only be put into practice in two different construction phases in order to guarantee the residents an apartment during the renovation period.
Kaminsky	— Originally, the idea was to install mechanical ventilation in the whole school, but not enough funds were available.	— The mechanical ventilation was therefore not incorporated into the design.
Traneparken, Hvalsø	— There were practical administrative barriers to convince the tenants that is was a good idea to carry out the energy renovation.	— These barriers were overcome without too much trouble by thoroughly informing the tenants about potential benefits and added values of the project.
Sems Have, Roskilde	— It is a challenge to upgrade existing buildings to contemporary and future-proof apartments especially if the new design uses other module lines etc. than the original design. The concrete structures (including decks) were maintained, however, this made it difficult to comply with modern requirements regarding acoustics.	— The problems with the acoustics couldn't be solved
	— PCB, asbestos and paint containing lead had to be removed from the building and safely deposited.	— The PCB, asbestos and old paint was removed and deposited
	— The Housing Association experienced difficulties in obtaining approval from the municipality to change the status of the buildings from dormitory/day-care centre to residential.	— The building association had to make a cost-benefit analysis to show that it was meaningful to change to another use. This was based on a technical report on the actual state of the building before renovation, including a proof that the load-bearing structure was adequate for the new use.

Designation	Barriers	Solutions
Ca' S. Orsola, Treviso	— The major barrier was related with the bureaucracy for obtaining the permission by Historical and Architectural Heritage Superintendence of Veneto. — High costs	— The investment costs were incurred by the contractor, that is also the owner. — Themes such as sustainability and energy retrofitting were understood and applied.
Pontes Country House	— Obtaining the building permit from the municipality and from national tourism entities is still a time consuming process that causes delays and doubts for the business plan;	— In this process, this barrier was not overcome;
	— With respect to the investment costs, the building owners not always understood the unconventional nature of the renovation project and, therefore, expected only conventional costs, both for the renovation works and for the consultants.	— This barrier was overcome giving substantial information to the owners about potential benefits and added values of the project.
Neighbourhood Rainha Dona Leonor	— The lack of financing to carry out the works at once was a big barrier;	— The works have been divided in several phases over several years;
	— Strong discussion whether the best solution was to renovate or to demolish and transfer tenants to other buildings;	— The decision has been of political nature. Benefits from energy related measures were not considered and could have helped the decision process.
	— The need to have the buildings vacant to carry out the renovation works.	— Vacant dwellings from other neighbour-hoods have been used to temporarily house the tenants.
Montarroio, Coimbra	— Obtaining permit for the building renovation	— The IEA EBC Annex 56 methodology, commonly developed during the evolution of this process, was important by providing means to visualize options to municipal stakeholders, thus helping them to understand the individual and collective implications.
Corazón de María, Bilbao	— The main barrier was the low income profiles of the residents. This was linked to the other significant barrier, which was the residents' reluctance to carry out the renovation works only under energy motivations. Improving the building accessibility (lift installations, moreover) was the main incentive for the tenants.	— This was overcome thanks to funding sources obtained from the public administration, (funding given with the aim of boosting the energy renovations).

Designation	Barriers	Solutions
Brogården, Alingsås	— A delay was caused by poor project management. The preservation of the area and accessibility questions took much time in the planning process;	— The project management was replaced;
	— The energy issues were first almost neglected.	— A person was put in charge of the energy issues.

The barrier observed in one of the Swedish projects was related to poor project management in the early phase, which obviously underlines the importance of a good plan from the start when a new renovation project is initiated.

In Portugal, the financing was a barrier in both cases and also in both, the lack of knowledge by some stakeholders and different opinions among involved partners, were issues necessary to deal with.

In all cases, the solutions found to overcome the barriers met were quite straightforward and can be summarized in one word: "perseverance". Many of these projects could not have been implemented if a single person or team had not taken ownership of the project and had fought for their completion.

Conclusions

The overall conclusion from the analysis of the 18 Shining Examples is that for 7 of these there were apparently no barriers worth mentioning. For 7 of them, the barriers were mainly of administrative matter – for example delay caused by poor project leadership. For 6 of the cases, the economical/ financing issues created barriers causing problems and delays. This conclusion differs somehow from the result of a questionnaire carried out earlier among the participants in this project where the lack of information and lack of economic incentives were mentioned as barriers for, respectively, all of the case-studies and in 9 of the 10 countries that answered the questionnaire. This may be explained by the fact that these are general barriers, which block the carrying through of energy renovation projects, whereas in the 18 Shining Examples presented here they were obviously overcome.

The Shining Examples documented may be characterized as forerunners and therefore not typical energy renovation projects, which may explain the fact that only few of the general barriers identified in the questionnaire are represented.

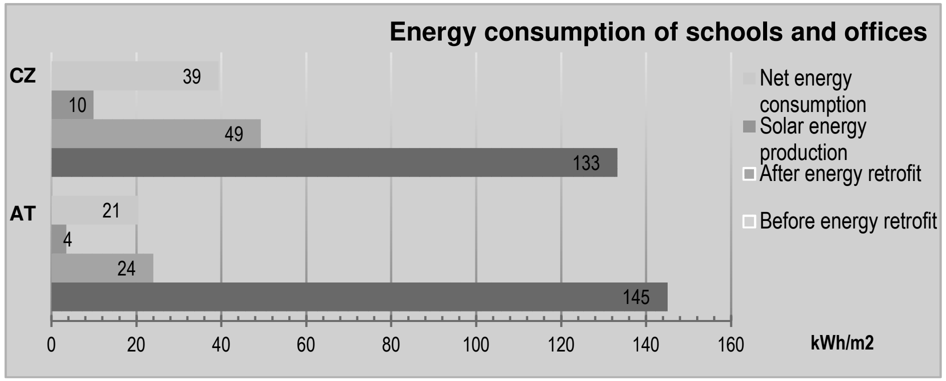
Conclusion – reached energy savings

One of the reasons for collecting the Shining Examples was to show building owners what energy saving potential lies ready for harvesting in a variety of building types and climates. In this chapter an analysis of the energy consumption before and after energy retrofit has been carried out In order to create an overview of the impact of the energy saving strategies that has been carried out. This has been done in the following way: The energy consumption before the renovation took place, after the renovation by rational use of energy (RUE) measures, the renewable energy (RE) contribution and the final net energy consumption have been mapped and compared in histograms. Thereby it is possible to evaluate the impact of implementing the RUE technologies and the RE technologies (solar energy) contributions separately and together. The analysis also included an attempt to find out if the energy saving have a climate/location dependent pattern.

The Shining Examples have been divided in three groups: Public buildings (schools & offices), single family buildings and multifamily buildings.

Public buildings

Only two public buildings are studied, The elementary school located in Kaminky, Czech republic and The federal Ministry of Justice of Bruck/Mur in Austria. Both presents a fairly high energy reduction by the incorporation of RUE by a 63% and 83% for the School and the Official building respectively, as it can be seen from Figure 1.



Overview of the Energy consumption before and after energy retrofit for the two Public building cases

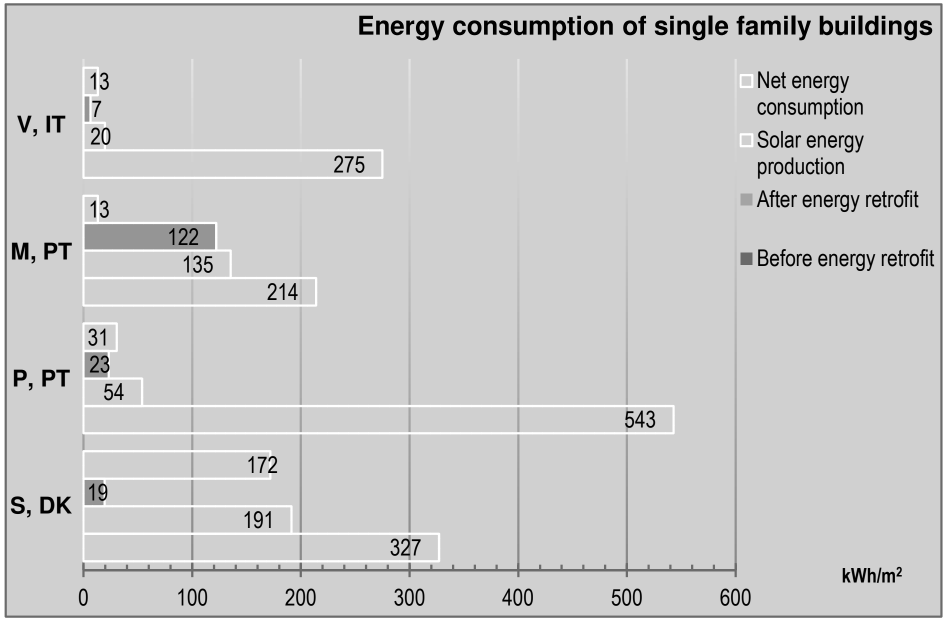
Single-family buildings

Four single-family buildings were analysed, two of them from Portugal, one from Italy and one from Denmark. See Figure 2. One single family house - Wijk van Morgen located in Netherland – did not provide energy consumption data, so it could not be included in the analysis.

By the foreseen use of RUE and RE technologies Montarroio, PT becomes a “Nearly Zero energy building”. Solar thermal and biomass energy supply 95% of the heating and DHW demand after the energy renovation.

Via Trento from Italy and Lugar de Pontes from Portugal present a considerable heating consumption reduction of 93% and 90%, respectively, after the RUE renovation. In addition, solar thermal collectors have been incorporated to the building reducing the heating consumption by additional 33% and 43%.

The single family house from Denmark, shows a heating energy reduction of only 42% after renovation and in addition 10% more is reduced by the incorporation of a solar thermal collectors.



Overview of the Energy consumption before and after energy retrofit for the four single-family buildings.

Multifamily houses

The Shining Examples are predominantly multifamily buildings. The 11 projects are shown in figure 3. The most remarkable heating energy consumption reduction is seen in Switzerland: 83% is reached by the integration of a passive solar façade and a new gas cogeneration system.

Among the Shining Examples located in the South of Europe, Ca'S. Orsola in Italy presents a heating energy reduction from RUE by 77%. The heating demand is provided by geothermal and solar thermal systems. In addition the building has been equipped with a small PV electrical contribution of 2 kWh/m2. The building from Spain stands out by its low energy RUE and RE reduction, since only 50% of the DHW consumption is supplied by a solar thermal system.

The highest percentage of solar energy contribution, both Solar thermal and PV electrical, is found in Kapfenberg, Austria, reducing 48% the total energy consumption after energy renovation by RUE.

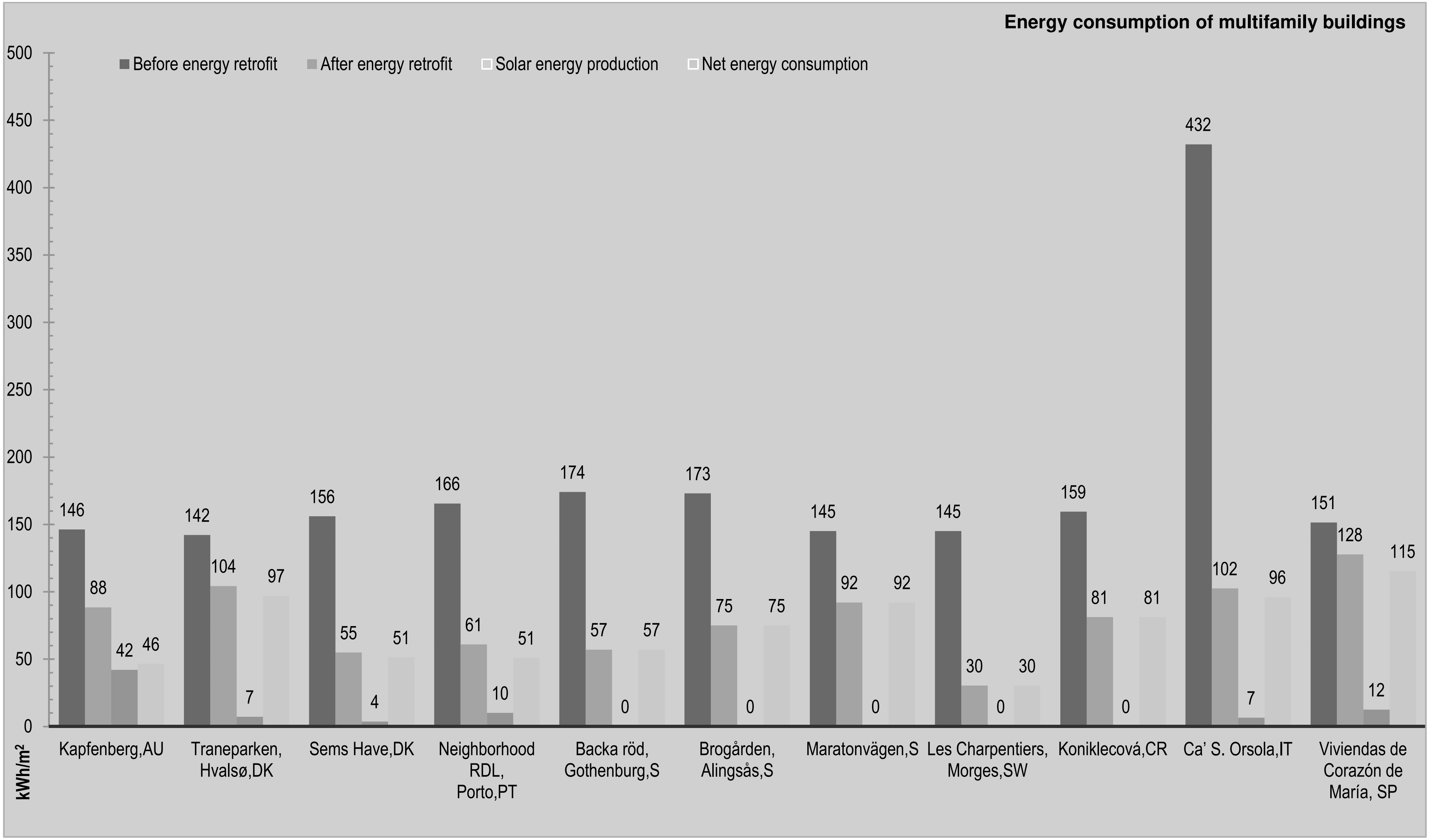
The Shining Examples in Sweden and the Check Republic do not have any RE-system added to the building. However, the total energy consumption has decreased by over 50% by the energy renovation of the building envelope and adding efficient ventilation and lighting features.

Overall energy savings by RUE and RE

For most of the Shining examples the energy reduction reached by implementing RUE technologies lie between 40% and 83% - extremes are 16% and 90%. The RE contribution to the remaining energy demand lies between 7% and 47% - extremes being 0% and 90%. The total energy reductions achieved by the combination of RUE- and RE-technologies are between 40% and 95%. Here the extremes are: 29% and 98%.

Climate and/or location effects

From the analysis of the collected Shining Examples, it has not been possible to conclude anything with respect to the amount of energy reduction reached or the mix of RUE and RE implemented.



Overview of the Energy consumption before and after energy retrofit of multifamily buildings.

Closing remarks

This brochure reflects some renovation examples that are useful as depictions of built realities that, in a way or another, approach the topics under analysis in the scope of Annex 56. This small illustration of “Shinning Examples” demonstrates that a “one size fits all” approach is unviable in the diversity of contexts where a “Cost Effective Energy and Carbon Emissions Optimization in Building Renovation” is needed. Case by case these examples show that the implemented RUE / RES measures were a consequence of local opportunities and constraints, ownership and local laws, and not only a design option.

The Shining Examples documented may be characterised as forerunners initiated by “first movers” and therefore the experiences documented may be somewhat different from what other new renovation project may meet.

However, the multidisciplinary design approach of these examples demonstrates the potential of the renovation measures beyond functionality and energy consumption reduction. As a whole they state that this potential can be harnessed in all the scope of existing buildings renovations, from single family to multi-family buildings, with the appropriate adaptations to each context.

The aim of the EBC Annex 56 on “Cost Effective Energy and Carbon Emissions Optimization in Building Renovation” has been to provide designers with the tools to narrow the possible solutions - there are several alternatives and options are interrelated — for each building specific context.

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ANYWAY MEASURES

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EBC is a programme of the International Energy Agency (IEA)