IEA ECBCS Annex 50
Prefabricated Systems for Low Energy
Renovation of Residential Buildings

Building Renovation
Case Studies

March 2011



International Energy Agency
Energy Conservation in
Buildings and Community
Systems Programme

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Prefabricated Systems for Low Energy Renovation of
Residential Buildings

Building Renovation Case Studies

March 2011

This report documents results of cooperative work performed under the IEA Programme for Energy Conservation in Buildings and Community Systems, Annex 50 "Prefabricated Systems for Low Energy Renovation of Residential Buildings"

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Building Renovation Case Studies

IEA - International Energy Agency
ECBCS - Energy Conservation in Buildings and Community Systems
Annex 50 – Prefabricated Systems for Low Energy Renovation of Residential Buildings

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Preface

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 co-operation among the twenty-eight IEA participating countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems

The IEA co-ordinates research and development in a number of areas related to energy. The mission of one of those areas, the ECBCS - Energy Conservation for Building and Community Systems 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.

The research and development strategies of the ECBCS Programme are derived from research drivers, national programmes within IEA countries, and the IEA Future Building Forum Think Tank Workshop, held in March 2007. The R&D strategies represent a collective input of the Executive Committee members to exploit technological opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy conservation technologies. The R&D strategies apply to residential, commercial, office buildings and community systems, and will impact the building industry in three focus areas of R&D activities:

- Dissemination
- Decision-making
- Building products and systems

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial. To date the following projects have been initiated by the executive committee on Energy Conservation in Buildings and Community Systems (completed projects are identified by *):

Annex 1: Load Energy Determination of Buildings*
Annex 2: Ekistics and Advanced Community Energy Systems*
Annex 3: Energy Conservation in Residential Buildings*
Annex 4: Glasgow Commercial Building Monitoring*
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities*
Annex 7: Local Government Energy Planning*
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Annex 17: BEMS 2- Evaluation and Emulation Techniques*
Annex 18: Demand Controlled Ventilation Systems*
Annex 19: Low Slope Roof Systems*
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Annex 21: Thermal Modelling*
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Annex 25: Real time HEVAC Simulation*
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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*
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Annex 38: Solar Sustainable Housing*
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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)*
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Annex 47: Cost Effective Commissioning of 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: Analysis 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: Energy and Greenhouse Optimised Building Renovation

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 - Energy Efficient Communities

Annex 50 "Prefabricated Systems for Low Energy Renovation of Residential Buildings"

Energy conservation is largely dominated by existing buildings. In most industrialized countries new buildings will only contribute 10% - 20% additional energy consumption by 2050 whereas more than 80% will be influenced by the existing building stock. If building renovation continues at the current rate and with the present common policy, between one to over four centuries will be necessary to improve the building stock to the energy level of current new construction.

Currently, most present building renovations address isolated building components, such as roofs, façades or heating systems. This often results in inefficient and in the end expensive solutions, without an appropriate long term energy reduction. Optimal results can not be achieved by single renovation measures and new problems could arise, including local condensation or overheating.

The objectives of this Annex have been the development and demonstration of an innovative whole building renovation concept for typical apartment buildings. The concept is based on largely standardised façade and roof systems that are suitable for prefabrication. The highly insulated new building envelope includes the integration of a ventilation system.

The concept is focused on typical apartment buildings that represent approximately 40% of the European dwelling stock. The advantages include:

- Achieving energy efficiency and comfort for existing apartment buildings comparable to new advanced low energy buildings i.e. 30-50 kWh/(m²·y);
- Optimised constructions and quality and cost efficiency due to prefabrication;
- Opportunity to create attractive new living space in the prefabricated attic space and by in-cooperating existing balconies into the living space;
- A quick renewal process with minimised disturbances for the inhabitants.

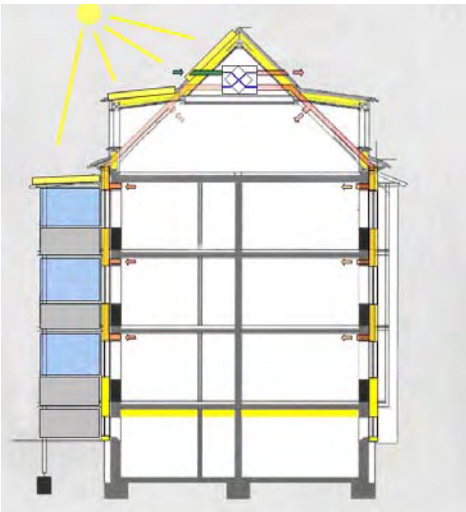


Figure 1: Prefabricated façade modules are used to construct a new building envelope around the building. This is physically optimal and does not reduce available space.

The deliverables of the project are:

Retrofit Strategies Design Guide
A building retrofit strategies guide [II] documenting typical solutions for whole building renovations, including prefabricated roofs with integrated HVAC components and for advanced façade renovation. The report is supplemented by the **Retrofit Simulation Report** [IX] and an electronic **'Retrofit Advisor'** [V] that allows a computer-based evaluation of suitable renovation strategies.

Retrofit Module Design Guide
Guidelines for system evaluation, design, construction process and quality assurance for prefabricated renovation modules [III]. This publication includes the technical documentation of all developed renovation solutions.

Case Study Building Renovations
Case studies of six demonstration buildings in Austria, Netherlands, and Switzerland [IV].

Technical Summary Report
A summary report for a broad audience, demonstrating the potential of prefabricated retrofit [I].

Additional publications are:
- Annex 50 Fact Sheet, offering a short overview of the project and its achievements
- Building Typology and Morphology of Swiss and French Multi-Family Homes [VI], [VII], [VIII]

Home Pages: www.empa-ren.ch/A50.htm, www.ecbcs.org/annexes/annex50.htm

Participating Countries: Austria, Czech Republic, France, Netherlands, Portugal, Sweden, Switzerland

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[I] Mark Zimmermann: ECBCS Project Summary report " Annex 50 Prefabricated Systems for Low Energy Renovation of Residential Buildings, October 2011

[II] Peter Schwehr, Robert Fischer, Sonja Geier: Retrofit Strategies Design Guide, ISBN 978-3-905594-59-1, March 2011

[III] René L. Kobler, Armin Binz, Gregor Steinke, Karl Höfler, Sonja Geier, Johann Aschauer, Stéphane Cousin, Paul Delouche, François Radelet, Bertrand Ruot, Laurent Reynier, Pierre Gobin, Thierry Duforestel, Gérard Senior, Xavier Boulanger, Pedro Silva, Manuela Almeida: Retrofit Module Design Guide, ISBN 978-3-905594-60-7, March 2011

[IV] Reto Miloni, Nadja Grischott, Mark Zimmermann, Chiel Boonstra, Sonja Geier, Karl Höfler, David Venus: Building Renovation Case Studies, ISBN 978-3-905594-61-4, March 2011

[V] Mark Zimmermann, Hans Bertschinger, Kurt Christen, Walter Ott, Yvonne Kaufmann, Stefan Carl: Retrofit Advisor, Beta-version, March 2011

[VI] Peter Schwehr, Robert Fischer: Building Typology and Morphology of Swiss Multi-Family Homes 1919 – 1990, January 2010

[VII] Bertrand Ruot: French housing stock built between 1949 and 1974, October 2010

[VIII] Bertrand Ruot: Elements of morphology of collective housing buildings constructed in France between 1949 and 1974, October 2010

[IX] Gerhard Zweifel: Retrofit Simulation Report, March 2011

[1] Further information at home pages: www.empa-ren.ch/A50.htm, www.ecbcs.org/annexes/annex50.htm

Abstract

Buildings have a considerable impact on the implementation of a more sustainable development. Within this context, "IEA ECBCS Annex 50 – Prefabricated Systems for Low Energy Renovation of Residential Buildings", focuses on the most important sector: multi-residential buildings. It aims at contributing to quality control and standardization based on prefabricated modules and advanced retrofit strategies. The project focuses on prefabricated and factory-assembled roofs, façades, and HVAC systems for multi-family houses.

However, it is not just a question of resolving technical issues. Today, holistic strategies have to meet the needs of investors, users and the public, as well as to account for architectural relevance. Planners are required to develop optimal retrofit strategies for existing buildings. Advanced retrofit strategies involve the whole building system, aiming to get buildings "fit" and to adapt them for current and future needs. The core element of every redevelopment should be an increase in value for the client (investor, building owner, and tenant). Focusing solely on the optimization of energy efficiency is ineffective, and does not meet overall requirements.

This report gives an overview of six demonstration projects that have been planned and modernized with the concept of prefabricated renovation modules. They demonstrate that industrialized prefabrication technologies are no longer only the domain of new buildings. The have a large potential for building renovation where they offer a better quality of workmanship and a faster construction process. Tables 1 and 2 give an overview of the kind of renovation that have been realized.

	Prefabricated faced elements	Prefabricated Roof elements	New balconies	Added elevator	Space extension	New attic
Zug	X	X	X	X	X	X
Zurich	X	X	X		X	X
Krummbach	X		X		X	
Roosendaal	X	X				
Dieselweg 3 - 19, Graz	X			X		
Dieselweg 4 , Graz	X			X	X	

Table 1: Overview of demonstration projects and renovation works done

The main conclusions from these six demonstrations are:

- Building renovations with prefabricated façade and roof elements change the architecture of an apartment building. This can be seen as an opportunity to improve the architecture and quality of the existing building envelope. However, if the architecture of an existing apartment building should be conserved, then traditional renovation measures should be favoured.
- Prefabrication technologies require additional planning efforts and accurate measuring of the existing building structure, but the construction process has proven to be very efficient.
- Economically considered, prefabrication technologies are competitive to traditional renovation measures but not necessarily cheaper. Two types of renovation have a large potential to become cheaper than traditional technologies: simple and repetitive façade and roof renewal (no complex building shapes) and holistic building renewals with extensive changes (window sizes, room extensions, new roof top apartments).
- The efficient construction process with prefabricated elements allows for an "inhabited construction site". However, for holistic building modernisation moving out for 3 to 6 months is recommended.

- The energy savings for heating, ventilation and domestic hot water are normally higher than 80%. The goal of 30-50 kWh/(m²·y) is well achievable for final energy consumption. However, this goal is not easy to achieve for primary energy if a factor of 2.97 for electricity is applied. This would mean an electricity consumption of less than 17 kWh/(m²·y) for heating, ventilation and domestic hot water. It is well achievable if PV systems are installed. All Swiss demonstration projects apply PV systems and reduce the energy consumption for heating, ventilation and domestic hot water close to or even below zero.

	Consumption before renovation kWh/(m²·y)	Consumption after renovation kWh/(m²·y)	Heating system	Thermal solar systems	PV systems Electricity produced kWh/(m²·y)	Primary energy savings %
Zug	226 (280)	25 (74.3)	Ground coupled heat pump	X	9.5 (28.2)	93.3 (83.5)
Zurich	175 (217)	20 (59.4)	Ground coupled heat pump	X	27.4 (81.4)	104.2 (110.1)
Krummbach	97 excl. DHW (120.3)	9.1 (27)	Ground coupled heat pump		10.5 (31.2)	100.1 (103.5)
Roosendaal	137 (151)	38 (43.7)	Gas	X		72.3 (72.3)
Dieselweg 3-19, Graz	142 (312)	14 (41.6)	Ground water heat pump	X		90.1 (86.7)
Dieselweg 4, Graz	184 (400)	12 (35.6)	Ground water heat pump	X		93.5 (91.1)

Table 2: Overview of demonstrated energy systems and savings achieved (primary energy values in brackets)

Regarding the prefabricated elements, the following observations have been made:

- Producers of prefabricated façade elements prefer large elements for logistical purposes. They are normally 2.8-3.3 m high and up to 12 m long.
- The façade modules are mostly made with wood frames and cement or wood fibre board planking. Integrated ventilation ducts are specially fire protected.
- Prefabricated modules are produced with high precision of about ±1 mm accuracy. Very important is the definition of the tolerance space needed between building and modules and the accurate mounting of the module support brackets around the building.
- Scaffolding is highly recommended as a working platform for the mounting of prefabricated façade elements.
- Façade finish is possible as rendering (Zurich), wood (Krummbach), metal (Zug), glass (Graz), and even slate stone (Roosendaal).
- Central ventilation systems with façade integrated air distribution have proven to be very practical. Single room ventilation systems integrated in façade modules are also possible.

The demonstrated concept of building renovation with prefabricated renovation modules has already been adopted by the building industry as an efficient way to modernize existing buildings. However, it will need more time to become a widespread technology. The building industry is generally a very conservative industry. Restructuring existing construction processes and further developing new concepts will need some time, but it is obvious that the demonstrated new technologies offer great opportunities for a sustainable built environment.

Passive house rehabilitation of post war residential building in Zug, Switzerland

Owner:
Erbengemeinschaft Ducret
Architect:
Miloni & Partner, Wettingen
Energy concept designer:
Zurfluh & Lottenbach, Luzern
Report: Reto Miloni
Location: Zug
Renovation: 2009

Key technologies

- Prefabricated light-weight timber elements
- Hi-compact insulation
- Ground source geothermal bore hole heat-pump
- Controlled ventilation
- PV and thermal collectors
- Thermal bridges avoided
- Rain water supply for toilets

Background

The problems of the old building were:

- insufficient insulation,
- lots of thermal bridges,
- reduced thermal comfort.

Consequently energy bills raised every year, structural damages induced condensation and fire standards were no longer met. Since the building is located in a nice residential area above the lake of Zug a rehabilitation combined with a new annex building and penthouse apartment was planned.

Figure 1: South-west view of apartment building before renovation

Figure 2: North-east view of apartment building before renovation

Data of building before renovation

Location	Zug
Altitude	495 m
Heating degree days	3,100 Kd
Year of construction	1946
Number of apartments	5
Heated floor area	442 m²
Total heating energy incl. hot water	226.2 kWh/(m²·y) (100,000 kWh/y)
Rents (net)	42,000 €/y
Additional costs	3,103 €/y

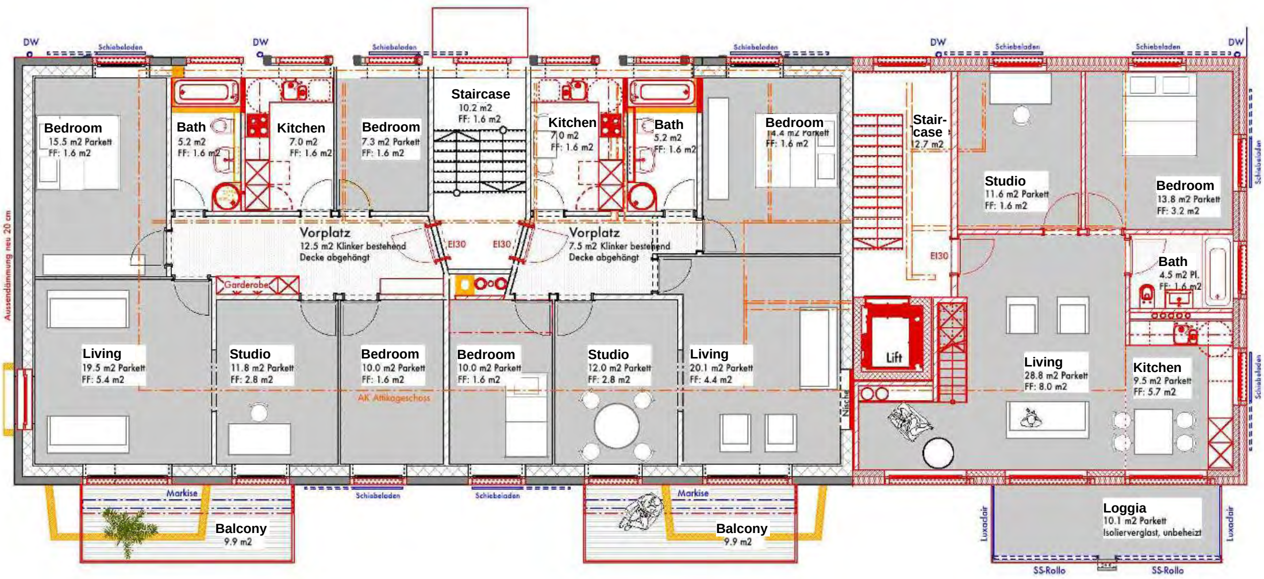

Figure 3: Typical floor plan of building with planned floor plan changes and new building annex (in red)

Renovation concept

Figure 4: View of old building and project

Renovation strategy

- The building had to be kept socially, environmentally and financially sustainable.
- The major transformation processes had to be carried out within 3 months.
- The r enovated building and new apartments had to fulfill the re quirements of the passive house standard.

Data of the renovated building

Year of renovation:	2009
Number of apartments:	8
Heated floor area:	803 m²
Total heating energy incl. hot water:	25.0 kWh/(m²·y)
Heating energy savings:	89 %
Contribution of solar thermal collectors (incl.)	10 kWh/(m²·y)
Contribution of PV-collectors (additional)	9.5kWh/(m²·y)
Rents:	158,000 €/y
Rent increase: max.	30 %
Total investment:	2.5 Mio. €

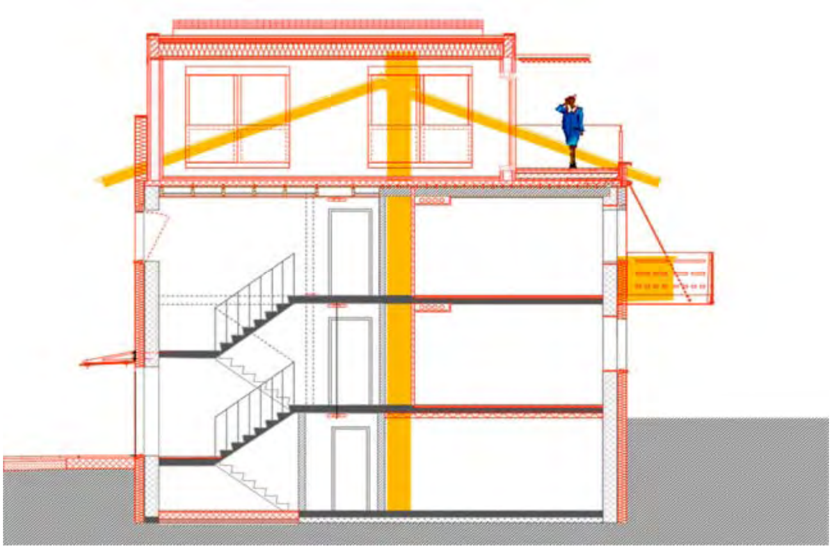

Figure 5: Section of renovated building

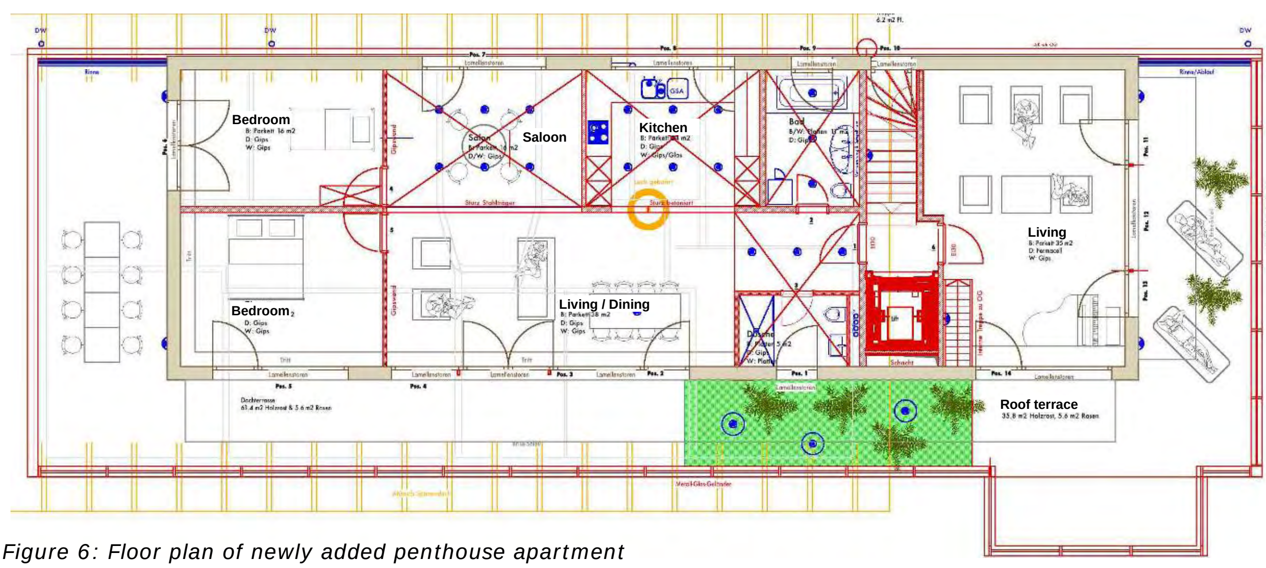

Figure 6: Floor plan of newly added penthouse apartment

Renovation design details

Façade & roof solutions

The first three floors of the old brick walls received a polystyrene insulation with polyurethane core, λ 0.023 W/(m·K). The top floor and the roof were built with prefabricated lightweight timber elements with glass wool fillings with λ 0.032 W/(m·K). All doors and double glazed windows of poor quality were replaced.

Figure 7: Insulation of façades with Hi-Compact insulation

Heating system

The new heating system consists of a heat pump (COP: 4.15) combined with controlled ventilation. The supply air is heated up in each apartment by a heat exchanger that is integrated in the duct system. In each apartment the room air temperature can be controlled individually.

Hot and grey water

10 vacuum collectors with a total area of 15.5 m² and a 2,850 litre storage tank for hot water were installed.

In order to cut raising costs for fresh water a rain water collector system was installed. It provides grey water for toilets and garden appliances.

Figure 8: Mounting of the prefab structure

PV system

Solar electricity is being produced on the roof with 36 PV modules à 210 Watts (7.6 kWp). The total PV area is 53.5 m².

Controlled ventilation

The ventilation system collects fresh air from a central air intake and serves each apartment.

In addition to the commonly known heat recovery system, a moisture recovery system was installed in the new apartments in order to prevent dry air during winter.

Figure 9: Air intake is placed 20 m in front of the house

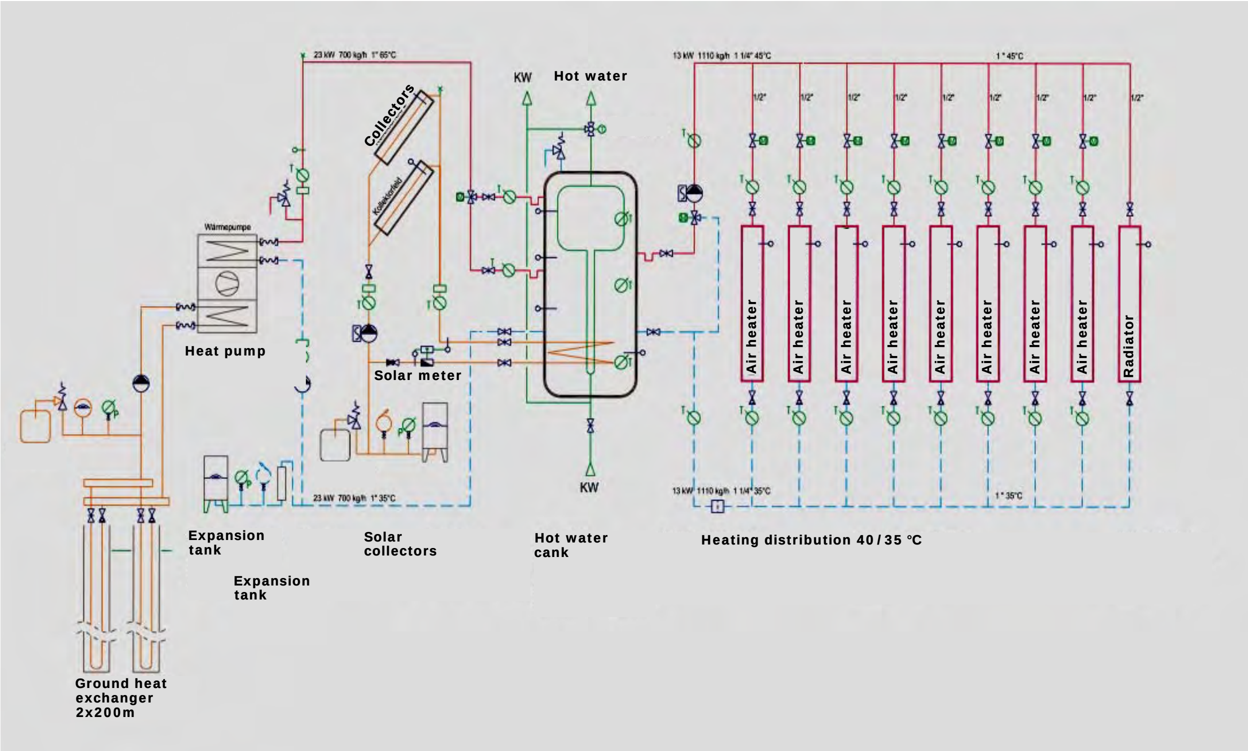

Figure 10: The heating system works with ground coupled heat pump and low temperature air heaters in the air supply system of each apartment

Figure 11: Thermal and PV-collectors on the roof reduce the yearly energy consumption close to zero

Construction process

Whereas the building annex for the new apartments was constructed with conventional concrete floor slabs and brick walls, the light weight roof structure was completely prefabricated. It was important to limit the weight of the roof structure for static reasons. This also allowed the construction of wall element that are not in line with the walls of the existing building below.

For mounting the roof elements, the existing roof was removed and the existing wooden beam slab was reinforced with light weight concrete and connecting screw bolts.

The existing concrete balconies (causing cold bridges) were removed. New and larger steel balconies were brought in by crane.

The prefabricated façade elements finally received an aluminium cladding and sun breakers were mounted.

Figure 12: Construction of building annex with two additional apartments

Figure 13: Mounting of prefabricated roof elements for new attic apartment

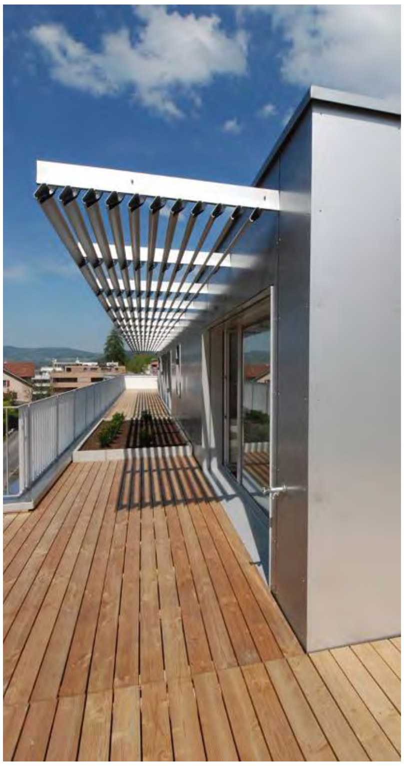

Figure: 14: Sunbreakers

Figure 15: Mounting of pre-fabricated balconies

Performance data

Temperature and humidity

Between Christmas and March 2009 indoor temperatures and humidity were monitored in all 5 renovated apartments of the old building. Indoor temperatures were as expected but the humidity was low:

- Mean room temp.: 23.4°C
- Lowest room temp.: 18.3°C
- Highest room temp.: 24.1°C
- Mean relative humidity: 29.9%
- Lowest rel. humidity: 17.5%
- Highest rel. humidity: 47.9%

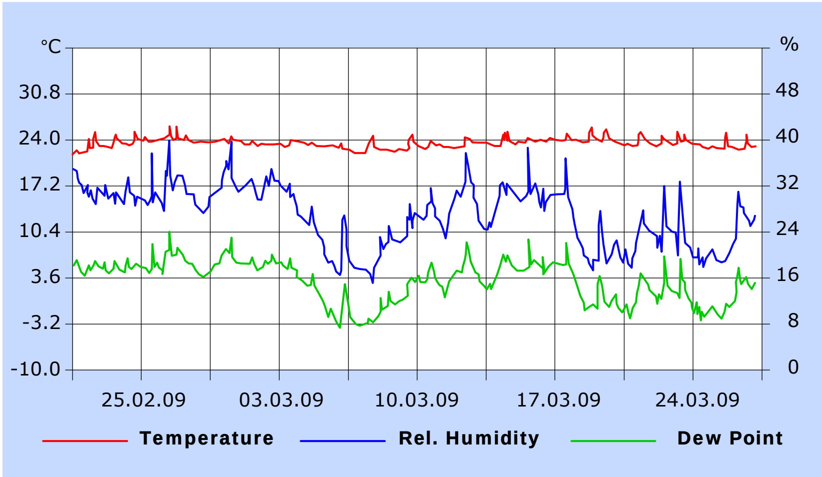

Figure 16: Room temperatures and relative humidity in typical apartment

Energy bill

The rehabilitation reduced the energy consumption from the worst category G to the best category A (Figure 18). The total energy consumption was 40'625 kWh/y (50.6 kWh/(m²·y) for household electricity and technical installations. 40% were consumed by the heat pump and 9.5% were used for heat distribution and ventilation.

The PV system reduced the electricity bill by 7'645 kWh/y and the solar thermal system contributed 8,061 kWh/y in the period from October 2009 – October 2011. The net electricity consumption for heating, hot water, and ventilation was (incl. PV gains). 12367 kWh/y or 15.4 kWh/(m²·y).

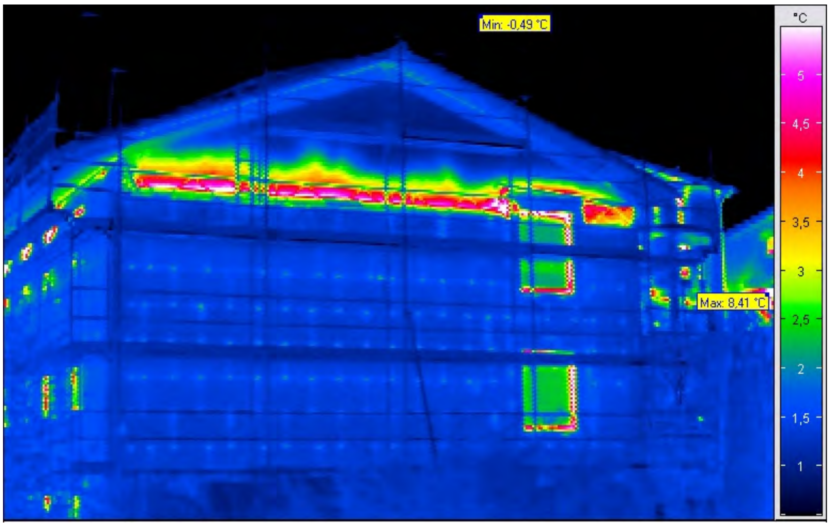

Figure 17: Thermographic view of building during renovation. The thermal losses against the not yet completed penthouse apartment are clearly visible.

Renovation costs

Total costs: € 2.5 Mio.

Ancillary costs	277,000
Structural work	489,000
Timber work	148,000
Metal work	160,000
Windows	128,000
Insulation	175,000
Electrical work	103,000
PV	47,000
Heating, ventilation	233,000
Water installation	151,000
Interior works	253,000
Exterior works	89,000
Fees	265,000

Additional space: 3 apartments and one office room.

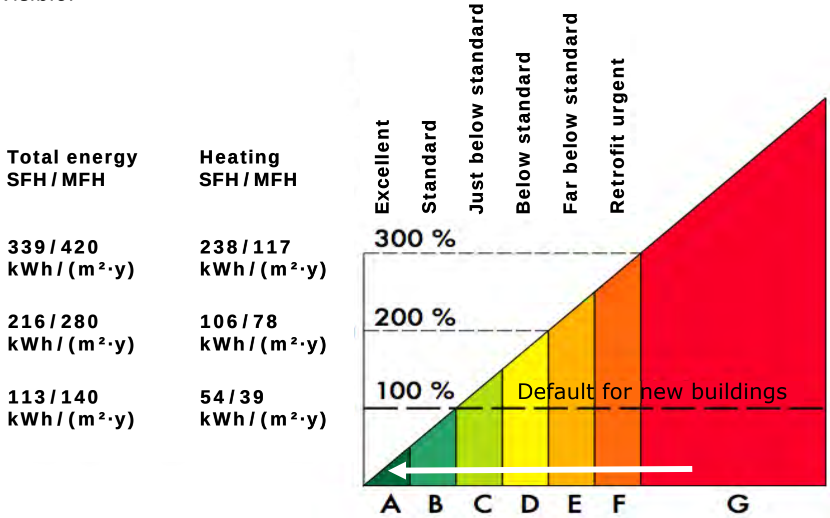

Figure 18: Transformation of a G-rated building into an A-rated building (15.4 kWh/(m²·y)

Summary

The envelope of the apartment building, constructed 1946, was properly insulated and a mechanical ventilation system with heat recovery was installed. The energy consumption was lowered more than 80 % and the retrofitted building was certified as MINERGIE-P-Standard (comparable to Passive House Standard).

The oil fired heating system was replaced by a ground coupled heat pump. Thermal collectors and PV-panels were installed.

In order to finance the renovation works, 3 additional apartments were added. Thus rent increase was nowhere higher than 30 %.

Figure 19: Mounting of reinforcement screws of the combined wood-concrete slab for the new attic floor

Figure 20: Internal view of new penthouse apartment

Practical experience

It is technically possible to rehabilitate a 60 years old building and bring down the energy consumption by a factor of 10. It is also financially feasible if added values such as improved apartments and/or additional living space can be created.

High building standards may only be achieved, provided adequate time, experience and funding are available - and vice versa: where a lack of money, time and skills for careful detailing and construction work are missing, prefabrication alone will not lead to an adequate quality.

The better the knowledge concerning building systems and their performance the more precise the energy consumption and thermal comfort may be predicted.

Thus the availability of precise data in the design phase are just as important as the quality of the construction work on site and during prefabrication.

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Acknowledgment

The demonstration project was supported by:

- SFOE Swiss Federal Office of Energy
- CTI Commission for Technology and Innovation
- CCEM Competence Centre for Energy and Mobility

From the 50's to the future

Net zero energy renovation of a Swiss apartment building in Zurich

Owners: Peter Rieben, Markus und Sara Rieben, Zürich
Architect: kämpfen für architektur, Zürich
Energy concept: René Naef, Zürich
Report: Nadja Grischott
Location: Zürich, Switzerland
Renovation: 2009-2010

Key technologies

- Large prefabricated wooden elements
- Façade integrated ventilation system
- Ground-source heat-pump with 260 m deep bore holes
- 12.5 m² vacuum solar collectors
- 16.1 kWp PV-system

Background

Since construction in 1954, only small renovations have been done. The house was therefore still in its original condition. Only the south façade has been renovated and the heating furnace was replaced. The building fabric was in good shape; the main facades and the central wall are the load bearing structure. The external brick walls are 32 cm thick and were not insulated before renovation. The exterior rendering was still well preserved.

The ceilings are reinforced concrete slabs; the light weight roof structure was also in good condition. Balconies and handrails were weather-beaten during the years and had some rust damage due to corroded reinforcement. Most of the windows still dated back to 1954 and only some have been replaced in recent years. They all had standard double-glazing. The floor coverings had mostly been replaced, while kitchens and bathrooms were still in original condition. The oil-heating dated back to 1983 and the heat distribution was done by by radiators. The decentralized hot water system worked with electric boilers.

Figure 1: View of former south-east façade

Figures 2+3: Former south-west façade and north-west façade with entrance

Project data of building before renovation

Location	Zürich
Altitude	506 m
Heating degree days $HGT_{12/20}$	3,735 K·d
Year of construction	1954
Number of apartments	5
Heated floor area	458 m²
Total heating energy (incl. hot water)	80,140 kWh/y
Spec. energy consumption	175 kWh/(m²·y)
Rents (net)	65,000 €/y
Additional costs	12,000 €/y

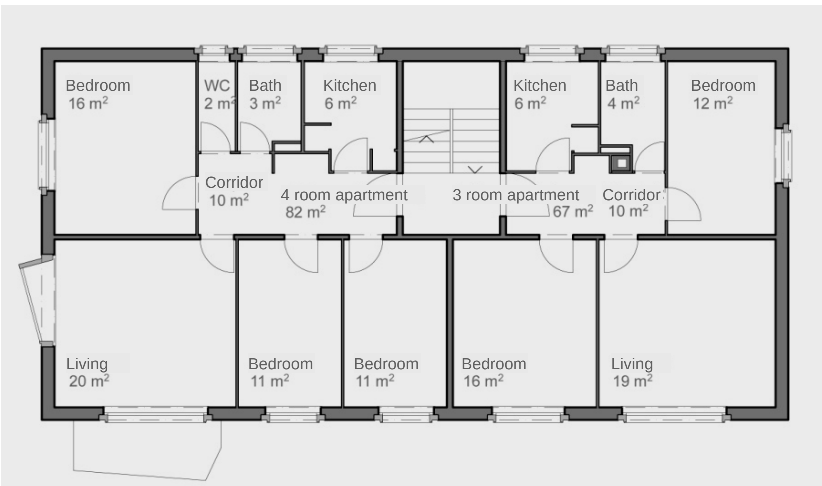


Figure 4: Typical floor plan of the existing building

Renovation concept

Figure 5: View of renovated building

Design data of renovated building

Year of renovation	2009-10
Measurement period	July 2010-June 2011
Number of apartments	6
Heated floor area	657 m²
Total heating energy (incl. hot water)	13,257 kWh/y
Spec. energy consumption	20 kWh/(m²·y)
Heating energy savings (per m²)	88.6%
PV electricity gains	1 17,983 kWh/y
Rents (net)	120,000 €/y
Additional cost	3,000 €/y
Rent increase	39%

Key points of renovation

Maximization of living surfaces with the construction of a new attic apartment and an extension of the ground floors.

Renovation of the building envelope in Minergie-P standard (Passive House standard), with preservation of the architectural quality.

Substitution and installation of new building technology systems: new heating system, but keeping the old radiators, new ventilation system, new hot domestic water system, and new electric installations.

Use of renewable energy: ground source heat-pump, solar collectors, and horizontal PV-system on the roof.

Inner refurbishment: new bathrooms and kitchens

Refurbishment with taking care to recycle existing structures and materials, in order to minimize the consumption of grey energy.

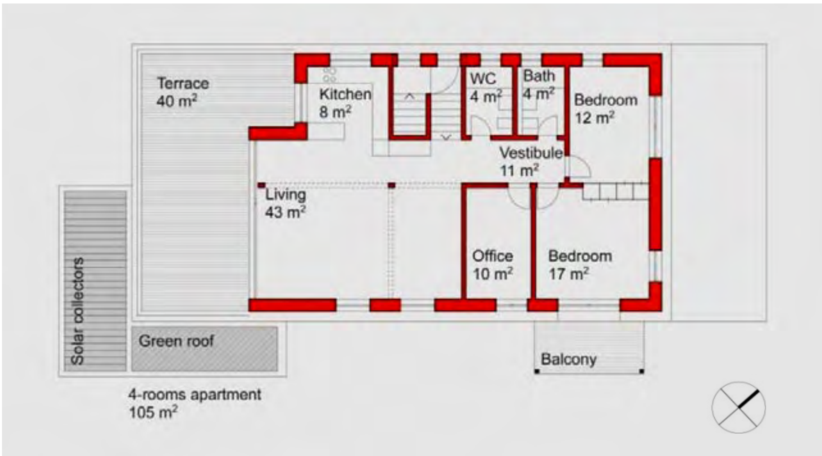


Figure 6: Floor plan of added penthouse apartment

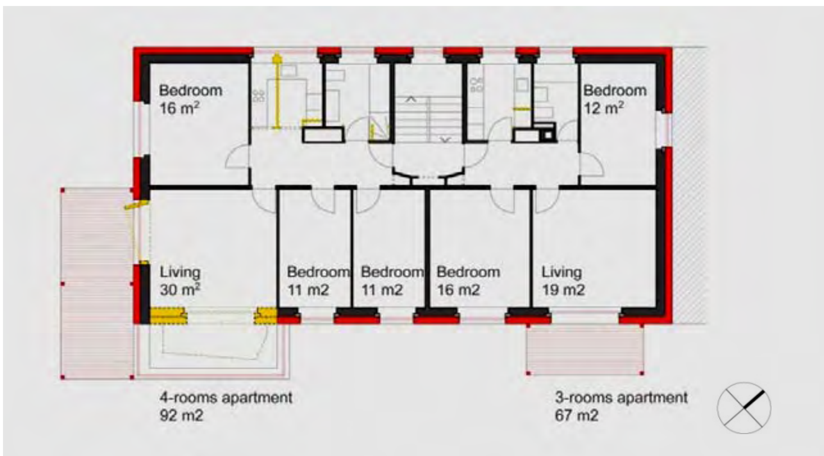


Figure 7: Floor plan showing the changes of the renovated building

Renovation design details

Façade solutions

The construction of the prefabricated large façade modules was a challenge. First measurements were taken by the University of Applied Sciences of North-Western Switzerland and by laser-measurements of the existing façades. The goal was to produce the elements based on this data. Because of difficulties to configure the data of the geometer to the needs of the architect, the contractor took also own measures. The new, large scale elements in timber construction had to fit on the imprecise and curved old walls. Because of this difficulty, cellulose insulation was used in order to fill all the gaps. The connections between the new windows and the old walls was covered by plasterboard and tightened by sealing tapes. The air-tightness of the renovated structure is excellent.

Wall construction

U-value: 0.18 W/(m^2·K)		Prefabricated element:	
Interior rendering	10 mm	Tolerance / thermal insulation (cellulose)	20 mm
Brick wall	320 mm	Insulation (cellulose)	180 mm
Exterior rendering	20 mm	Wood fibre board	40 mm
		Exterior rendering	10 mm
		Total (incl. existing wall)	600 mm

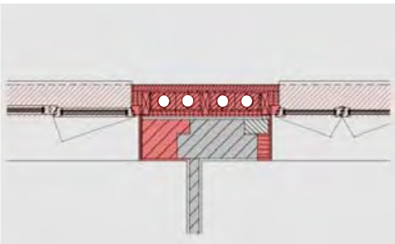


Figure 8: Horizontal section of façade element with integrated ventilation ducts

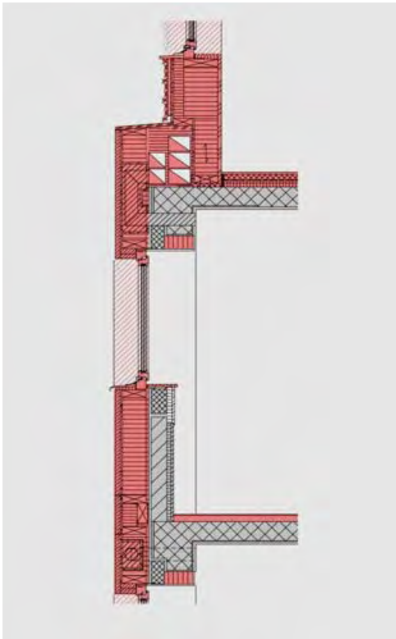


Figure 9: Vertical section with horizontal ventilation distribution

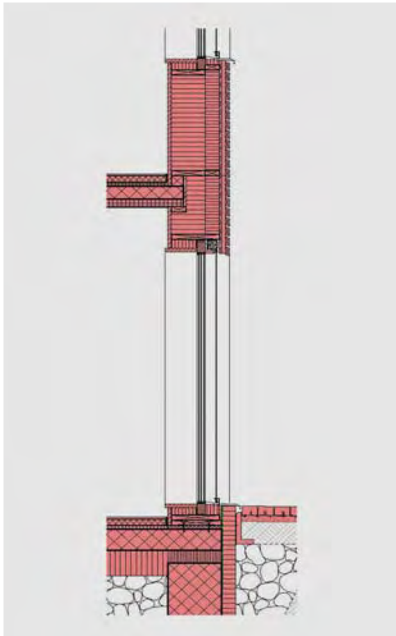


Figure 10: Vertical section of living room extension

Roof solutions

Figure 11: Vertical section of building. New parts in red (new balconies to the South, additional penthouse apartment, building annex for new heating system

Roof construction

U-value: 0.11 W/(m^2·K)	
Three-layer slab	27 mm
Thermal insulation	360 mm
Three-layer slab	27 mm
Air space / Three-layer slab	200 mm
Polymer bitumen seal	10 mm
Recycled rubber mat	7 mm
Substrate geo-membrane	60 mm
Total	691 mm

Ventilation system

The ventilation ducts are integrated in the new façade elements. The air inlets are positioned above each window and guarantee optimal ventilation of each rooms.

This solution does not consume any valuable interior space for the ventilation system. The interior room dimensions are not affected and a suspended ceiling is not required.

However, the integration of the ventilation ducts into the prefabricated elements was a technical and constructive challenge.

Figures 12-14: Ventilation main distribution with space saving rectangular ducts (top left), connecting the telescopic vertical round ducts between façade elements (bottom left), air inlet above window (right)

Figure 15: Ventilation distribution on south-east façade

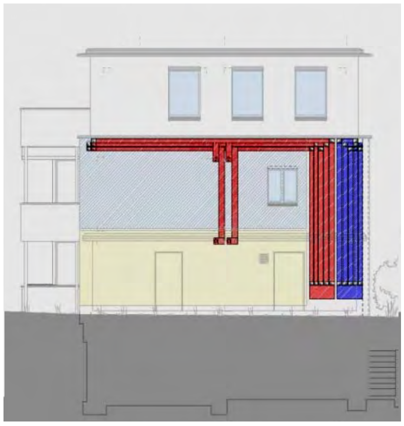


Figure 16: Ventilation distribution on north-east façade

Heating and hot water installations

Space-heating and domestic hot water are supplied by a geothermal heat-pump and by vacuum solar collectors. 75% of the hot water and 7% of the energy for the space heating are renewable energy from the sun.

On the upper ro of a PV-system was installed with an area of around 115 m² and an energy production of 16.1 kWp.

A small annex-building was added on the north-east side of the house for the installation of the head pump and the ventilation devices.

Figure 17: Renovated building from the north-eastern side. The building annex is used as technical space for the new heating system (ground coupled heat pump)

Construction process

The prefabrication of the façades with timber elements are a new construction method, which has not often been applied in Switzerland before.

The elements were made as large as possible, e. g. height: 3 m, length: 10 m.

The air distribution system and the electric conduits were placed in the prefabricated elements before they were in-stalled at the building.

Unfortunately, the windows arrived too late to the work shop of the carpenter and they could not be built in. They had to be mounted on-site.

Figure 18: Factory assembling of façade module with fire proof ventilation cavity

Figure 19: Transportation of large façade elements with flat bed trailer

Figure 20: Mounting of 3 m by 10 m façade elements

Figure 21: The step back of the penthouse floor is used for the horizontal ventilation distribution

Figure 22: Preparation work for the living room extension

Figure 23: Prefabricated roof element for the living room extension

Figure 24: Mounting of the living room extension

Figure 25-26: Module prefabrication for north-west façade (left) and south-west façade (right)

Performance data

Increase of thermal insulation

The thermal insulation, expressed by the U-value, has been increased extremely. Much less energy is now needed to achieve a high comfort level.

An air tightness of 1.5 h^{-1} was required for the existing part and the 0.5 h^{-1}. has been achieved. For the new penthouse apartment air tightness of 0.6 h^{-1} was required and 0.4 h^{-1} was achieved.

Renovation costs

The chance to rebuild an existing house like this was only possible due to the enlargements of the apartments and their increased rents. After the renovation, the building of 1954 is like a new one, and overall with an excellent energy standard.

The overall costs of the renovations are 1,285,000 €. The governmental subsidies have been 80,000 €.

Energy consumption

The period from July 2010 to June 2011 was measured. The energy consumption for space heating and hot water was reduced by 88.5% for final energy and 76% for primary energy. 4200 kWh/y are contributed by the thermal solar collectors. Together with the with the PV electricity produced on the roof, the building was turned into a net zero energy heating building.

Summary of U-values $W/(m^2 \cdot K)$	Before	After	Reduction
Wall construction	1.07	0.18	83 %
Basement ceiling	1.60	0.18	89 %
Roof construction	1.19	0.11	91 %
Windows (frame + glass)	2.5	0.8	68 %

Energy performance $kWh/(m^2 \cdot y)$ primary energy	Before	After	Reduction
Space + water heating	253	60	76 %
PV electricity production		81	108%

Renovation (m^2)	Before	After	Increase
Heated floor area	458	657	143 %

Figure 28: Renovated building from west side

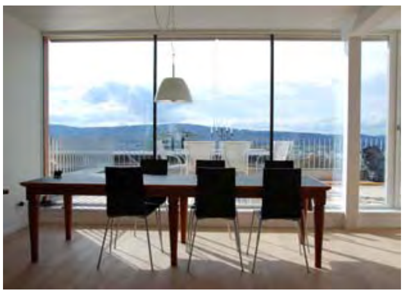


Figure 27: Comfortable living on the rooftop

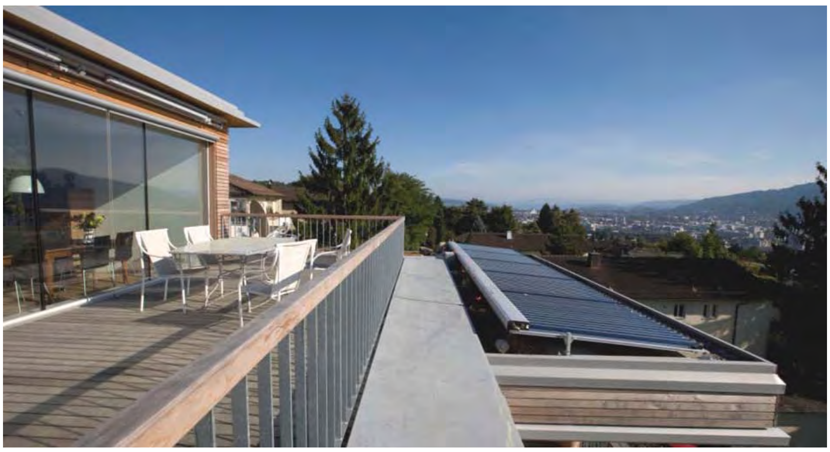


Figure 29: View from new penthouse terrace over Zurich, with 12.5 m² vacuum solar collectors on the balcony roof

Summary

Figure 30: Renovated building from the south-eastern side. New are the large south oriented balconies, the living room extensions where the small balconies were before, the additional penthouse apartment and the additional balconies at the north-east corner.

Figure 31: Apartment building just at beginning of renovation works

Practical experience

Renovations with this deep intervention have to generate added values. These additional values offer the potential to achieve energy efficiency and to adapt the building to future needs. But they have also to cover most of the costs for the renovation. Finally, the allow the building to become a new building with a modern comfort and modern architecture.

That means from an aesthetic point of view, the living comfort and the new technologies are like in a new house.

For a next renovation in this way, we see further potential for optimizing the building-process, the distribution system of the ventilation and simplified construction of the elements.

Figure 32+33: Building before and after renovation, seen from the west side

Figures and phots by Kämpfen für Architektur

Acknowledgment

The demonstration project was supported by:

- SFOE Swiss Federal Office of Energy
- CTI Commission for Technology and Innovation
- CCEM Competence Centre for Energy and Mobility

School building renovation for sustainable second life

Owner:
Alexander Ritz
Architect:
Bruno Thoma, Freienbach
Contractor prefab modules:
Renggli HolzbauWeise, Schötz
Report:
Mark Zimmermann, Empa
Supported by:
SFOE, CTI, CCEM
Location:
Krummbach-Geuensee
Renovation: 2011

Key technologies

- Prefabricated light-weight timber elements
- Sheep wool insulation
- Ground source geothermal bore hole heat-pump
- Controlled ventilation
- PV system on roof
- Thermal bridges avoided

Background

The small school building belongs to the hamlet Krummbach near Geuensee, Switzerland. It was used to teach three primary school classes till 2004. Since then it was not used anymore due to demographic changes. Also the attached apartment of the caretaker was empty.

As a school building dating back to 1969 it was built with bricks and hollow brick slab, but was basically not insulated. Only the roof was insulated with 80 mm mineral wool.

During 2010 the school building was sold by the community to a private owner under the condition that it will be again used for education purposes.

The building had a oil fired heating with separate electric hot water system and was only naturally ventilated.

The new owner intends to use the old school as training centre for continued education. The building renovation should not only modernize the building, it also should allow an energy efficient operation.

Figure 1: The school building belongs to the rural hamlet of Krummbach.

Figure 2: North view of the school building before renovation

Project data of building before renovation

Location	Krummbach/Geuensee
Altitude	695 m
Heating degree days	3,215 Kd
Year of construction	1969
Number of classrooms	3
Number of apartments	1
Heated floor area	568 m²
Total heating energy excl. hot water	97 kWh/(m²·y)

Figures by Empa if not mentioned differently

Figure 3: South view of the school building before renovation with the caretakers apartment on the left

Renovation concept

Renovation strategy

The goal of the renovation was not only the modernization of the old building. It was also aimed to improve the construction quality and the energy efficiency.

A new building envelope was constructed around the whole building. The façade modules are made from prefabricated timber frames, up to 3.3 m high and 10 m long, highly insulated with 280 mm natural sheep wool. The triple glazed low-e windows are factory mounted.

The roof construction was reused but also insulated with sheep wool.

The existing balconies were enclosed with the new building envelope in order to enlarge the living area and to avoid thermal bridges. A new balcony was constructed in front of the new façade.

PV-modules were installed on the roof.

The existing oil fired heating was preplaced by a ground source heat pump. Radiators are used for heat distribution.

A new ventilation system with heat recovery was installed in the attic space.

Design data of the renovated building

Year of renovation:	2011
Number of apartments:	1
Number of classrooms:	3
Heated floor area:	576 m²
Total heating energy incl. hot water:	9.3 kWh/(m²·y)
Heating energy savings:	92%
Primary energy savings:	79%
Total investment:	1.25 Mio. €

Figure 4: View from west of renovated caretakers apartment with school building behind (source: Bruno Thoma)

Figure 5: View from south of renovated caretakers apartment (left) and school building (right) (source: Bruno Thoma)

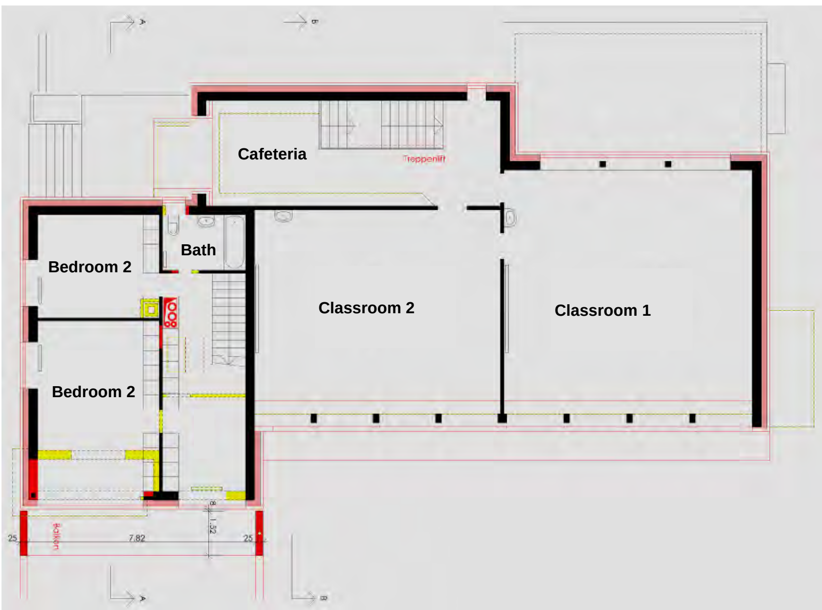


Figure 6: 1st floor plan of school building with caretakers apartment (left). Red: new construction / building envelope, yellow: removed construction (source: Bruno Thoma)

Renovation design details

Façade solution

The large size façade elements have been factory made with a timber frame construction. First, the timber frame was fixed onto a medium dense fibre board.

Installations such as electric conduits and ventilation ducts were mounted before the space of the timber frame was filled with 280 mm sheep wool. Special mineral wool insulation sections were used around the ventilation ducts for fire protection (Figure 9).

Finally, the timber frame was covered again with on a medium dense fibre board, the windows and the ventilated wood cladding was mounted.

The overall U-value of the insulated wall construction is 0.12 W/(m²·K) and for the windows 0.88 W/(m²·K).

Envelope construction:

- Existing brick wall 300 mm
- Ductile sheep wool insulation 20-40 mm
- Medium dense fibre board 15 mm
- Timber frame 60/280 mm
- Sheep wool insulation 280 mm
- Medium dense fibre board 15 mm
- Ventilated space 27 mm
- Wood finish 21 mm

Roof solution

The old roof was removed, except the rafter construction was kept. 60 mm insulating wood fibre board was used as supporting layer for the 280 mm scantlings and the sheep wool insulation. A vapour open polymer layer is protecting the construction and ensuring air tightness. Cement fibre panels are used as final roofing layer.

Figure 7: 3-D sketch of the timber frames, also showing the integrated ventilation pipes (source: Renggli HolzbauWeise)

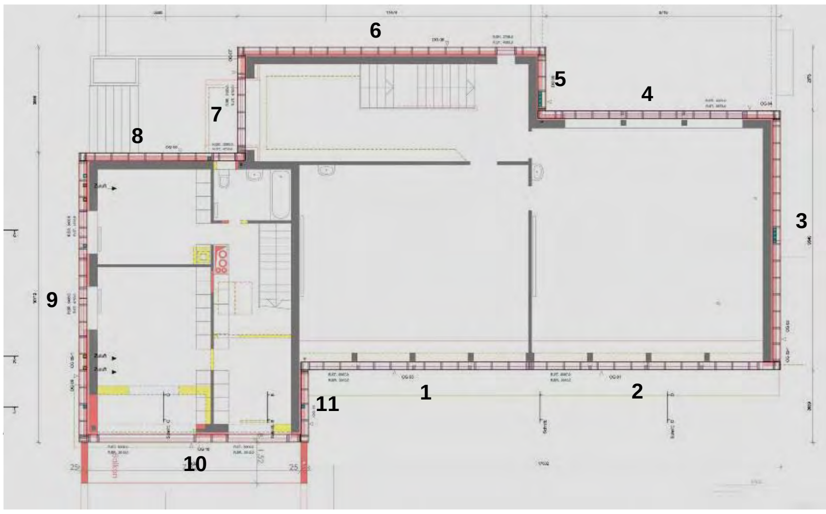


Figure 8: 1st floor plan of school building with modules 1 – 11 (source: Renggli HolzbauWeise)

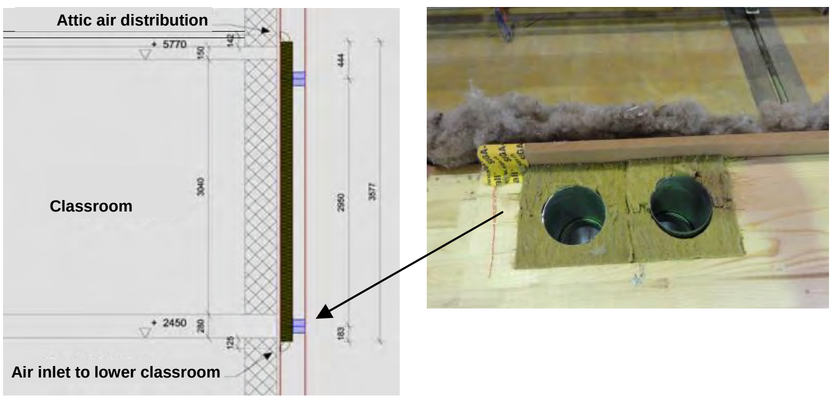


Figure 9: Wall section with integrated ventilation pipes

Heating system and hot water

The new heating system consists of a heat pump (expected COP: 4.35 for heating, 3.13 for hot water) that is using two 90 m boreholes as heat source. The heat pump is heating a 400 litre heating boiler and a 400 litre hot water boiler.

PV system

Solar electricity is being produced on top of the roof with 58.85 m² amorphous PV modules (6.24 kWp). The yearly production of PV electricity is expected to be 6027 kWh.

Controlled ventilation

Two ventilation units with combined heat recovery (η 86%) and moisture recovery are providing fresh air for the classrooms and the caretakers apartment. They are installed in the attic space of the steep roof.

The horizontal air distribution is also done in the attic space. It is connected with the module integrated vertical ventilation ducts (Figure 9).

In addition to the commonly known heat recovery system, a moisture recovery system was installed in the new apartments in order to prevent dry air during winter.

Figure 10: Ventilation pipes and electric conduits are integrated into the modules.

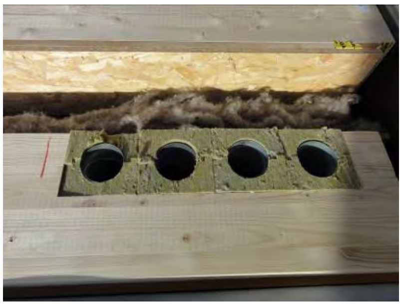


Figure 11: The ventilation ducts are fire protected with specially designed mineral wool sections.

Figure 12: The timber frame construction is filled with sheep wool after the ventilation pipes and electric conduits have been mounted.

Figure 13: The insulated timber frame construction is closed with a medium dense fibre board.

Figure 14: PV modules have been installed on the south roof.

Figure 15: The windows and the wood cladding are installed, except for areas where the module has to be fixed on site

Construction process

The modules have been completely prefabricated except for the large sliding doors and areas of the façade cladding where the fixing is done on site.

Steel angles were first mounted around the existing walls. They are supporting the new façade elements and guarantee a precise positioning of these elements (Figure 20). The accuracy has to be in the range of a millimeter. Without this accuracy it will be difficult to position the large scale modules precisely and to fit them together. The space below these steel brackets was filled with foam glass insulation.

Most existing windows have been removed shortly before mounting the modules and the air inlets and outlets have been drilled (Figure 20).

Two days were needed to mount the 24 façade modules. During the first day, the ground floor row was mounted, and the next day the upper floor elements and the two gables. The sequence of mounting has to be carefully planed in the design phase.

The mounting of the heavy elements is done by crane. A scaffolding is needed as working platform. It is important that the elements are well balanced and are hanging vertically. Only little adjustments should be needed for their final positioning. A roof overhang would constrain the mounting process.

A mastic strip is applied to ensure air tightness between the modules and the telescopic section of the ventilation pipes are inserted just before the modules are fully lowered (Figure 20). Also here, a high precision is required in order to make sure that all modules fit together.

Finally, the modules were screwed together at the corners and fixed to the existing wall (metal bracket on Figure 20). The remaining renovation work has been done in a traditional way.

Figure 16: Prefabrication of modules in factory

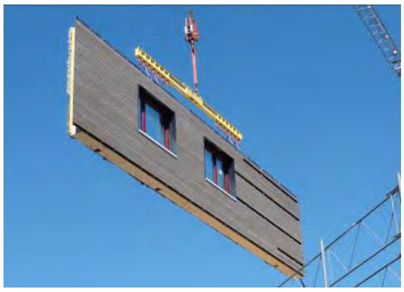


Figure 17-18: Module delivery on site

Figure 19-20: Horizontal mounting angle and a modules just before its final position

Figure 21: Mounting of the second module row

Performance data

The building renovation was done during fall 2011. Therefore, no measured data is yet available. However, based on the results from other projects, there is no doubt that the planning targets can be achieved.

Energy bill

It is expected that the rehabilitation reduces the heating and ventilation energy consumption by 92% for final energy or 83% for primary energy.

Hot water energy (electricity) is reduced by 68%, for final energy as well as for primary energy.

The total savings are expected to be 91% for final energy or 79% for primary energy.

Due to the 60 m^2 PV installation, the energy needs for heating, ventilation, and hot water are more than compensated. However, estival electricity gains will also be used as household electricity. Electricity used during the cold season will be mainly supplied by the utilities.

Renovation costs

Total costs:	€ 1.25 Mio.
Builder	216,000
Façade / roof constr.	552,000
Ventilation system	36,000
Heating, hot water	82,000
PV	32,000
Electrical work, lighting	68,000
Interior renovation	81,000
Equipment	28,000
Landscaping	16,000
Planning, management	68,000
Labeling, monitoring	71,000

Technical data

U-value walls	0.12 W/(m^2·K)
U-value windows	0.88 W/(m^2·K)
g-value windows	60%
U-value roof	0.16 W/(m^2·K)
U-value floor	ca. 0.35 W/(m^2·K)

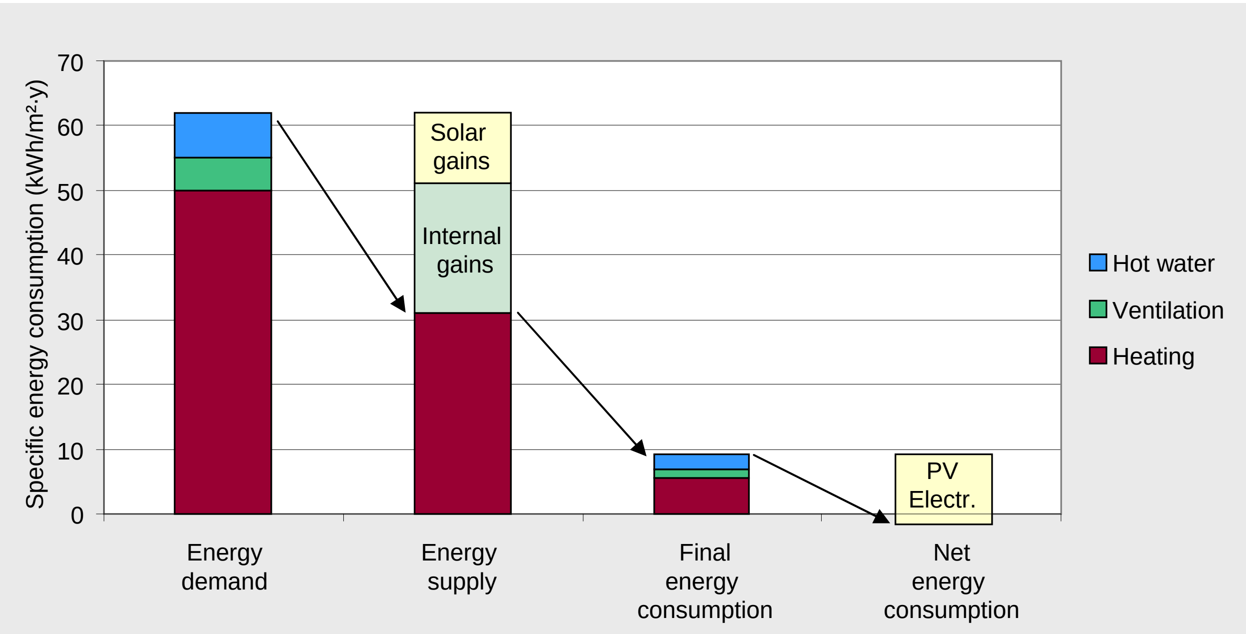
Energy consumption

Transmission	50 kWh/(m^2·y)
Ventilation	5 kWh/(m^2·y)
Internal gains	11 kWh/(m^2·y)
Solar gains (without PV)	20 kWh/(m^2·y)

Heating demand	24 kWh/(m^2·y)
COP heat pump	4.35
Heating energy	5.5 kWh/(m^2·y)
Ventilation energy	1.4 kWh/(m^2·y)
Hot water demand	7 kWh/(m^2·y)
COP heat pump	3.13
DHW energy	2.2 kWh/(m^2·y)
Pumps	0.2 kWh/(m^2·y)
PV produced electricity	10.5 kWh/(m^2·y)
Total energy consumption	-1.2 kWh/(m^2·y)

Seen over a whole year, the building is expected to be a net zero energy building for heating, ventilation, and hot water.

Figure 22: Energy consumption for heating, ventilation, hot water of renovated Krummbach school building



Summary

The Krummbach school building and caretakers apartment was refurbished after not being used for 6 years. A new highly insulated building envelope was constructed around the building. Sheep wool was used as sustainable and healthy insulation material. The façades were efficiently renovated with prefabricated façade elements.

The old oil fired heating system was replaced by a modern ground coupled heat pump that is also providing the hot water.

Two ventilation systems with heat and moisture recovery were installed. They provide fresh air to the classrooms and the caretakers apartment. The air distribution ducts have been integrated in the new façade modules.

The renovation concept has proven to be efficient and trouble free. A good quality at a competitive price was possible due to the prefabrication technology. The expected primary energy savings are as high as 79%. The demonstrated solution could become a standard for the building renovation industry.

Figure 23: The new building owner is inspecting the prefabrication process.

Figure 24: Areal view of the construction site, just before the façade elements were mounted (source: FHNW, René Kobler)

Figure 25: View of renovated building just before completion

Practical experience

At the beginning was the wish, to renew the school building Krummbach as sustainable oasis in the middle of nature: Use of natural, renewable, and healthy materials and recourses. The energy needed for heating and hot water should be covered by own solar electricity and geothermal heat.

It was not allowed to change the building size but it was allowed to insulate the building from outside. Prefabricated wood elements seemed to be the most efficient way to do this. The 32 cm thick cavity filled with natural sheep wool insulation offered enough space for the integration of ventilation ducts, heating pipes and electrical conduits. This was an important advantage because it was difficult or even impossible to integrate these installations into the existing construction.

The renovation concept developed by FHNW and Empa proofed to be ideal. It allowed an easy and precise integration of important parts of the ventilation system. The tolerance layer between the old building wall and the new façade elements was wide enough to integrate heating pipes.

The decision to use prefabricated elements was absolutely right. It allowed to renovate the building efficiently, sustainable and cost effective. The elements were mounted in very short time and reduced the construction time remarkably.

Being the new owner, I always felt comfortable in the building. The place was ideal for the new centre for professional education. The old building and the new renovation harmonize and jointly create now a sustainable future.

Alexander Ritz, owner

Acknowledgment

The demonstration project was supported by:

- SFOE Swiss Federal Office of Energy
- CTI Commission for Technology and Innovation
- CCEM Competence Centre for Energy and Mobility

Passive renovation
De Kroeven 505
Roosendaal, NL

Owner: Aramis Allleewonen
Architect: DAT architecten
Energy concept:
Trecodome
Report: Trecodome
Location: Roosendaal, NL
Renovation: 2010-2011

Key technologies

- Prefabricated timber facades and roofs
- Triple glazed windows
- Prefabricated timber roofs
- Heat recovery ventilation
- Condensing gas boiler
- Solar thermal collectors

Background

Social housing provider Allee Wonen owns 19,000 properties in Roosendaal and Breda, The Netherlands. In Roosendaal, in 1960 a large scale residential development was built in an area called De Kroeven, which mainly consists of identical single family houses.

After 40 years of use, and only gradual improvements and normal maintenance, Allee Wonen decided to upgrade and re-design the area. Also the tenants had expressed interest in an energy efficient renovation. Whereas Allee Wonen had learned about the passive house concept as part of her involvement in the European Treco network for social housing providers, Allee Wonen and the tenants developed a shared interest in low energy renovation.

The full upgrade of Kroeven consists of 370 single family houses, of which 246 will be renovated and 124 units will be newly constructed, replacing about 100 existing houses.

The renovation was planned in such a way that the tenants shall stay in their houses. This requires a fast, and non-intrusive renovation process.

Two architect firms and energy consultants have been appointed to develop different approaches to passive renovation, and to ensure a variety in architectural and technical solutions, whilst aiming at the same low energy demand for space heating and domestic hot water.

Figure 1: Overview of the area Kroeven in Roosendaal, The Netherlands

Project data of building before renovation

Location	Roosendaal, NL
Altitude	5 m
Year of construction	1965
Number of apartments	134
Heated floor area (120 m² per house)	16,080 m²
Total heating energy (incl. hot water)	16,500 kWh/y
Spec. energy consumption	137 kWh/(m²·y)
Installed heating capacity	20 kW
Spec. heating capacity	160 W/m²
Household electricity (without heating)	3,500 kWh/y
Spec. electricity consumption	29 kWh/(m²·y)
Rents (net per unit)	6,000 €/a
Heating costs	1,140 €/a

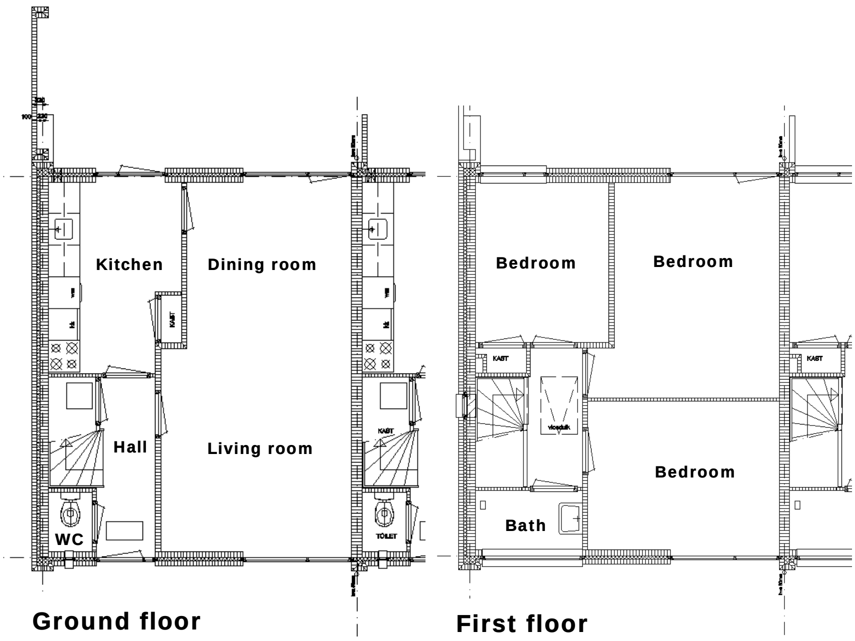


Figure 2: Typical floor plan of building

Renovation concept

Figure 3: View of renovated building

Approach 1 resulted in two test houses, demonstrating how the houses can be insulated using 200 mm external EPS insulation and a façade with plaster rendering, passive house window frames and triple glazing, and prefabricated timber roof elements, filled with 350 mm cellulose insulation.

This approach has been implemented in 112 houses from 2010 to 2011.

Approach 2 resulted in one test house demonstrating how the houses can be insulated using a new 350 mm timber frame element with cellulose insulation, with triple glazed passive house window frames, and again prefabricated timber roof elements, filled with 350 mm insulation. The external façade cladding is made with natural slates.

This approach has been implemented in 134 houses from 2010 to 2011.

Design data for renovated building

Year of renovation	2011
Number of apartments	134
Heated floor area	16,080 m²
Total heating energy per unit (incl. hot water)	4,500 kWh/y
Spec. energy consumption	38 kWh/(m²·y)
Heating+DHW energy savings (per m²)	72%
Installed heating capacity	3.5 kW
Spec. heating capacity	30 W/m²
Houshold electricity per unit (without heating)	3,500 kWh/y
Spec. electricity consumption	29 kWh/(m²·a)
Electricity savings	0%
Rents (net per unit)	6,780 €/y
Heating costs	335 €/y
Rent increase per m² (net)	-0.3%

Figure 4: Section of renovated building

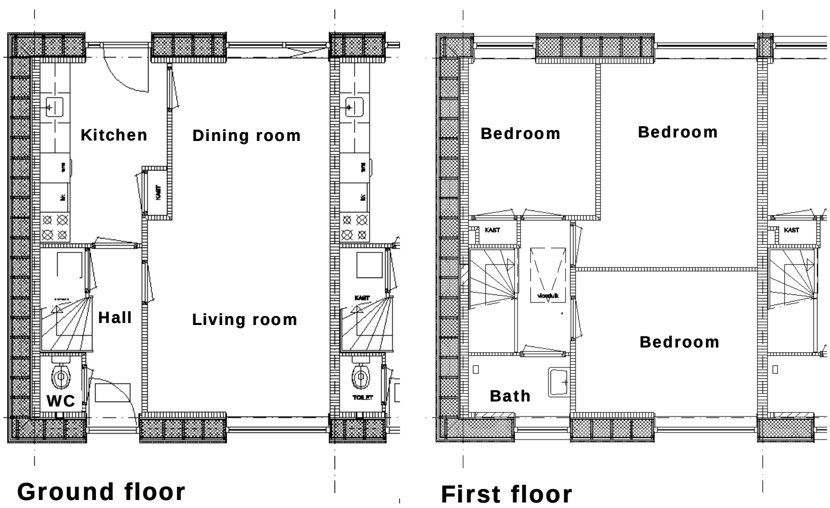


Figure 5: Floor plan changes of renovated building

Renovation design details

Façade solutions

The renovation of Kroeven, complex 505 consisted at first of the demolition of the outer leaf of the cavity wall construction.

The next step was to insulate the perimeter around the houses with EPS insulation, and to create the foundation for the timber elements.

The new prefabricated timber elements are 360 mm wide and contain cellulose fibre insulation. The U-value is 0.11 W/(m²·K).

Thermally broken windows with triple glazing have been factory mounted. The U-value of the frame is 0.87 W/(m²·K), the U-value of the glazing 0.5 W/(m²·K), and the g-value 0.47.

The new cavity between the inner leaf and the timber element is sealed around the window frames.

Finally battens were mounted on site to allow the installation of natural slate tiles as a ventilated façade.

Roof solutions

The roof elements are 360 mm wide, and are covered with PVC roofing material. The U-value is 0.10 W/(m²·K).

Solar collectors for preheating domestic hot water have been factory mounted on the prefabricated elements.

Also the ventilation supply and exhaust ducts and air supply and exhaust for the gas heated equipment have been pre-installed.

Floor solutions

The ground floor is insulated using either PU spray underneath the floor or EPS chips to fill the crawl space under the floor.

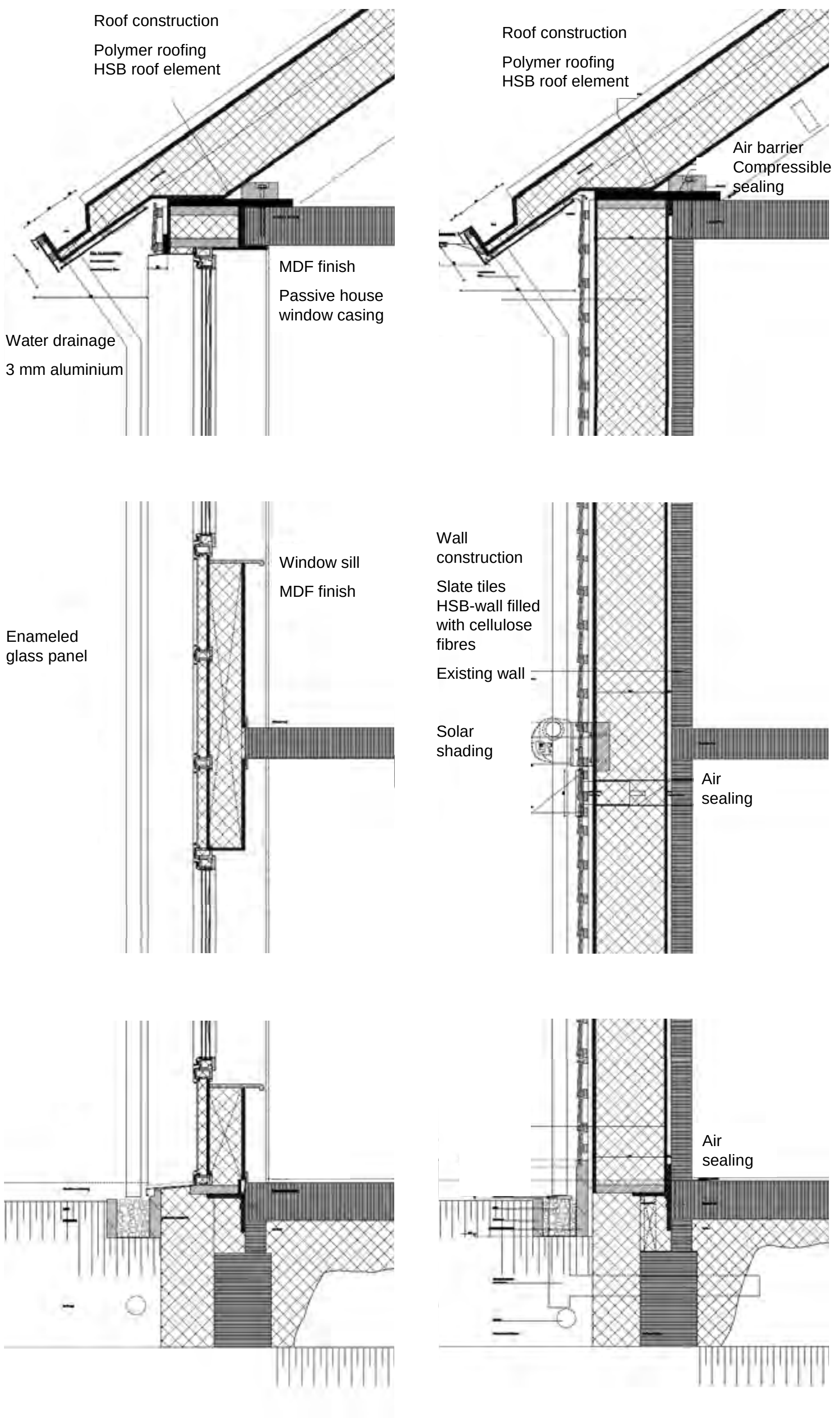


Figure 6: Cross section of prefab renovation

Heating, ventilation

Heating and ventilation is provided by a compact heating system, developed by Brink Climate Systems, which has all components in one system:

- 150 liter storage tank
- Mechanical heat recovery ventilation
- Condensing gas boiler
- Connection to solar thermal collectors

Due to the limited storey height in the attic the compact system has been divided in two parts - heat recovery unit and the other components - and placed next to each other (Figure 7).

The original radiator system has been adjusted to the smaller heat demand. The living room has one new radiator to replace two large ones. The flow in the bedroom radiators has been reduced to the new heating demand, and have thermostatic valves.

Fresh air is provided by the ventilation unit to the habitable spaces, i.e. living room and bedrooms, and exhausted via a toilet, bathroom and kitchen.

To avoid discomfort at any time an additional heat loop is installed to postheat the ventilation air. This is done by manual operation and in addition to the thermostatic control of the radiator system.

Hot water installations

Hot water is provided from the storage tank which is fed by the 5 m² solar thermal collectors, and the condensing gas boiler.

Typical hot water use in residential buildings is around 35 liter/day of water at 60°C.

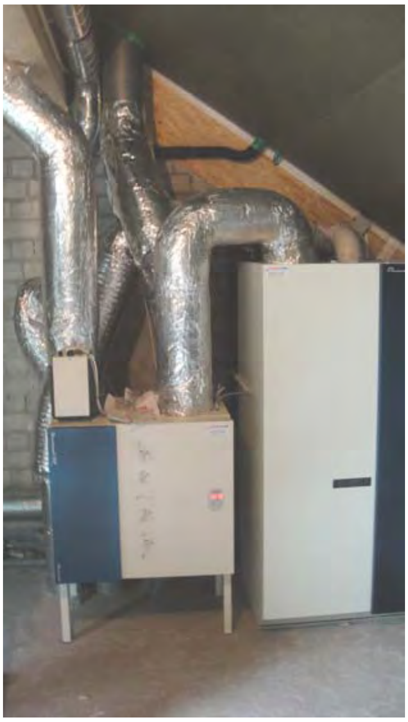


Figure 7: Combined heating, ventilation and hot water system

Figure 8: Prefab roof element with factory mounted solar thermal collector

Construction process

The prefabricated elements have been produced by VDM, a company that is based 250 km away from the renovation site in Roosendaal.

The process of renovating 134 units has been streamlined in order to allow the renovation of 4 houses per week.

The elements for one house have been transported on one truck load which travelled during the night and installed the next day.

Tenants experienced only one day when there was no roof and no windows. At the day of mounting, the prefab elements, also the compact heating and ventilation system was craned into the attic.

The whole process from start to completion took only six weeks.

Before the elements were mounted, gardens were partially cleaned and the external cavity leaf demolished. Next, the perimeter was insulated and the foundation for the elements was adjusted.

Figure 9: Prefab elements of one house at the factory

After mounting the prefabricated elements, the facades were cladded with the natural slate tiles, the radiator system was completed, the ventilation ducts were installed, and final finishing works were done.

The renovation process was completed with the preparation of new front gardens and the tree planting.

Figure 10: Prefab elements mounted on site

Figure 11: Renovation in progress: one house per day

Performance data

The project has been completed at the time of writing of this summary in 2011. Therefore no monitored results are available at this point of time, except the results of the blowerdoor tests.

Monitoring system

A full monitoring programme shall be executed to learn lessons. Within the framework of the new European Commission funded FP7 project E2ReBuild monitoring will take place. Also national research and demonstration programmes help supporting the monitoring works.

It is anticipated to collect key energy performance data in a large part based on quarterly questionnaires and meter readings.

In five houses a detailed measurement programme will be executed addressing detailed hourly monitoring of gas and electricity consumption with a breakdown into specific uses of the compact heating system. Also temperature curves in different seasons and indoor climate parameters such as air quality and pollutants will be monitored.

At completion of the renovation works blowerdoor tests have been made resulting in an airtightness figure of 1.0 air changes per hour at 50 Pa.

Infrared imaging of the units did not show any anomalies.

Energy consumption

The energy consumption of the houses is expected to change significantly.

Space heating demand will reduce to a calculated figure of around 25 kWh/(m²·y) for a mid terrace and around 30 kWh /(m²·y) for an end terrace. These figures are 80% better than the current performance.

Hot water demand will reduce by 50% to 60% due to the installed solar thermal collectors and the high efficiency of hot water production by the compact system.

Highly efficient fans are part of the compact system. But otherwise there are no building related electricity savings in the units.

The building related energy bill is expected to reduce by 70%, whereas the full bill for additional costs reduces by 40%, at constant energy prices.

The significantly lower heating bills make the houses future proof and affordable, even if energy prices keep rising.

Renovation costs

Compared to normal renovation costs for these fairly typical house types, the renovation to passive house level requires an additional investment of around € 25,000 per house.

In Roosendaal, both an on site external insulation concept and the prefab concept have been done at 112 and 134 houses. The prefab approach in this case turned out to be slightly cheaper. Also the renovation process is faster, and thus less intrusive to tenants.

The tenants benefit by a lower heating bill, which in future is less sensitive to energy price increases.

The building owner has accepted a rent increase of € 65 per month, which equals the calculated energy saving at current energy prices. The owners has guaranteed that the cost of living for tenants will not increase.

Added values are the long life time of the prefab renovation concept and in future the building owner may also expect a higher property value on the market.

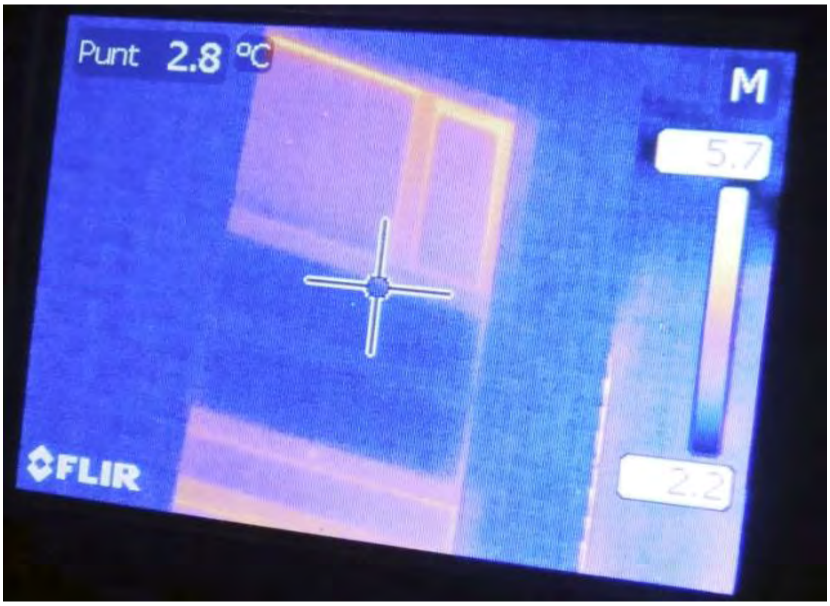


Figure 12: Infrared image of renovated house Kroeven 505

Summary

Social housing provider Allee Wonen owns 19,000 properties in Roosendaal and Breda, The Netherlands. In Roosendaal, in 1960 a large scale residential development was built in an area called De Kroeven, which mainly consists of identical single family houses.

After 40 years of use, and only gradual improvements and normal maintenance, Allee Wonen decided to upgrade and redesign the area. Also the tenants had expressed interest in an energy efficient renovation.

The renovation process based on prefabricated façade and roof elements has proofed to be efficient and cost effective. The tenants were less disturbed by the renovation process and benefit by a lower heating bill, which in future is less sensitive to energy price increases. And also the building owner may expect a higher property value on the market.

Key technologies for the 134 houses using prefab renovation elements:

- Prefabricated timber facades and roofs
- Triple glazed windows
- Prefabricated timber roofs
- Heat recovery ventilation
- Condensing gas boiler
- Solar thermal collectors

The heating energy demand is expected to reduce by 80%.

The hot water demand decreases with 50%, thus resulting in a 70% lower building related energy demand

The significantly lower heating bills make the houses future proof and affordable, even if energy prices keep rising.

Future improvements

Future improvements in the system are foreseen by integrating the ventilation ducts into the design of the prefabricated elements.

Also alternative solutions for the new cavity between the existing wall and new prefabricated elements are being investigated.

Practical experience

The passive renovation using prefab elements can be done whilst the houses are in occupation.

Tenants experience only one day when there is no roof and now windows. At the day of mounting the prefab elements, also the compact heating and ventilation system is craned into the attic.

The prefab approach in this case turns out to be slightly cheaper than an on site passive renovation. Also the renovation process is faster, and thus less intrusive to tenants.

Figure 13: Impression of renovated and unrenovated houses

References

[1] Experiences by Trecodome gained throughout the design, development and renovation process.

Renovation of residential area Dieselweg 3-19 / Graz

Owner: GIWOG Gemeinnützige Industrie Wohnungs AG
General planer: gap-solution GmbH
Architect: Architekturbüro Hohensinn ZT GmbH
Energy concept: ESA-Energie Systeme Aschauer GmbH
Report: AEE INTEC
Location: Graz, Austria
Renovation: 2008-2010

Key technologies

- Solar façade
- prefabrication of facade modules
- Energy concept based on renewable energy sources (mainly solar thermal energy)
- New heating and DHW supply system installed between the façade and existing wall
- Decentralized ventilation systems with heat recovery
- Control and remote maintenance via internet

Background

The residential area Dieselweg is located in the south of Graz (Styria, Austria). In former days the residential area was called „Steyr-Daimler-Puch settlement". (The famous car-company built apartments for theirs workers).

Since the time of construction no improvement measures have been carried out. Therefore the building stock showed a very energy inefficient and poor situation. The existing building structure had no insulation of exterior walls, the basement ceiling or the floor to the attic. Some of the old windows were replaced by PVC-Windows already, some were in since the 1950's. Furthermore the apartments were heated with single heating devices – using solid or fossil fuels or electric heating devices.

Due to poor structural condition and energy performance the heating costs were high and the thermal comfort and living quality were low. But the most challenging circumstance was the fact that it was considered to be impossible to resettle the tenants during constructions works.

Figure 1: View of "Dieselweg 3-19" before renovation

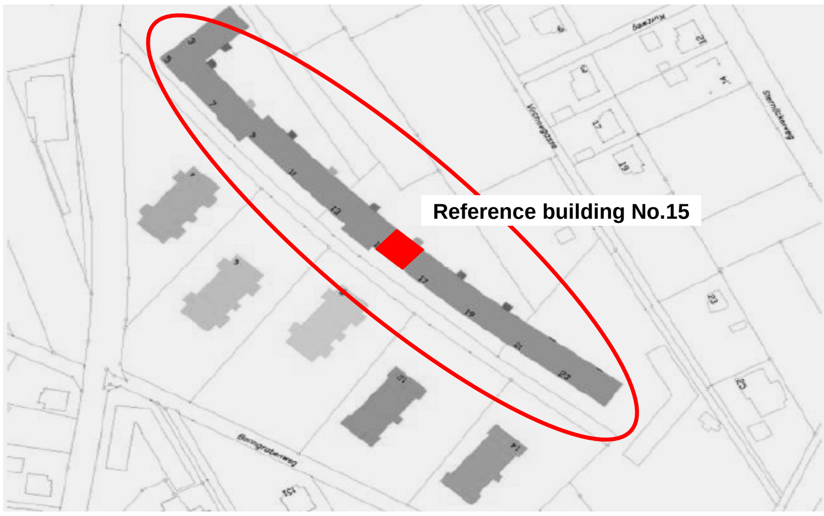


Figure 2: Site plan showing the entire area and location of building "Dieselweg 3-19" (source: Hohensinn ZT GmbH)

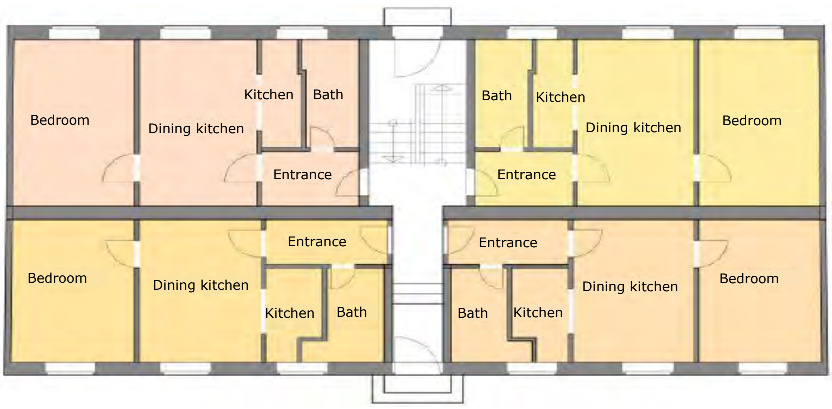


Figure 3: Exemplary floor plan of building Dieselweg No.15 (Source: Hohensinn ZT GmbH)

Project data of building before renovation

Location	Dieselweg 3-19, Graz
Altitude	345 m
Heating degree days $HGT_{12/20}$	3,500 K·d
Year of construction	1952
Number of apartments	126
Net floor area	7,722 m²
Heat demand	142 kWh/(m²·y) (PHPP 2004)
Heat supply	13% solid fuel 33% fossil fuel 54% electricity

Figures by AEE INTEC if not mentioned differently

Renovation concept

The renovation concept for the "Dieselweg" was mainly based on following aspects:

- The essential improvement of the thermal envelope with prefabricated façade modules.
- The integration of a series of components into the prefabricated façade module system like windows, ventilation devices and solar thermal collectors.
- The implementation of a new and innovative solar-active energy concept.

This concept should lead to a significant reduction of the heat demand (about 90%) and the greenhouse gas emissions.

Furthermore the decrease of running costs for space-heating and DHW-preparation should spare an increase of rents. Moreover the housing association predicted lower resulting monthly charges for the tenants.

Figure 4: Dieselweg 3 and 19 – covered with new façade modules

Figure 5: Overview site plan. Dieselweg No. 13 and 15 are marked in red (Source: Hohensinn ZT GmbH)

Design data for renovated building

Year of renovation	2008-2010
Number of apartments	134
Net floor area	7,889 m²
Heat demand	14 kWh/(m²·y) (PHPP 2004)
Reduction	90 %
Heat supply	Solar thermal plant 3 m²/ apartment Ground water heat pump

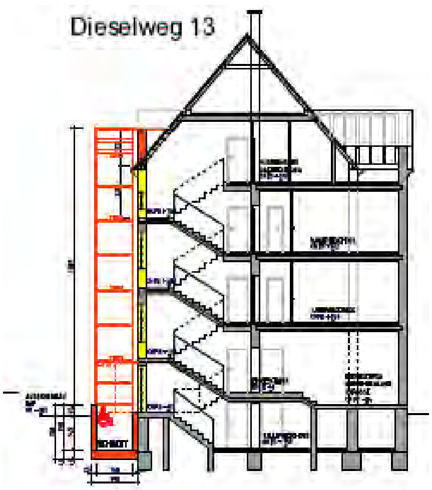


Figure 6: Cross section of Dieselweg No.13 (Source: Hohensinn ZT GmbH)

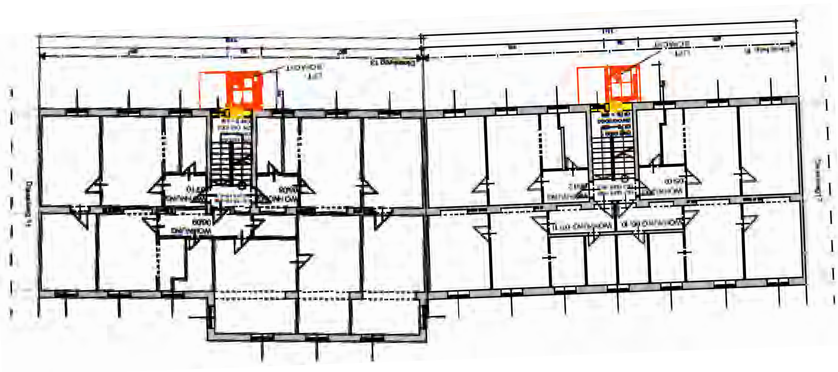


Figure 7: Floor plan of Dieselweg 13 and 15. New lifts are marked in red (Source: Hohensinn ZT GmbH)

Renovation design details

Façade solution

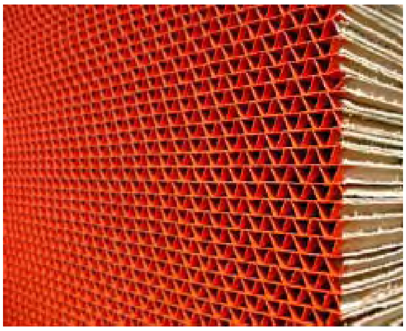


Figure 8: Detailed view of solar comb

Figure 9: Solar comb protected by a toughened glass panel

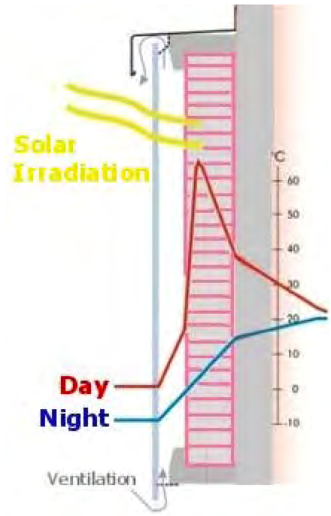


Figure 10: Basic principle of the solar comb (Source: Gap-Solution GmbH)

The basic principle of the solar façade is the solar comb. it is arranged on the OSB board, covered by a glass panel. In-between is a rear ventilated air space. Sunlight falls through the glass and leads to an increased temperature in the airspace and the solar comb. This increased temperatures lowers the difference between inside and outside temperature in winter and leads therefore to reduced heat losses and an improved effective U-value (compared to the static U-value).

Integrated components – windows, shading devices, ventilation ducts

Figure 11: Boreholes in the existing wall: full penetration only at completion

Figure 12: Integration of window and ventilation ducts in the module

Figure 13: Window with integrated shading device and opaque field beside the window, covering supply and exhaust air ducts for ventilation

The apartments are equipped with decentralized single room ventilation devices with a heat recovery (efficiency factor about 73%). The ducts for supply air and exhaust air are integrated in the module.

The existing wall was penetrated with boreholes for the air ducts to the ventilation device inside the apartment. But the existing wall was not penetrated totally at once. After the modules have been mounted, the penetration and installation was completed.

The ventilation systems are positioned beside the windows – on the outside the ducts are covered with opaque glass panels. These are visible within the façade structure (see figure 13).

The supply air is now sucked in the bottom of the field and the exhaust air on the top.

Energy concept

Solar thermal energy

Core of the innovative energy concept is the integration of solar thermal collectors to a great extend.

The façade of the long building row (Dieselweg 3-19) which is facing south and southwest got integrated collectors.

The roof of the carport was also covered with collectors.

Additional collectors were installed on the flat roofs of the five single buildings.

So the entire plant provides a collector area of 3m² per apartment.

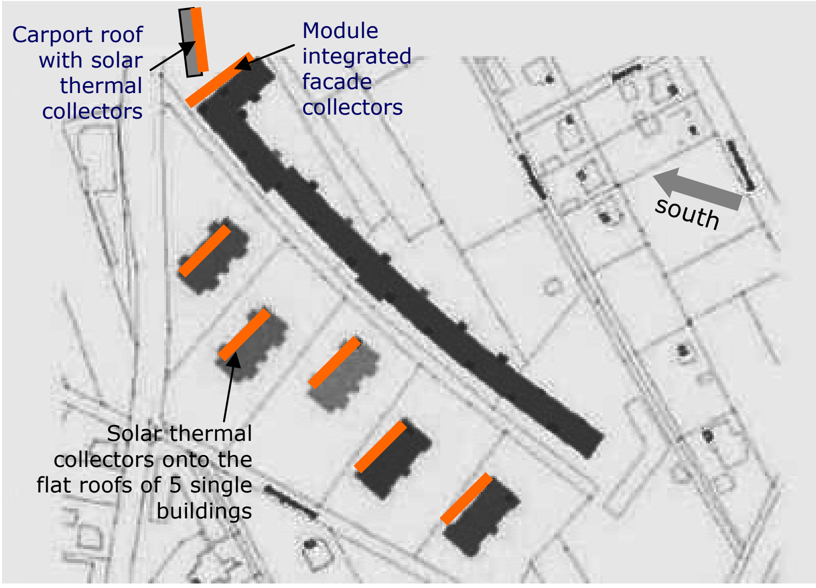


Figure 14: Site plan showing the solar thermal collector areas. (Source site-plan: Hohensinn ZT GmbH)

Heat storage

Heat storage tanks (5 m³) are installed in the basement – three of them in the long building row (Dieselweg 3-19). The are supplied by the solar thermal plant and a ground water heat pump.

Figure 15: Site plan showing the position of the heat storage tanks (Source site-plan: Hohensinn ZT GmbH)

Heat distribution

The heat distribution is done by heating pipes which are running in the space between leveling laths.

The heat distribution is done by small heating pipes which are inserted in XPS insulation boards and mounted on the existing walls. So these walls are warmed from the outside.

DHW

The DHW preparation is done decentralized in the apartments, but supported by the heat storage tanks. The supply pipes are running - like the heating pipes in the space between old and new façade.

Figure 16: Heat distribution on the outside of the existing walls

Figure 17: Heating pipes are inserted in XPS insulation boards.

Construction process

Figure 18: The on-site preparation is done by leveling laths. In-between the distribution system and supply pipes are installed.

Figure 19: The solar collectors were integrated into the prefabricated modules.
(Source: Gap-Solution GmbH)

The renovation proceeded very smoothly:

The on-site preparation comprised the installation of the levelling laths, where in-between the heat distribution panels and supply lines were mounted. Afterwards the remaining space was filled with rock-wool. The modules were brought by a low-loader to the building site, lifted by a truck-mounted crane to the facade. Additionally on each side two assembly operators supported the fitting procedure. After the entire facade was covered with the new modules the old windows were removed from the inside, the vapour barriers were sealed (building angles, window-reveal,...) and the collectors were connected to the supply pipes.

Figures 20-22: Sequence of assembly of the modules on the south-oriented façade
(Source: Gap-Solution GmbH)

Performance data

Monitoring system

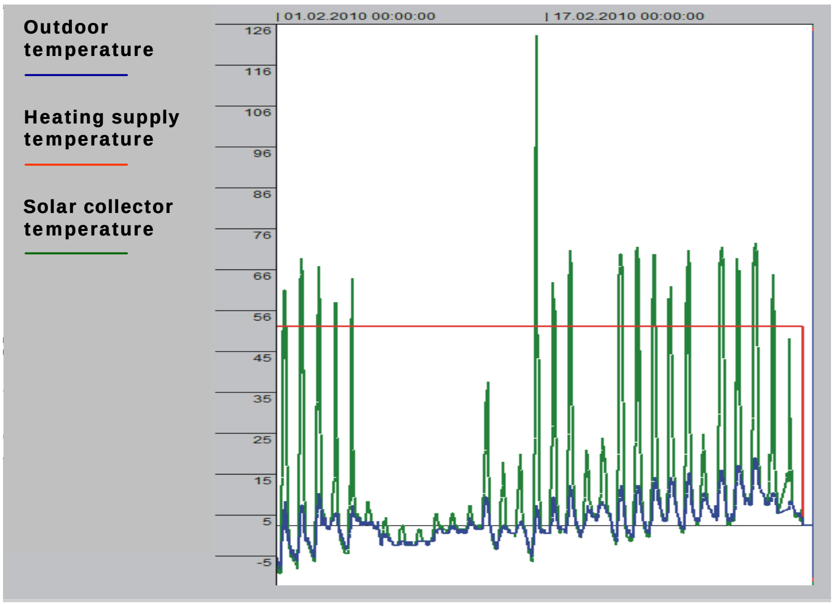


Figure 23: Measured temperatures by control and remote maintenance via control centre (Source: FUTUS Energiesysteme GmbH)

Evaluation and performance assessment

- Energy consumption and flows
- Spot measurements of relevant comfort parameters: Room temperature, room humidity and CO_2 concentration
- Evaluation of the renovation concept concerning the building physics
- Indoor quality in winter as well as in summer
- Questionnaires on users comfort

Renovation costs

Complete Investment

- € 8.8 Mio. excl. of VAT (without external works)
- € 816 per m² (net floor area after renovation)
- € 862 per m² (net floor area before renovation)

Financing

- € 7.3 Mio. GIWOG Gemeinnützige Industriewohnungs AG (including subsidies from the Styrian Government)
- € 1.0 Mio. funding by Federal Government of Austria
- € 0.5 Mio. funding by Styrian Government, Department of Environmental Affairs

Running costs

Heating

- Before renovation about € 2.00 m² net floor area / month (calculated for an apartment heated by electric heating device)
- After renovation about € 0.11 m² net floor area / month

DHW

- Before renovation about € 0.40 m² net floor area / month
- After renovation about € 0.10 m² net floor area / month

Cooperation

- GIWOG Gemeinnützige Industrie Wohnungs AG
- Gap-Solution GmbH
- Hohensinn ZT GmbH
- Klima Aktiv Partner
- ESA Energiesysteme TB Aschauer
- FFG Österr. Forschungs-förderungsgesellschaft GmbH
- klima + energie fonds
- Haus der Zukunft, ÖGUT
- bmvit, bmwfj
- Land Steiermark
- AEE INTEC

Summary

At this showcase project for the high-performance renovation of a large-volume residential building, the passive house standard was achieved and the heating costs could be significantly decreased by about 90%. CO_2 emissions were also reduced by the use of renewable energy sources, e.g. solar thermal energy.

Prefabricated large-scale façade modules with integrated windows and ventilation systems were used. In this way, an essential increase of the thermal and user comfort was achieved the indoor environment was improved.

Practical Experience

Our reconstruction project in Graz, Dieselweg is remarkable for many reasons:

All 204 flats were rented before and throughout all the construction time. The room heating was based on electricity, oil and coal. There were no elevators and a majority of senior inhabitants. The buildings were in a very poor condition according their age.

Aiming a sustained, global technical solution - passive house standard, sustainable energy based heating, barrier free access, healthy room climate - we also had to provide a perfect financial solution in order to convince the inhabitants to accept all the interference and disturbances.

Supported by the Austrian system of public housing aid, by additional research funds and by special support provided by the governor of environmental affairs of Styria and the non-profit organisation "Wohnungsgemeinnützigkeit" of the GIWOG Corporation we found a solution, that kept the social rental fees low and allows an amortization of the investments within reasonable time.

We achieved affordable sustainability. The evaluation of the first results makes us confident, that we can keep our promises, given as well to our customers as to the aiding institutions and our share-holders.

Georg Pilarz (CEO) GIWOG AG

Figure 24: View of the renovated building from the back showing the additionally installed passenger lift

Figure 25: View on a renovated part (left) and a non renovated part of the façade (right)

Renovation of residential area Dieselweg 4 / Graz

Owner: GIWOG Gemeinnützige Industrie Wohnungs AG
General planer: gap-solution GmbH
Architect: Architekturbüro Hohensinn ZT GmbH
Energy concept: ESA - Energie Systeme Aschauer GmbH
Report: AEE INTEC
Location: Graz, Austria
Renovation: 2008-2009

Key technologies

- Solar façade
- Prefabrication of facade modules
- Energy concept based on renewable energy sources (mainly solar thermal energy)
- New heating- and DHW supply system installed between the façade and existing wall
- Decentralized ventilation systems with heat recovery
- Control and remote maintenance via internet

Background

The residential area Dieselweg is located in the south of Graz (Styria, Austria). The buildings were built in the 1960's.

Due to the fact that since the time of construction no improvement measures have been carried out the building stock showed a very energy inefficient and poor situation. The existing building structure had no insulation of exterior walls, the cellar ceiling or the floor to the attic. The balcony slabs reached out without thermal separation and caused significant thermal bridges.

Furthermore the apartments were heated with single heating devices – using solid or fossil fuels or electric heating devices.

Due to poor structural condition and energy performance the heating costs were high and the thermal comfort and living quality were low. But the most challenging circumstance was the fact that it was considered to be impossible to resettle the tenants during constructions works.

Figure 1: View of building (source: GIWOG)

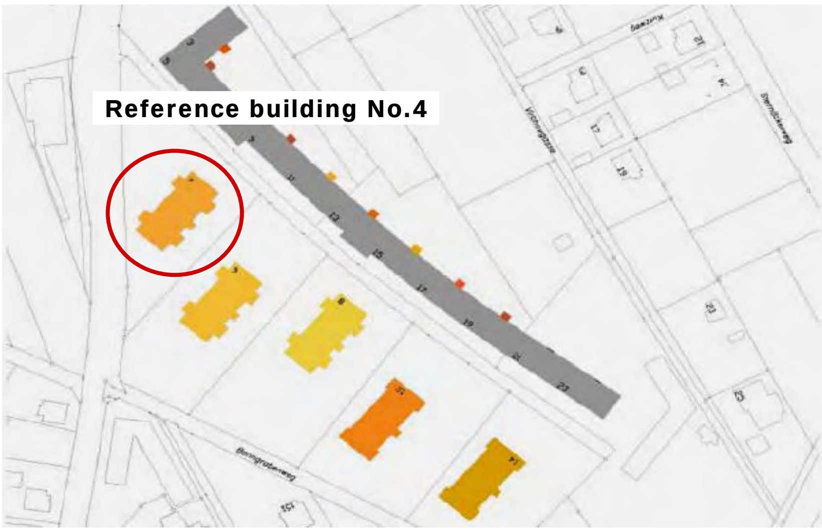


Figure 2: Site plan of the entire area and the specific position of the building "Dieselweg No. 4" (Source: Hohensinn ZT GmbH)

Figure 3: Exemplary floor plan Dieselweg No.4 (Source: Hohensinn ZT GmbH)

Project data of building before renovation

Location	Dieselweg 4, Graz
Altitude	345 m
Heating degree days $HGT_{12/20}$	3.500 K·d
Year of construction	1970
Number of apartments	16
Net floor area	1,240 m²
Heat demand	184 kWh/(m²·y) (PHPP 2004)
Heat supply	13% solid fuel 33% fossil fuel 54% electricity

Figures by AEE INTEC if not mentioned differently

Renovation concept

Figure 4: View of building (rendering) (Source: Hohensinn ZT GmbH)

Design data for renovated building

Year of renovation 2008-2009
Number of apartments 16

Net floor area 1,589 m²

Heat demand 12 kWh/(m²·y) (PHPP 2004)

Reduction 93 %

Heat supply Solar thermal plant 3 m²/ apartment
Ground water heat pump

The renovation strategy

- Prefabricated façade modules
- "Climate wall concept"
- Integration of balconies
- Innovative energy concept
- Innovative heat distribution system
- "Inhabited construction site" No resettlement of occupants

The renovation concept for the "Dieselweg" was mainly based on two facts:

- The essential improvement of the thermal envelope with prefabricated façade modules
- The implementation of a new and innovative solar-active energy concept.

Both should lead to a significant reduction of the heat demand (about 93%) in order to reach passive house standard within renovation and thus contribute to an increased thermal comfort and living quality. Furthermore the decrease of running costs for space-heating and DHW-preparation should spare an increase of rents. Moreover the housing association predicted lower resulting monthly charges for the tenants.

The integration of the balconies into the new thermal envelope contributed to the elimination of the thermal bridges and an added value – increased living space for the occupants.

Figure 5: Exemplary floor plan of renovated building – showing new thermal envelope, integrated balconies and new lift (Source: Hohensinn ZT GmbH).

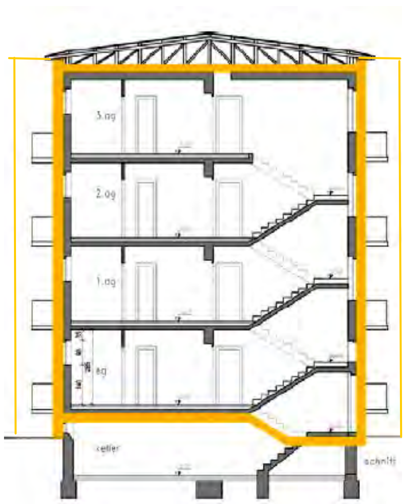


Figure 6: Cross section of new thermal envelope (Source: Hohensinn ZT GmbH)

Renovation design details

Façade solutions

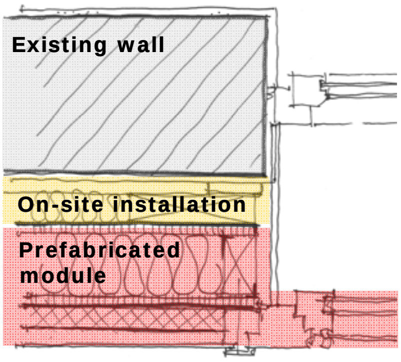


Figure 7:Prefabricated façade module

Layer composition of basic facade module

Existing wall	10 mm	Internal plaster
	300 mm	Existing exterior wall
	25 mm	External plaster
On-site installation	100 mm	Levelling laths in-between rock-wool
Prefabricated module	19 mm	OSB-board
	120 mm	Timber frame between rock wool
	15 mm	OSB-board
	19 mm	MDF- board
	30 mm	Solar comb
	29 mm	Rear ventilation
	6 mm	Toughened safety glass

Concept of the solar-façade

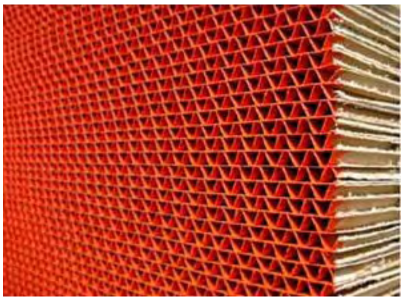


Figure 8: Solar comb (Source: Gap-Solution GmbH)

Figure 9: Solar comb protected by a toughened glass panel

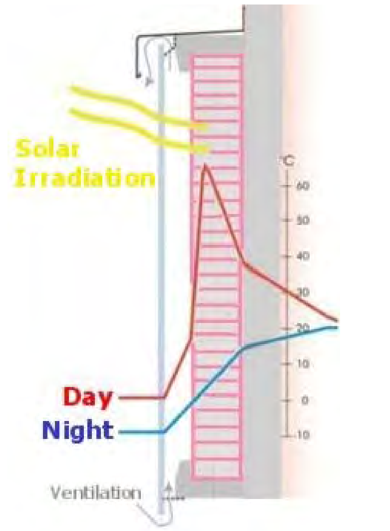


Figure 10: Basic principle of the solar comb (Source: Gap-Solution GmbH)

Figure 11: View on facade

The façade modules are equipped with further integrated components like windows, shading appliances (blinds arranged between the glass panels of the windows) and ventilation ducts. The ducts are in the fields beside the windows (more bright yellow glass panels – to avoid look-through).

The basic principle of the solar façade is the solar comb. it is arranged on the OSB board, covered by a glass panel. In-between is a rear ventilated air space. Sunlight falls through the glass and leads to an increased temperature in the airspace and the solar comb. This increased temperatures lowers the difference between inside and outside temperature in winter and leads therefore to reduced heat losses and an improved effective U-value (compared to the static U-value).

Energy concept

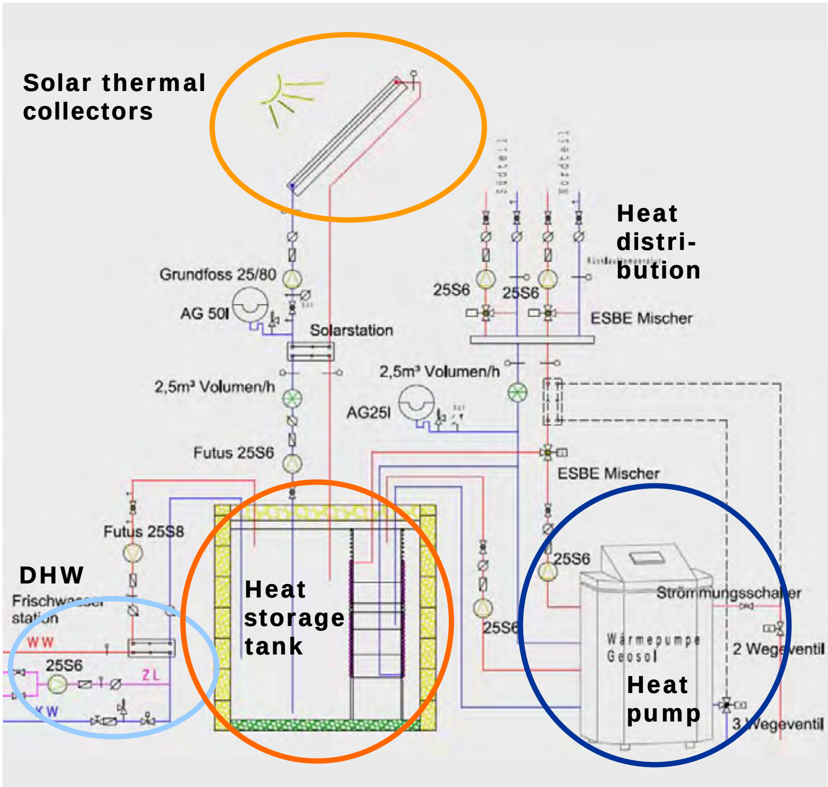


Figure 12: Heating and DHW system

Figure 13: Heat distribution and XPS–boards are installed on existing façade

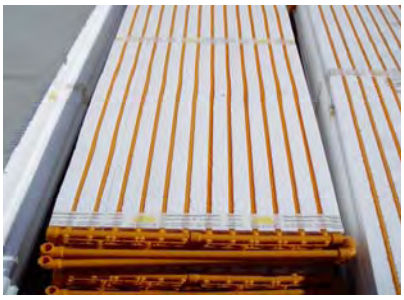


Figure 14: Heating pipes are inserted in XPS boards, which are mounted on the existing wall.

Figure 15: Heat storage tank in the basement of each building block

Heat storage, distribution and DHW

- Heat storage tank (5 m³) installed in the basement.
- Supply pipes are running in the space between existing façade and new façade modules.
- The heat distribution system is mounted on the outside of the exterior wall. The heating pipes are integrated in insulation boards.
- The DHW preparation is done decentralized in each apartment, but supplied by the heat storage tanks.

Heat supply concept

- 3 m² thermal solar collector area per apartment (installed within façade, on flat roofs and on the car port – feeding a heat storage tank per building block
- Groundwater coupled heat pump – feeding additionally into the heat storage tank
- DHW in each apartment supplied by the heat storage tank, supply lines running in the space between existing façade and new module.

Ventilation concept

- Decentralized ventilation with heat recovery system (efficiency factor 73%)
- Air ducts integrated in the façade modules
- Electrical preheating of the supply air if necessary

Advantage of the renovation concept

- Energy performance = passive house standard
- Improvement of indoor and outdoor living quality
- Smart and quick on-site construction procedure
- Occupants are less disturbed during the construction phase
- The existing static system stays unaffected
- Thermal bridges are eliminated
- High quality due to prefabrication in fabrication hall
- Weather-independent fabrication
- Separable and particularly reusable components

Construction process

Concept of prefabrication

Figure 16: Sequence of prefabrication procedure in the fabrication hall (Source pictures 5-6: Gap-Solution GmbH)

Concept of assembly

Figure 17: Sequence of assembly of the façade modules (Source view: Kulmer Bau)

Figure 18: Steel-bearing angles on the plinth

Figure 20: Mounting of 3rd module

Module dimension: 12 x 3 m

Dimension of modules is fixed by the line of the intermediate floor and the window lintel.

First module is the lowest one. It is mounted on steel-bearing angles, which are fixed on the plinth. All other modules rest on the previous one. Therefore all joints are horizontally designed.

Figure 19: Assembly of lowest module

Figure 21: One building side is closed (Source: Gap-Solution GmbH)

Performance data

The performance evaluation was jointly done for whole Dieselweg refurbishment. It includes buildings 4, 6, 8, 12, 14, which are all similar to Dieselweg 4, and Dieselweg 3-19, which is also separately documented.

Monitoring system

Evaluation and performance assessment

- Energy consumption and flows
- Spot measurements of relevant comfort parameters: room temperature, room humidity and CO_2 concentration
- Evaluation of the concept concerning the building physics
- Indoor quality in winter as well as in summer
- Questionnaires on users comfort

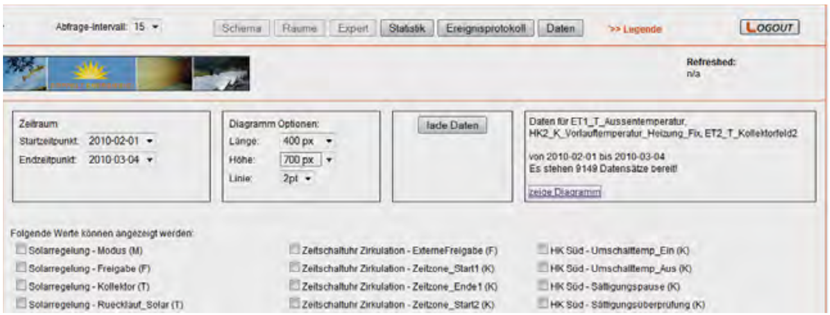


Figure 22: Control and remote maintenance is done via control centre (Source: FUTUS Energiesysteme GmbH)

Renovation costs

Complete Investment

- € 8.8 Mio. excl. of VAT (without external works)
- € 816 per m² (net floor area after renovation)
- € 862 per m² (net floor area before renovation)

Financing

- € 7.3 Mio. GIWOG Gemeinnützige Industriewohnungs AG (including subsidies from the Styrian Government)
- € 1.0 Mio. funding by Federal Government of Austria
- € 0.5 Mio. funding by Styrian Government, Department of Environmental Affairs

Running costs

Heating

- Before renovation about € 2.00 m^2 net floor area / month (calculated for an apartment heated by electric heating device)
- After renovation about € 0.11 m^2 net floor area / month

DHW

- Before renovation about € 0.40 m^2 net floor area / month
- After renovation about € 0.10 m^2 net floor area / month

Cooperation

- GIWOG Gemeinnützige Industrie Wohnungs AG
- Gap-Solution GmbH
- Hohensinn ZT GmbH
- Klima Aktiv Partner
- ESA Energiesysteme TB Aschauer
- FFG Österr. Forschungsförderungsgesellschaft GmbH
- klima + energie fonds
- Haus der Zukunft, ÖGUT
- bmvit, bmwfj
- Land Steiermark
- AEE INTEC

Summary

At this showcase project for the high-performance renovation of a large-volume residential building, the passive house standard was achieved and the heating costs could be significantly decreased by about 90%. CO_2 emissions were also reduced by the use of renewable energy sources, e.g. solar thermal energy.

Prefabricated large-scale façade modules with integrated windows and ventilation systems were used. In this way, an essential increase of the thermal and user comfort was achieved the indoor environment was improved.

Practical Experience

Our reconstruction project in Graz, Dieselweg is remarkable for many reasons:

All 204 flats were rented before and throughout all the construction time. The room heating was based on electricity, oil and coal. There were no elevators and a majority of senior inhabitants. The buildings were in a very poor condition according their age.

Aiming a sustained, global technical solution - passive house standard, sustainable energy based heating, barrier free access, healthy room climate - we also had to provide a perfect financial solution in order to convince the inhabitants to accept all the interference and disturbances.

Supported by the Austrian system of public housing aid, by additional research funds and by special support provided by the governor of environmental affairs of Styria and the non-profit organisation " Wohnungsgemeinnützigkeit" of the GIWOG Corporation we found a solution, that kept the social rental fees low and allows an amortization of the investments within reasonable time.

We achieved affordable sustainability. The evaluation of the first results makes us confident, that we can keep our promises, given as well to our customers as to the aiding institutions and our share-holders.

Georg Pilarz (CEO) GIWOG AG

Figure 23: Façade detail of renovated building

Figure 24: View on the finished façade – showing the new façade structure with integrated windows and balconies, and the solar thermal collectors on the flat roof

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