Case Study 2.1
Deep retrofit with extension

Renovation of residential area in Dieselweg 3-19, Graz

Overview

Climate

Temperate, no dry season, warm summer (Cfb)
Degree day: 3500
Altitude: 345 a. s. l.

Building details

- Owner: GIWOG Gemeinnützige Industrie Wohnungs AG
- Location: Graz, Austria
- Building Type: Residential
- Number of apartments: 126
- Year built: 1952
- Net floor area: 7722 m2
- Heat demand: 142 kWh/m²·y
- Heat supply:
  13% solid fuel
  33% fossil fuel
  54% electricity

Original situation

The concept of Dieselweg 3-18 is the same as Dieselweg 4, since they are all part of the same residential area, located in the south of Graz (Styria, Austria), built in the 1960's and without retrofitting works since then. This means that the building stock show very poor materials conditions and energy inefficiency. In the previous conditions, the structure had no had no insulation on the exterior walls, the cellar ceiling nor on the floor to the attic. The balcony slabs reached on the outside without thermal separation, which caused heavy thermal bridges. Moreover, the apartments were heated by individual heating plants, which uses solid or fossil fuels, or electric devices. The bad insulation conditions brought to very high energy costs and bad thermal comfort conditions, resulting in a low living quality. Also, maybe the most challenging characteristic of the project, was the fact that it was considered to be impossible to resettle the tenants during the retrofit works.

Figure 1 - View of apartment building before renovation

Efficiency Measures

- Solar façade
- Prefabrication of façade 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
- Prefabricated façade modules
- Integration of balconies
- Innovative energy concept
- Innovative heat distribution system
- No resettlement of occupants

Data of renovated building

- Year of renovation: 2008-2010
- Number of apartments: 134
- Net floor area: 7889 m^2
- Heat demand: 14 kWh/(m^2·y)
- Reduction in energy consumption: 90%
- Total investment: 5.3 Mln. € (for the whole district)

Renovation concept

The renovation project for the Dieselweg complex took its way basically on two main points:

- The essential improvement and enlargment of the thermal envelope in order to create a controlled high performance ambient with prefabricated façade modules.
- Windows, ventilation devices and solar thermal collectors were implemented in the prefabricated façade module.
- The implementation of a new and innovative solar-active energy concept which is explained in the following.

In any case, these three strategies have to lead to a significant reduction of the heat demand (in this case of around 90%) in order to reach the passive house standard and reducing GHG emission thanks to the fall of energy consumption. Together with the energy requirements should come also the increased thermal comfort and living quality. Furthermore, the decrease of operating costs for ambient heating and DHW preparation should spring an increase of rent income for the owner, with a better economic perspective.
The addition of the balconies to the thermal envelope increase the value of the asset and the thermal behavior.

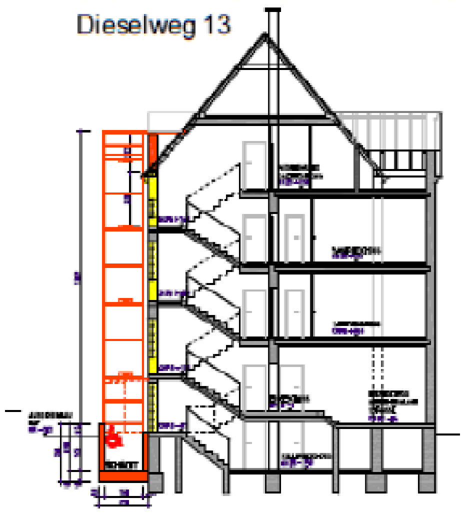


Figure 2 - Cross section of new thermal envelope (Source: Hohensinn ZT GmbH)

Figure 3 - Example floor plan of the old building (Source: Hohensinn ZT GmbH)

Modernization proposal

Façade solutions

The solar façade basic principle is the one of the solar comb, which is arranged in the OSB board, covered by a glass panel. A rear-ventilated air space is located in between these two layers and accumulates sun heat gains to store it. During the night, it is released in the internal ambient giving higher night-time comfort. The incoming sunlight enter through the glass and increase the temperature in the comb holes, which during the night insulate the wall, and during the day convey the heat in the ambient (see Figure 4).

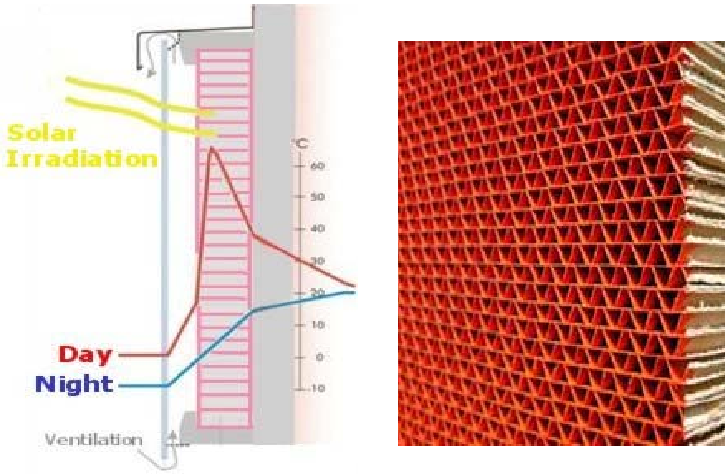


Figure 4 - basic behaviour of the solar comb and cavity detail

The increased temperature in the day in winter limits the losses towards the ambient and gives an improved effective U-value (compared to the static U-value). In addition to this system, produced by Gap Solutions GmbH, the façade modules are equipped with further integrated components like windows, shading appliances. In this case, the blinds are arranged between the glass panels of the windows. The ducts are located beside the windows, behind the more bright yellow glass panels in order to avoid look-through.

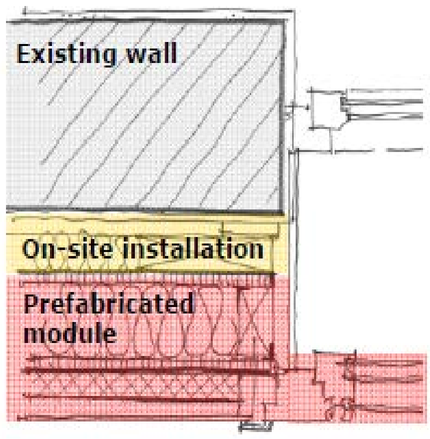


Figure 5 - Prefabricated façade module

Existing wall	10 mm	Internal plaster

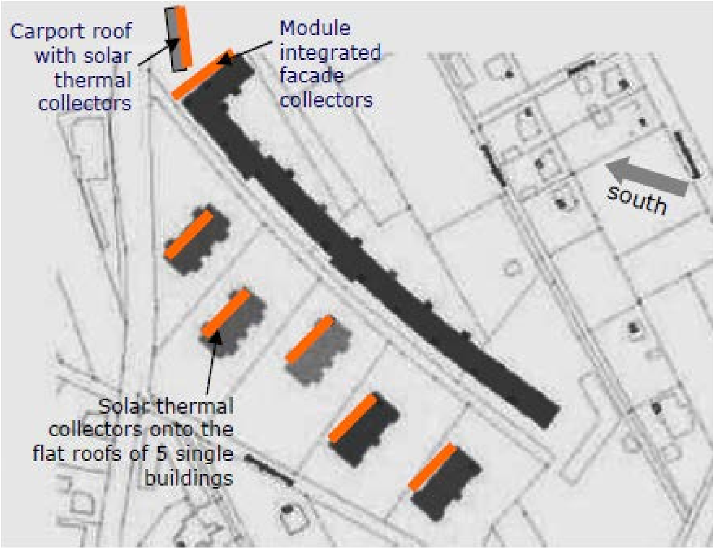
	300 mm	Existing exterior wall
	25 mm	External plaster
On-site installation	100 mm	Levelling laths inbetween rock wool
Prefabricated module	19 mm	OSB-board
	120 mm	Timber frame between rock wool
	15 mm	OSB-board
	19 mm	MDF- board
	30 mm	Solar comb
	29 mm	Rear ventilation

Heat storage, distribution and DHW

- 5 m3 heat storage tanks have been installed in the basement, with three of them just for the Dieselweh 3-19. They are supplied by the solar thermal plant and by a ground heat pump.
- Supply pipes are installed in the space between existing façade and new façade modules, resulting in a new system of heat distribution.
- The heat distribution system is mounted on the outside of the exterior wall. The heating pipes are integrated in insulation boards made of XPS and visible in Figure 6.
- Domestic hot water production is decentralized for each apartment, but supplied by the heat storage tanks

Figure 6 - Heat distribution and XPS-boards are installed on the existing facade

- The roof of the carport was also covered with collectors, as shown in figure, and Additional collectors were installed on the flat roofs of the five single buildings. In this way So the entire plant provides a collector area of 3 m2.per apartment.



Heat supply concept

As explained earlier, an area of 3 m² of thermal solar collector is installed per apartment (it is installed among different zones, within façade, on flat roofs and on the car port. They all feed a central heat storage tank, one per building block).

Also, a ground water coupled heat pump for each block which also feeds the heat storage tank contributing to the solar thermal collectors. The DHW in each apartment is supplied by the heat storage tank, with supply lines running in the space between existing façade and new module.

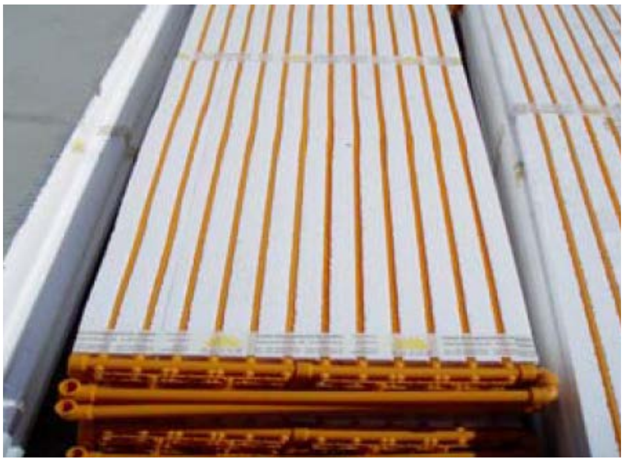


Figure 7 - detail of the heating pipes inserted in the XPS board

Ventilation concept

- The ventilation is now performed by a decentralized ventilation system with heat recovery (efficiency factor 73%)
- Air ducts are integrated in the façade modules similarly to what happen with the heating pipes.
- If necessary, an electrical preheating of the supply air is performed in order to improve the efficiency of the system

Advantages of the innovative system applied

- Energy performance is at the level of a passive house standard.

- Improvement of indoor and outdoor living quality with the related benefits in terms of health and comfort
- Smart and quick on-site construction procedure thanks to the prefabricated elements
- Occupants are less disturbed during the construction phase because the intervention is limited to the application of a new layer on the old one, improving airtightness, insulation and thermal mass. The old wall, checked for static behavior are the basis for the new intervention.
- The existing static system stays unaffected, except for the small weight of the new prefabricated elements.
- Thermal bridges are eliminated with the enlargement of the envelope that now includes balconies.
- High quality due to prefabrication, which enable higher precision control on the components.
- Weather-independent fabrication, even if this particular prefabrication is more adapt to a cold climate like Austria's one.
- Separable and reusable components thanks to the assembly design.

Construction process

The renovation works proceeded without particular obstacles: 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-reeveal) and the collectors were connected to the supply pipes.

Figure 8 - The solar collectors were integrated into the prefabricated modules.(Source: Gap-Solution GmbH)

Figure 9 - assembly of the modules on the south oriented facade

Performance data

After the renovation a monitoring system and the evaluation of performance was performed, and in particular the following parameters were collected.

- Energy consumption and flows
- Measurements of relevant comfort parameters: room temperature, room humidity and CO2 concentration
- Evaluation of the concept concerning the building physics
- Indoor air quality in winter and in summer
- Questionnaires were given to users to measure the comfort conditions

Renovation costs

Complete Investment

- € 8.8 Mio. excl. of VAT (without external works), but only 5.3 Mln. for the block 3-19.
- € 816 per m² (net floor area after renovation)
- € 862 per m² (net floor area before renovation)

Running costs

	Before [€/m²month]	After [€/m²month]
Heating	2	0.11
DHW	0.40	0.10

Financing

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

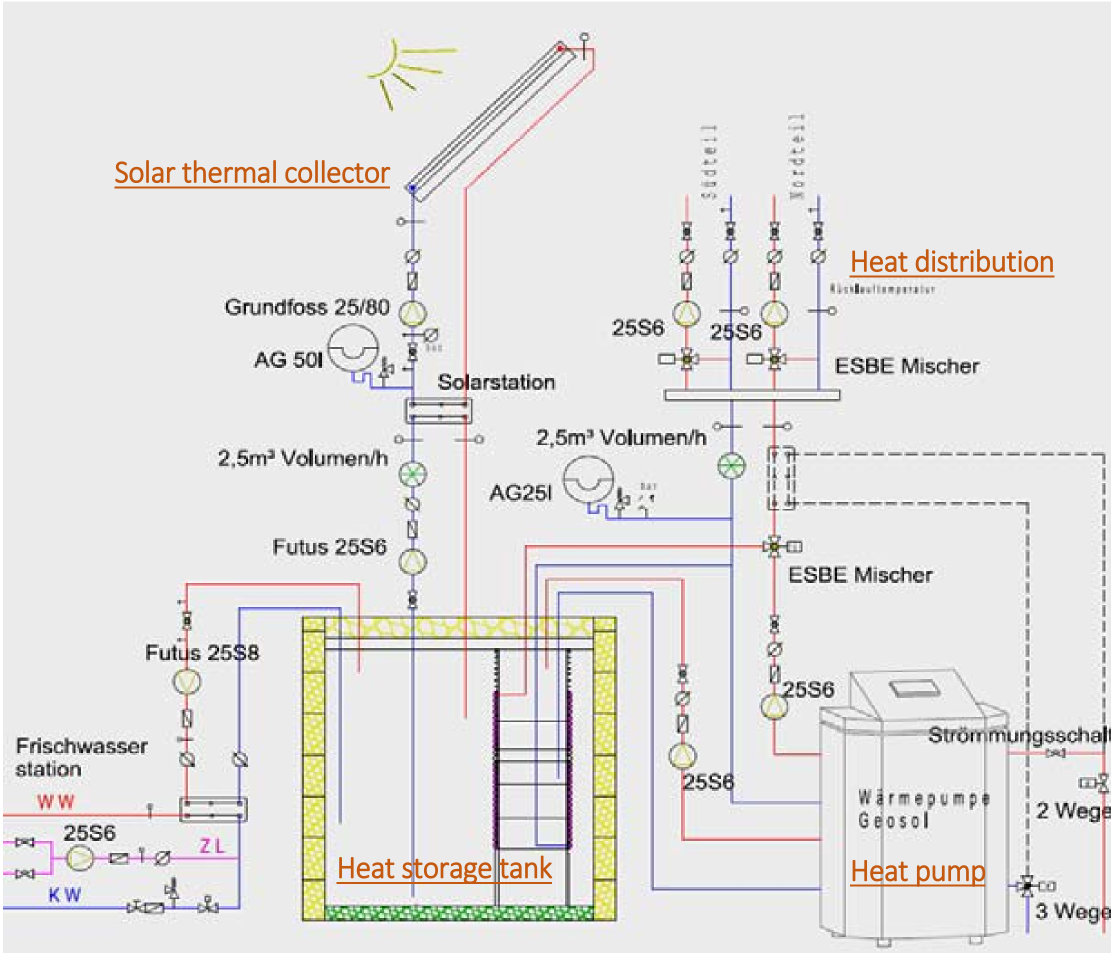
- Before renovation about € 0.40 m2 net floor area / month
- After renovation about € 0.10 m2 net floor area / month

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

Systems overview



Economic balance

In the following an approximated evaluation of the economic balance (Net Present Value). A possible observation is that without incentives and without rent increase (usually reached thanks to a space extension) is very difficult to reach a reasonable payback time.

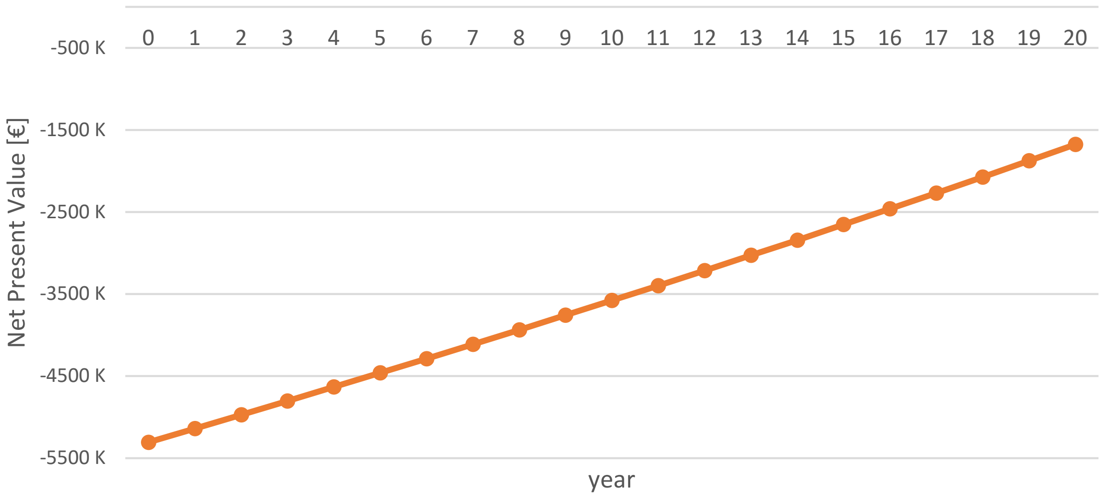


Figure 10 - Extimated investment scenario

Case Study 2.2
Deep retrofit

Renovation of residential area in Dieselweg 4, Graz

Overview

Climate

Temperate, no dry season, warm summer (Cfb)
Degree day: 3500
Altitude: 345 a. s. l.

Building details

- Owner: GIWOG Gemeinnützige
- Industrie Wohnungs AG
- Location: Graz, Austria
- Building Type: Residential
- Number of apartments: 16
- Year built: 1970
- Net floor area: 1.240 m^2
- Heat demand: 184 kWh/m^2·y
- Heat supply:
  13% solid fuel
  33% fossil fuel
  54% electricity

Original situation

Dieselweg is a residential area located in the south of Graz (Styria, Austria), built in the 1960's and without retrofitting works since then. This means that the building stock show very poor materials conditions and energy inefficiency. In the previous conditions, the structure had no had no insulation on the exterior walls, the cellar ceiling nor on the floor to the attic. The balcony slabs reached on the outside without thermal separation, which caused heavy thermal bridges. Moreover, the apartments were heated by individual heating plants, which uses solid or fossil fuels, or electric devices. The bad insulation conditions brought to very high energy costs and bad thermal comfort conditions, resulting in a low living quality. Also, maybe the most challenging characteristic of the project, was the fact that it was impossible to resettle the tenants during the retrofit works.

Figure 1 - View of apartment building before renovation

Efficiency Measures

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

Data of renovated building

- Year of renovation: 2008-2009
- Number of apartments: 16
- Net floor area: 1.589 m²
- Heat demand: 12 kWh/(m²·y)
- Reduction in energy consumption: 93.5%
- Total investment: 8.8 Mln€

Motivation of the project

The renovation project for the Dieselweg complex took its way basically on two main points:

- The essential improvement and enlargement of the thermal envelope in order to create a controlled high performance ambient with prefabricated façade modules.
- The implementation of a new and innovative solar-active energy concept which is explained in the following.

In any case, these two strategies have to lead to a significant reduction of the heat demand (in this case of around 93%) in order to reach the passive house standard. Together with the energy requirements should come also an increased thermal comfort and living quality. Furthermore, the decrease of operating costs for ambient heating and DHW preparation should spring an increase of rents. Moreover, the housing association was able to predict lower monthly charges for the occupants, which is crucial in the case of low-income families.
The addition of the balconies to the thermal envelope increase the value of the asset and the thermal behavior.

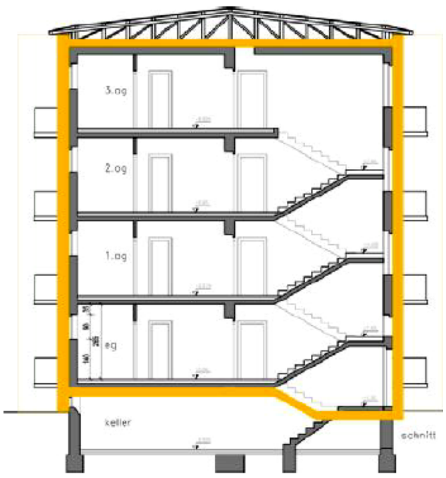


Figure 2 - Cross section of new thermal envelope (Source: Hohensinn ZT GmbH)

Figure 3 - Exemplary floor plan of renovated building – showing new thermal envelope, integrated balconies and new lift (Source: Hohensinn ZT GmbH)

Modernization proposal

Façade solutions

The solar façade basic principle is the one of the solar comb, which is arranged in the OSB board, covered by a glass panel. A rear-ventilated air space is located in between these two layers and accumulates sun heat gains to store it. During the night, it is released in the internal ambient. The incoming sunlight enter through the glass and increase the temperature in the comb holes, which during the night insulate the wall, and during the day convey the heat in the ambient (see Figure 4).

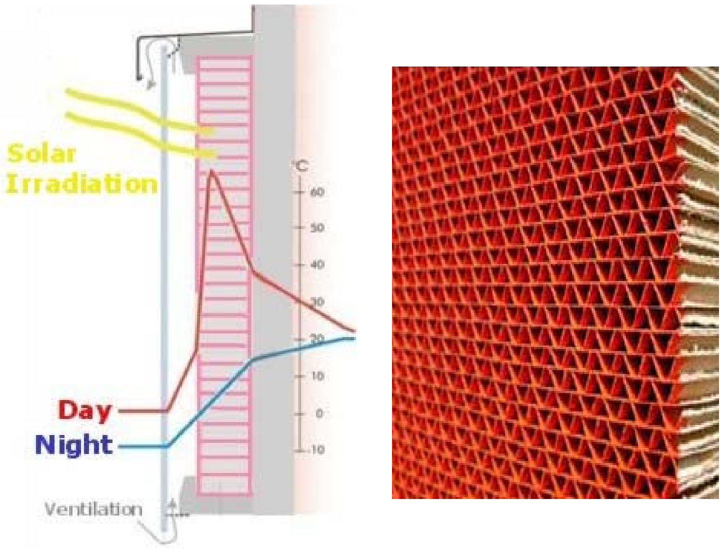


Figure 4 - basic behaviour of the solar comb and cavity detail

The increased temperature in the day in winter limits the lossed towards the ambient and gives an improved effective U-value (compared to the static U-value). In addition to this system, produced by Gap Solutions GmbH, the façade modules are equipped with further integrated components like windows, shading appliances. In this case, the blinds are arranged between the glass panels of the windows. The ducts are located beside the windows, behind the more bright yellow glass panels in order to avoid look-through.

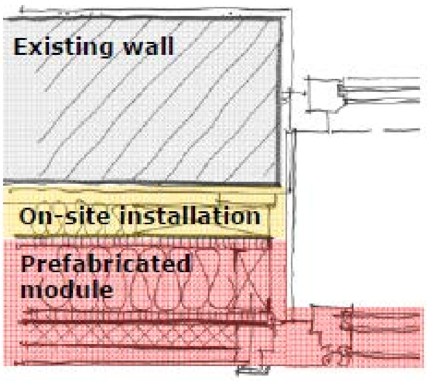


Figure 5 - Prefabricated façade module

Existing wall	10 mm	Internal plaster

	300 mm	Existing exterior wall
	25 mm	External plaster
On-site installation	100 mm	Levelling laths inbetween 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

Heat storage, distribution and DHW

- A 5 m^3 heat storage tank has been installed in the basement for Dieselweg 4 only.
- Supply pipes are installed in the space between existing façade and new façade modules, resulting in a new system of heat distribution.
- The heat distribution system is mounted on the outside of the exterior wall. The heating pipes are integrated in insulation boards made of XPS and visible in Figure 6.
- Domestic hot water production is decentralized for each apartment, but supplied by the heat storage tanks.

Figure 6 - Heat distribution and XPS-boards are installed on the existing facade

Heat supply concept

An area of 3 m² of thermal solar collector is installed per apartment (it is installed among different zones, within façade, on flat roofs and on the car port. They all feed a central heat storage tank, one per building block.
In addition, a ground water coupled heat pump which also feeds the heat storage tank contributing to the solar thermal collectors. The DHW in each apartment is supplied by the heat storage tank, with supply lines running in the space between existing façade and new module.

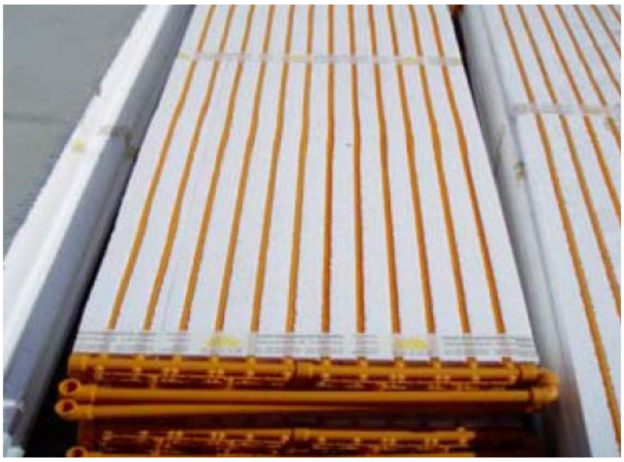


Figure 7 - detail of the heating pipes inserted in the XPS board

Ventilation concept

- The ventilation is now performed by a decentralized ventilation system with heat recovery (efficiency factor 73%)
- Air ducts are integrated in the façade modules similarly to what happen with the heating pipes.
- If necessary, an electrical preheating of the supply air is performed in order to improve the efficiency of the system

Advantages of the innovative system applied

- Energy performance is at the level of a passive house standard
- Improvement of indoor and outdoor living quality with the related benefits in terms of health and comfort
- Smart and quick on-site construction procedure thanks to the prefabricated elements
- Occupants are less disturbed during the construction phase because the intervention is limited to the application of a new layer on the old one, improving airtightness, insulation and thermal mass. The old wall, checked for static behavior are the basis for the new intervention.
- The existing static system stays unaffected, except for the small weight of the new prefabricated elements.
- Thermal bridges are eliminated with the enlargement of the envelope that now includes balconies.
- High quality due to prefabrication, which enable higher precision control on the components.
- Weather-independent fabrication, even if this particular prefabrication is more adapt to a cold climate like Austria's one.
- Separable and reusable components thanks to the assembly design.

Construction process

The construction of the new envelope develops in a top-down way, and steel plinth are used to sustain the prefabricated elements, which are laid on bearing angles. The dimension of modules is fixed to 12x3 m, going from the line of the intermediate floor to the window lintel. When designing such elements, the producers prefers large elements for logistical purposes. They normally have dimensions of 2.8-3-3 m in height and up to 12 meters long.

Figure 8 - Preparation of the timber frame

Figure 9 - Solar comb installation (source Gap-Solutions)

Figure 10 - Assembly of the lowest module

Performance data

After the renovation a monitoring system and the evaluation of performance was performed, and in particular the following parameters were collected.

- Energy consumption and flows
- Measurements of relevant comfort parameters: room temperature, room humidity and CO2 concentration
- Evaluation of the concept concerning the building physics
- Indoor air quality in winter and in summer

- Questionnaires were given to users to measure the comfort conditions

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)

Running costs

	Before [€/m²month]	After [€/m²month]
Heating	2	0.11
DHW	0.40	0.10

Financing

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

Acknowledgment

The demonstration project was supported by:

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- CTI Commission for Technology and Innovation
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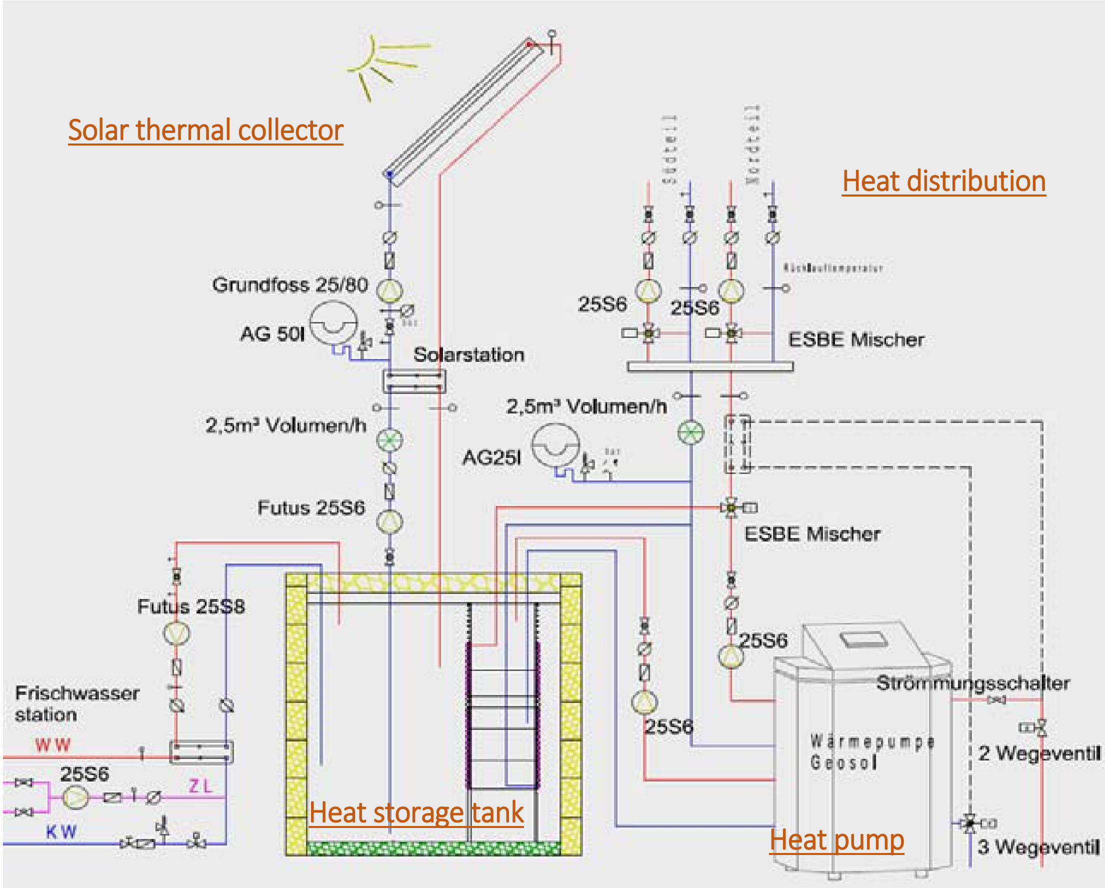
Systems overview



Economic balance

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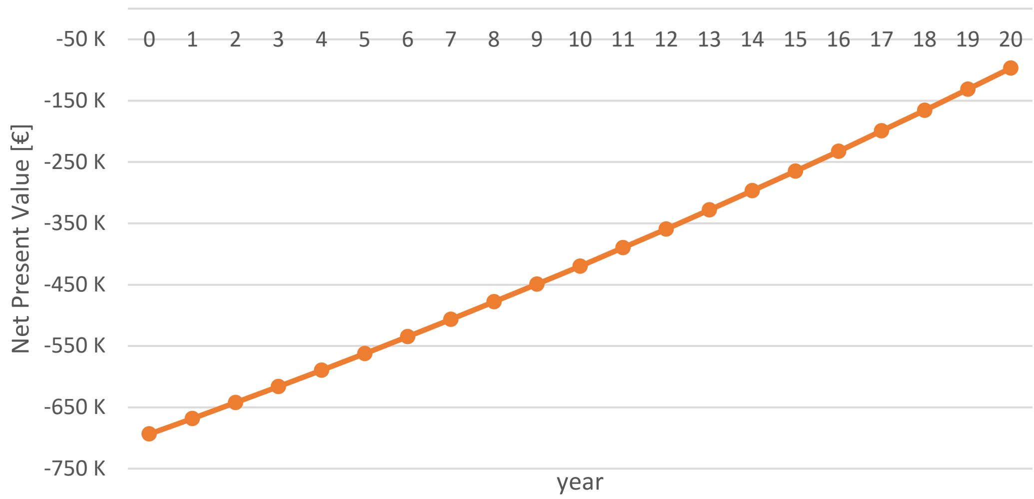

Case Study 2.3
Deep retrofit with extension

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

Overview

Climate

Temperate, no dry season, warm summer (Cfb)
Degree day: 3100
Altitude: 495 a. s. l.

Building details

- Owner: Erbengemeinschaft Ducret
- Location: Zug, Switzerland
- Building Type: Residential
- Number of apartments: 5
- Year built: 1946
- Project Description: PH rehabilitation
- Size: 442 m^2
- Renovation: 2009
- Treated floor area: 442 m^2
- Total heating energy incl. hot water: 226.2 kWh/(m^2·yr) or (100,000 kWh/yr)
- Rents (net) 42,000 €/yr
- Additional costs 3.103 €/yr

Original situation

In the beginning the main problems of the building, situated in Zug, Switzerland, ranged in the usual criticity of old buildings. Which means:

- Poor thermal insulation,
- Presence of thermal bridges,
- As a consequence, poor thermal comfort

The previous conditions brought the complex to higher and higher expenses for thermal comfort, in addition to the structural problems that started to raise of importance due to the non neglectable age of the building.

Figure 1 - North-east view of apartment building before renovation

Motivation of the project

As said, the complex was built in 1946, and the first important intervention needed to modify the critical condition of the envelope. The envelope was in fact insulated with polystyrene for both facades and roofs, as it is explained in the following in detail. Also, a mechanical ventilation system was installed. Thanks to these two intervention only, the energy consumption of the complex felt down by a relevant

Efficiency Measures

- 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

Data of 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·yr)
- Heating primary energy savings: 89 %
- Contribution of solar thermal collectors (incl.): 10 kWh/(m²·yr)
- Contribution of PV-collectors (additional): 9.5kWh/m²·yr
- Rents: 158.000 €/yr
- Rent increase (net): max 30%
- Total investment: 2.5 Mln. €

80%. As a result, the building was able to be classified and certified as MINERGIE-P-Standard, a classification system similar to Passive House standard.

Goals of the intervention

When renovating such an old construction, as well as for a new construction, the internal condition and interventions has to be well calibrated in order to reach both good energy efficiency and indoor quality of life. In this particular case:

- The building, after the deep intervention, has to be socially, environmentally and economically sustainable.
- The major transformation processes has to be completed within 3 months in order to reduce as much as possible the impact on the occupants.
- As a main objective, the renovated building, comprehending the new apartment that is going to be installed on top, has to fulfil the requirements of a passive house standard.

Figure 2 - View of old building and project

The main challenge of the project is that of rehabilitating an old construction, more than 60 years old, and at the same time the energy consumption should decrease by ten times. Furthermore, the intervention has to be economically feasible, and in this sense the creation of new apartments would give strong impulse to the economical validity of the project.
Not only the economic value has to be considered, but also energy standards have to be integrated (as said, reaching Passive House quality) and to reach this goal, time, experience and funding have to be available. If one these elements is missing, the overall result may be not respected. Details have to be considered in the smallest scale, meaning that time and skills are needed.
In the present case study, prefabrication plays an important role, but it is not enough to guarantee high quality to the intervention, even if it is a good starting point thanks to the high level of prefabricated components.

Modernization proposal

Façade & roof solutions

As explained earlier, all the three floors of the brick wall were insulated with a polystyrene insulation with polyurethane core, with a lambda value of 0.023 W/mK. On the top floor an additional attic is built substituting the old inclined roof. The new attic is made of prefabricated lightweight timber elements, transported on place already finished via truck and installed with a crane. They are filled with glass wool, which has a lambda value of 0.032 W/(mK). All the doors and double glazed windows which showed sign of damages and poor quality were replaced with new ones.

Heating system
To face the new need, even if reduced if compared with the previous ones, a new heating pump was installed, with a COP of 4.15. It was also combined with a controlled ventilation system. In each apartment the supply air is heated by a heat exchanger that is integrated in the duct system. In addition to that, in every apartment is possible to regulate individually the temperature, in order to avoid energy waste.

Hot and grey water
A total of 10 vacuum collectors, with a total area that counts up to 15.5 m² combined with a 2.850 litre storage tank for hot water were installed. Moreover, in order to cut the cost for fresh water, a rain water collector has been installed. It is used for the grey water for toilets and garden appliances.

PV system
On the roof a total of 7.6 kWp of photovoltaic power were installed thanks to 36 PV modules of 210 Watts each. The resulting total PV area is 53.5 m².

Controlled ventilation
A heat recovery system was installed, with the addition of a moisture recovery system, in order to prevent dry air during winter. A central air intake pipe was installed a short distant from the building, as it is visible in the figure.

Figure 3 - Air intake is placed 20 m in front of the house

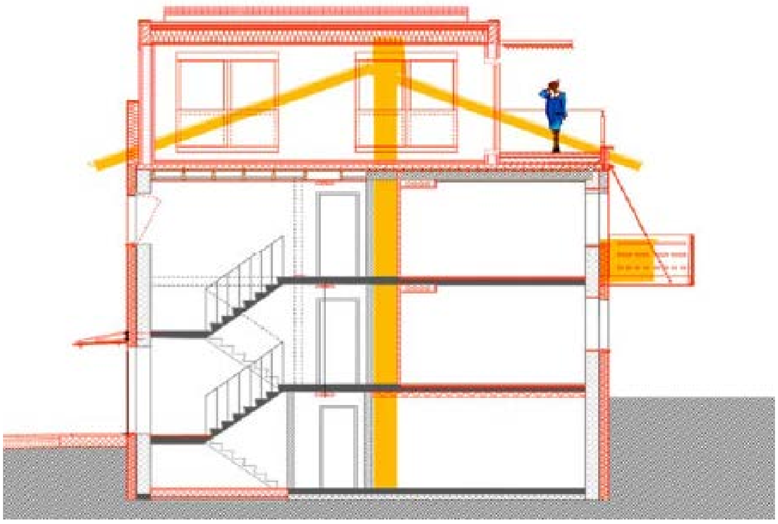

Figure 4 - Section of renovated building

Construction process

A peculiarity of this intervention is that the prefabricated attic was installed next to the old structure. While the old structure was made of concrete floor slabs and brick walls, the lightweight structure was completely prefabricated in timber with glass wool infills. In this perspective, it is important to limit the weight of the superimposing element in order to keep under control the static forces. This strategy of creating a new attic allows to not be limited by the geometry of the below building, leaving the possibility to not stay in line with the old walls. In order to mount the new roof elements, the existing inclined roof was removed and the existing wooden beam slab has been reinforced with lightweight concrete and screw bolts.

The existing balconies were clearly bringing cold thermal bridges inside. For this reason they were removed and a new larger steel balcony were installed, already prefabricated, by crane. As the final intervention, the facades of the prefabricated elements were covered with an aluminium cladding.

Figure 5 - Mounting of the prefab structure

Figure 6 - Mounting of prefabricated roof elements for new attic apartment

Performance data

After the renovation, temperature and humidity were monitored in the period of time that goes from Christmas to March 2009. Indoor temperatures and humidity were monitored in all the 5 renovated apartments in order to check for the effectiveness of the intervention. Indoor temperatures were as expected by the pre-calculations, but the humidity was found to be lower than the previous analysis:

- 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%

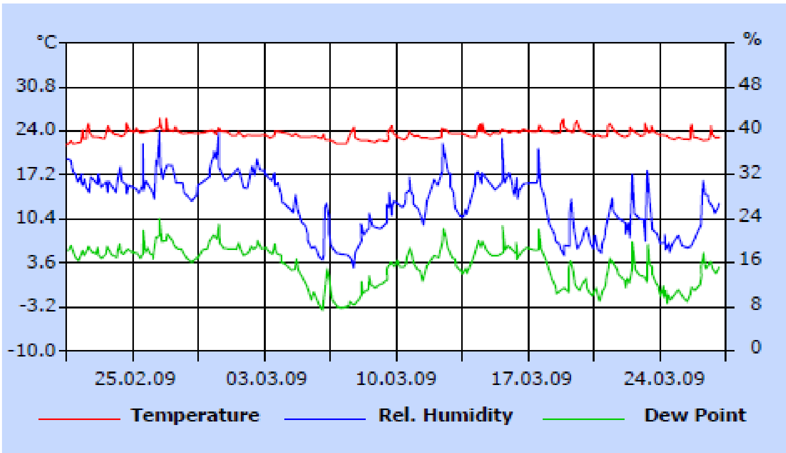

Figure 7 - Room temperatures and relative humidity in typical apartment

Energy bill

The explained intervention were able to reduce the energy consumption, and bring the asset from a category G to the best energy class A. Which means reaching the value of 40.625 kWh/y (50,6 kWh/m²·y) expenditure for electricity and the energy related investment.

The 40% of this electricity used by the heat pump, and a 9.5% is used for heat distribution and ventilation of the indoor air. 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 (incl. PV gains) reached the value of 12.367 kWh/yr, or **15.4** kWh/m²yr over the period of one year.

Energy performance

Total electricity expenditure and the energy related investment:	50.6 kWh/m²yr
• Electricity for HP for heating + DHW + Ventilation in final energy use:	20.2 kWh/m²yr
• ventilation	4.8 kWh/m²yr
• Other electricity use:	25.4 kWh/m²yr
PV produced electricity	9.5 kWh/m²y
Solar thermal	10.05 kWh/m²y
Total net energy consumption (seen over a whole year period, the building is expected to be a net zero energy building for heating, ventilation, and hot water)	15.4 kWh/m²yr

Renovation costs divided by area

	Costs in €
Total costs:	2.5 Mln.
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

References

[1] www.miloni.ch
[2] Saint-Gobain Isover energy efficiency award 2009
[3] Miloni, R.P.: Retrofit statt Dynamit – energetische Sanierung an Stelle des Abbruchs eines Nachkriegs- Mehrfamilienhauses, 16. Status-Seminar 2010 «Forschen und Bauen im Kontext von Energie und Umwelt», ETH Zürich, 2./3. September 2010

Acknowledgments

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

Results and economic balance

In the following an approximated evaluation of the economic balance (Net Present Value) evaluated in the case of the attic addition and the related rent (dark blue line). The light blue line is instead the case in which the attic is not added and the relative rent income disappear. The lower investment of this case does not allow for an economic reasonable return time.

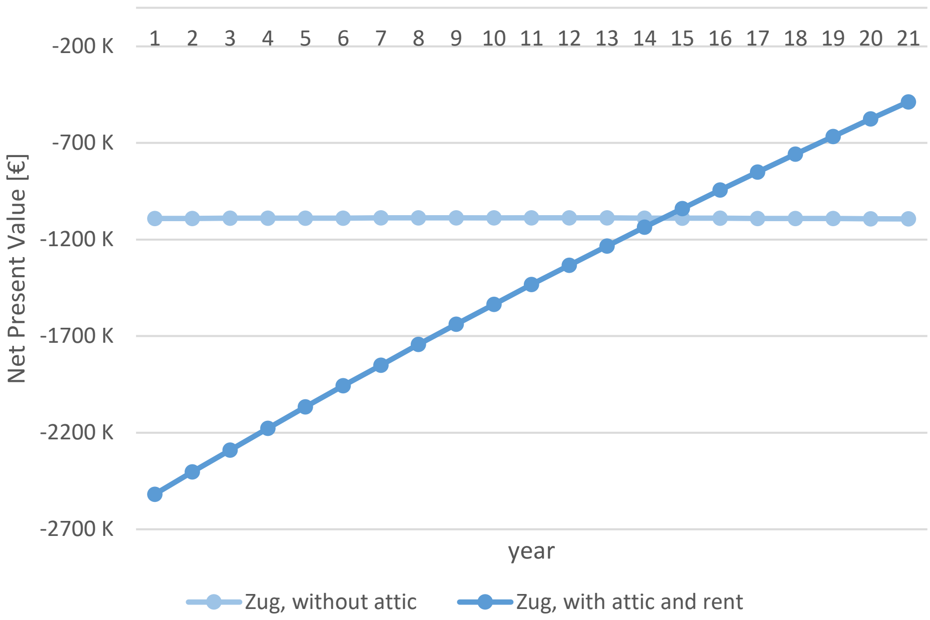

Figure 8 - Mounting of pre-fabricated balconies

Figure 9 - Internal view of new penthouse apartment

Case Study 2.4
Deep retrofit with extension

Net zero energy renovation of a Swiss apartment building, Zurich (CH)

Overview

Climate

Temperate, no dry season, warm summer (Cfb)
Degree day: 3735
Altitude: 506 a. s. l.

Building details

- Owner: Peter Rieben, Markus und Sara Rieben, Zürich
- Location: Zurich, Switzerland
- Building Type: Residential
- Number of apartments: 5
- Year built: 1954
- Project Description: deep retrofit
- Size: 458 m^2
- Treated floor area: 442 m^2
- Total heating energy incl. hot water:
  80.140 kWh/(m^2·y) or 175 kWh/(m^2·y)
- Rents (net) 65.000 €/y
- Additional costs 12.000 €/y

Original situation

Since its construction in 1954, small renovations only have been performed on the complex situated in Zurich. Before the main restoration the building was still in its original conditions, and only the south façade was renovated and the heating furnace was replaced. The building fabric was observed to be in a actually good shape even if not perfect. In this case the main facades and the central wall are the load bearing structure. The external walls are 32 cm thick and are brick-made walls, which were not insulated before the renovation. The exterior rendering on the outer layer was still well preserved when the works took place. The ceilings are made of reinforced concrete slabs. Also, the lightweight structure of the roof was also in good condition. Balconies and handrails showed sign of weather corrosion that occurred during the years and had rust damages due to corroded reinforcement. Most of the windows were still dating back to 1954 which brings heavy problems for insulating capacity and only some of them have been replaced in recent years. The covering of the floors had mostly been replaced in recent years, while kitchens and bathrooms were still the original installed, and in original condition. The oil-heating dated back to 1983, already replaced after the construction, and the heat distribution was done by radiators along the building. The decentralized hot water system instead worked with electric boilers.

Efficiency Measures

- 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

Data of renovated building:

- Year of renovation: 2009-10
- Measurement period: July 2010-June 2011
- Number of apartments: 6
- New 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: 17.983 kWh/y
- Rents (net): 120.000 €/y
- Additional cost: 3.000 €/y
- Rent increase per m2: 39%

Figure 1 - View of former south-east façade

Key points of renovation

The construction of a new attic apartment and an extension of the ground floors answer to the objective of maximizing of living surfaces, in order to create new apartments. Renovation of the building envelope has been performed to the Minergie-P standard (Passive House standard), taking care of the architectural quality.
Substitution and installation of new building technology systems, e.g. new heating system keeping the old radiators, new ventilation system, new DHW system, and new electric installations.
Use of renewable energy was implemented in the following strategies: ground source heat-pump, solar collectors, and horizontal PV system installed on the roof.
For the internal finishing, new bathrooms and kitchens were installed, taking care to recycle existing structures and materials, in order to reduce the environmental effect of the works in the the consumption of embodied energy.

Figure 2 - Vertical section of building. New parts in red

Renovation strategy

When a renovation process is started, some added value has to be generated in order to justify the outlay. The added value is a key point in order to be perform a strong intervention, to achieve energy efficiency and to adapt the building to future needs. In the best case, the added value could cover most of the costs for the renovation, so that the intervention is almost without costs. And to allow the building to become a new building with a modern comfort and modern architecture, which would increase the asset value. That means from an aesthetic point of view, the living comfort and the new technologies have to be like in a new house. For a next renovation in this way, we see further potential in the optimization of the building-process, the distribution system of the ventilation and in the simplification of construction elements.

Modernization proposal

Façade

With the help of the University of Applied Sciences of North-Western Switzerland, the first measures were taken and by laser-measurements of the existing façades. The new, large scale elements made in timber had to fit on the imprecise and curved old walls of the building. Because of this difficulty, cellulose insulation was used in order to fill all the undesired gaps that formed due to the different geometries. The connections between the new windows and the old walls was covered by plasterboard and tightened by sealing tapes, guaranteeing a very good air-tightness in the renovated structure.

U-value	0.18 W/(m²·K

Wall construction:	
Interior rendering	10 mm
Brick wall	320 mm
Exterior rendering	20 mm

Prefabricated element:	
Tolerance / thermal insulation (cellulose)	20 mm
Insulation (cellulose)	180 mm
Wood fiber board	40 mm
Exterior rendering	10 mm
Total (including existing wall)	600 mm

Roof solutions

U-value	0.11 W/(m²·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

In the new prefabricated elements, the ventilation ducts are integrated in the new façade elements with the air inlets positioned above each window. They guarantee optimal ventilation of each room and optimizes spaces, since this solution does not consume any valuable interior space to occupy for the ventilation system. In this way the interior room dimensions are not affected by the systems and a suspended ceiling is not required anymore. However, the integration of the ventilation ducts into the prefabricated elements was a technical and constructive challenge since it requires best attention in the design phase.

Figure 3 - 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 4 - Ventilation distribution on south-east façade

Heating and hot water installation

A geothermal heat-pump and by vacuum solar collectors supply space-heating and domestic hot water. 75% of the hot water and 7% of the energy for the space heating are renewable energy from the sun exploitation. On the upper roof, a PV-system was installed with an area of around 115 m² and a peak power of production of 16.1 kWp. A small building was added on the north-east side of the house to host the heat pump and the ventilation devices necessary for the systems.

Figure 5 - 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 newly developed construction method, which has not often been applied in Switzerland previously. The prefab elements were built as large as possible in order to reduce the detail design, 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, this practice allow to allocate less space for systems. Unfortunately, the windows arrived too late to the work shop of the carpenter and they could not be built in, and instead they had to be mounted on-site.

Figure 6 - Factory assembling of façade module with fire proof ventilation cavity

Figure 7 - The step back of the penthouse floor is used for the horizontal ventilation distribution

Performance data

Increase of thermal insulation

The thermal insulation, and therefore the R-value, has been extremely increased with the addition of the prefab elements. Thanks to this, less energy is now needed to achieve a high comfort level, leading to lower expenses for fuel.

An air tightness of 1.5 h^{-1} was required for the existing part and a very good value og 0.5 h^{-1} has been achieved instead. For the new penthouse apartment, and air tightness value 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 possible only thanks to the enlargements of the apartments, which brings increased rents, which would repay the initial investment. The overall costs of the renovations count to 1.285 Mln € with governmental subsidies counted to 80.000 €.

Energy consumption

The period from July 2010 to June 2011 was measured after the intervention to check for the correctness of data. The energy consumption for space heating and hot water was reduced by 88.5% for final energy and 76% for primary energy. 4.200 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.
See the results section for more data about the new consumption.

	Decrease in final energy use	Decrease in primary energy use
Heating, ventilation and hot water	-88.5%	-76%

Acknowledgment

The demonstration project was supported by:

- SFOE Swiss Federal Office of Energy
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- CCEM Competence Centre for Energy and Mobility

Results

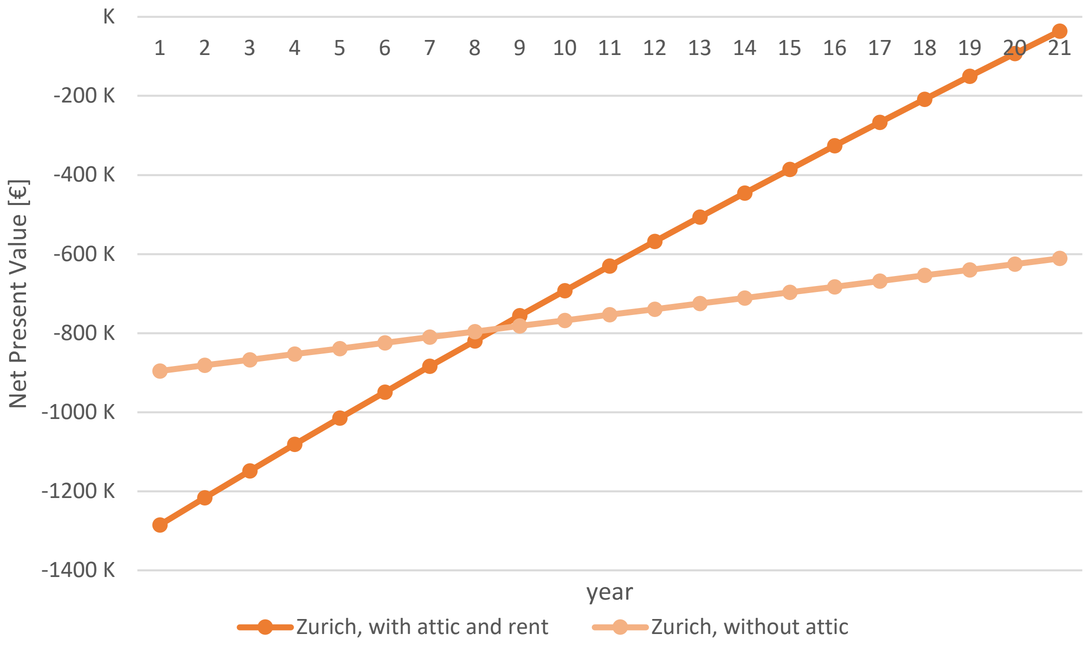
Summary of U-values W/(m²·K)	Before	After	Reduction
Wall construction	1.07	0.18	83 %
Basement ceiling	1.60	0.18	89 %
Roof construction	1.19	0.11	91 %
Windows (frame + glass)	2.5	0.8	68 %

Energy performance kWh/(m²·y) primary energy	Before	After	Reduction
Space + water heating	253	60	76 %
PV electricity production	-	81	108%

Renovation (m²)	Before	After	Increase
Heated floor area	458	657	143 %

Economic balance

In the following an approximated evaluation of the economic balance (Net Present Value) evaluated in the case of the attic addition and the related rent (dark blue line). The light blue line is instead the case in which the attic is not added and the relative rent income disappear. The lower investment of this case does not allow for an economic reasonable return time.



Case Study 2.5
Deep retrofit with extension

School building renovation for sustainable second life in Krummbach, Switzerland

Overview

Climate

Temperate, no dry season, warm summer (Cfb)
Degree day: 3215

- Altitude: 695 a. s. l.

Building details

- Owner: Alexander Ritz
- Location: Krummbach/Geuensee
- Building Type: school
- Number of classrooms: 3
- Number of apartments: 1
- Year built: 1969
- Project Description: PH rehabilitation
- Renovation: 2011
- Total heating energy excl. hot water: 97 kWh/(m²·yr)
- Heated floor area:
- 568 m2

Original situation

The rural hamlet of Krummbach near Geuensee, hosts the small school building, in Switzerland, in a temperate climate. In the school, three primary school classes were held, until 2004. After that, due to demographic changes and the impossibility of having full classes, it was abandoned. Also, the adjacent apartment of the caretaker was left unused for several years.
As many of the buildings built in 1969, it was built with bricks and hollow brick slab; basically, it is not insulated, except for the roof, which present an 80 mm mineral wool insulation.
In 2010, the building was sold to a private owner by the community, under the condition that he would retrofit it and that it would have again an education purpose.
At first, the building had an oil fired heating with separate electric hot water system and was only naturally ventilated. The new owner intend to use the complex as a training center for continued education, looking at the Krummbach older community.

Goals of the intervention

Not only is the modernization the objective of the renovation, but also the quality and the energy efficiency target. In this case, a new envelope was designed and applied around the whole construction. In the facades, modules are made from prefabricated timber frames up to 3.3 meters high and 10 meter long in order to cover the highest points of the envelope. The prefabricated elements are highly insulated with 280 mm of natural sheep wool; in addition to this, triple glazing low-e windows have been installed. The prefabrication process allows installing high quality components in the factory.
In addition, in the roof construction sheep wool was used as insulating material and the existing balconies were enclosed within the new envelope, in order to increase the available indoor space and to avoid thermal bridges. A new balcony was constructed in front of the new façade.
Moreover, PV-modules were installed on the roof in order to provide a renewable energy source and the existing old oil-fired

Efficiency Measures

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

Data of renovated building

- Year of renovation: 2011
- Number of classrooms: 3
- Number of apartments: 1
- Heated floor area:
  568 m2
- Total heating energy incl. hot water:
  9,3 kWh/(m²·yr)
- Final eating energy savings:
  91 %
- Primary heating energy savings: 79%
- Total investment: 1.25 Mln€

heating system was replaced by a ground source heat pump. Radiators are now used for heat distribution and a new ventilation system with
heat recovery was installed in the attic space.

Figure 1 - View of old building and project

Modernization proposal

Façade solution

For the façade, the solution was to install a wooden factory-made timber frame, which was firstly fixed onto a medium dense fibre board. Before the infill was inserted in the spaces of the timber frame (the insulation used is a 280 mm of sheep wool), cavities and holes for electric conduits and ventilation ducts were completed. In the imagine are visible the ventilation pipes spaces already included in the timber frame. Moreover, special mineral wool insulation were applied around the ventilation ducts for fire protection.

Finally, the timber frame was covered with a medium dense fibre board to close the gap. After that, the windows and the ventilated wood cladding were mounted. In the end of the process, the overall U value of the insulated construction wall is 0 is 0.12 W/(m²·K) and 0.88 W/(m²·K) for the windows.

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

Figure 2 - Timber frame with infills and a medium dense fibre board

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

Roof solution

The old roof was substituted, exception made for the rafters of it, which were kept. A 60 mm thickness of insulating wood fiber was used as supporting layer for the 280 mm thick scantling and the sheep wool insulation. Vapour polymer barrier is protecting the construction from mould formation and ensuring air tightness. Moreover cement fiber panels are used as the final roofing panel to cover the whole construction.

Heating system and hot water

The newly installed heating system replace the old one and consists of a heat pump with a COP of 4.35 for heating and 3.13 for hot water) that uses two 90 meters boreholes as heat source and sink. The buffer capacity of the heat pump is of 400 litre for the heating boiler and another one of 400 litres of DHW.

PV system

A total of 58.85 m^2 of amorphous PV modules are placed on the roof, reaching 6.24 kWp of electrical peak power. The annual production of electricity produced by them is around 6027 kWh/y.

Controlled ventilation

Two ventilation units were installed and equipped with combined heat recovery (efficiency=86%) and moisture recovery. They provide fresh air for the classrooms and for the teachers and caretakers apartments. The systems are installed in the attic space of the steep roof, and the horizontal air distribution is performed in the attic space in the same location.

Figure 4 - Cavities for air ducts and electric conduits are integrated into the modules

The vertical distribution is performed connecting vertical pipes to the horizontal ones, and they are fire-protected with a special fireproof mineral wool, as it is visible in Figure 3.

Figure 5 - Mineral fireproof wool protecting the ventilation pipes

Likewise, a moisture recovery system was installed in the new apartments in order to prevent dry air during winter times and to regulate air moisture inside.

Construction process

The modules for the construction are prefabricated, completely built before being brought on site, except for the large sliding doors and the points of the façade that have to be fixed on site.

Around the existing walls, in order to support them, steel angles are mounted; they guarantee precision in the mounting of the different elements (see Figure 6). It has to be remembered that the precision in this stage has to be in the range of a millimetre so that the remaining parts can be installed without issues.

Figure 6 - Horizontal mounting angle and a modules just before its final position

In the spaces between the steel brackets foam glass is inserted foam glass insulation. Windows of the previous complex have been removed before the mounting of the new elements, together with the drilling for air inlet and outlets (see Figure 7). In total 24 modules were mounted to cover the facades, and two working days were needed for the installation; in the first day the ground floor row was mounted, while the second floor and the gables were installed in the second day.

Figure 7 - ventilation ducts integrated in the prefab module

The very high construction speed is possible thanks to the accurate design of the mounting phases in the previous design stage. All the mounting is performed with a crane, and a scaffolding is needed as working platform, which needs to be well balanced in the construction. Also, the suspended modules have to hang vertically in the positioning phases so that minor adjustment are needed. A mastic strip is applied to ensure air tightness between the modules and the telescopic section of the ventilation pipes are
inserted just moments before the modules are fully lowered onto the lower element. In this phase a high precision is required in order to make sure that all modules fit together without residual stresses. Finally, the modules were screwed together thanks to the steel brackets elements at the corners and fixed to the existing wall. The

remaining renovation works have been performed in a traditional way.

Performance data

All the works explained earlier were performed in fall 2011, and no data are available until now, but there is no doubt that the results will be achieved thanks to previous experiences.

Energy bill

Heating and ventilation energy consumption are expected to decrease by 92% for final energy or 83% for primary energy. Hot water energy use (in electricity) is reduced by 68%, for final energy as well as for primary energy thanks to the local production of DHW. In this perspective, the total savings are expected to be 91% for final energy and 79% if accounted for primary energy.
Thanks to the 60 m² PV installation, the energy needs for heating, ventilation, and hot water are more than compensated. Nonetheless, summer electricity gains will also be used as household electricity. Electricity used during the cold season will be mainly supplied by the utilities.

Energy performance

	Decrease in final energy use	Decrease in primary energy use
Heating and ventilation	-93%	-83%
Hot water	-68%	-68%
Total	-91%	-79%

Energy consumption

Demand	
Transmission	50 kWh/(m²·y)
Ventilation	5 kWh/(m²·y)
Hot water demand	7 kWh/(m²·y)
Total	62 kWh/(m²·y)
Energy supply	
Internal gains	11 kWh/(m²·y)
Solar gains (without PV)	20 kWh/(m²·y)
Heating demand (from HP)	24 kWh/(m²·y)
Hot water	7 kWh/(m²·y)
Total	62 kWh/(m²·y)
Final	
Heating energy	5.5 kWh/(m²·y)
COP heat pump	4.35
Ventilation energy	1.4 kWh/(m²·y)
DHW energy	2.2 kWh/(m²·y)
COP heat pump for DHW	3.13
Pumps	0.2 kWh/(m²·y)
Total	9.3 kWh/(m²·y)
PV produced electricity	10.5 kWh/(m²·y)

Total energy consumption (seen over a whole year period, the building is expected to be a net zero energy building for heating, ventilation, and hot water)	(9.3 – 10.5) = -1.2 kWh/(m²·y)

Renovation costs divided by area

	Costs in €
Total costs:	€ 1.25 Mln. €
Builders	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

Acknowledgment

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Results

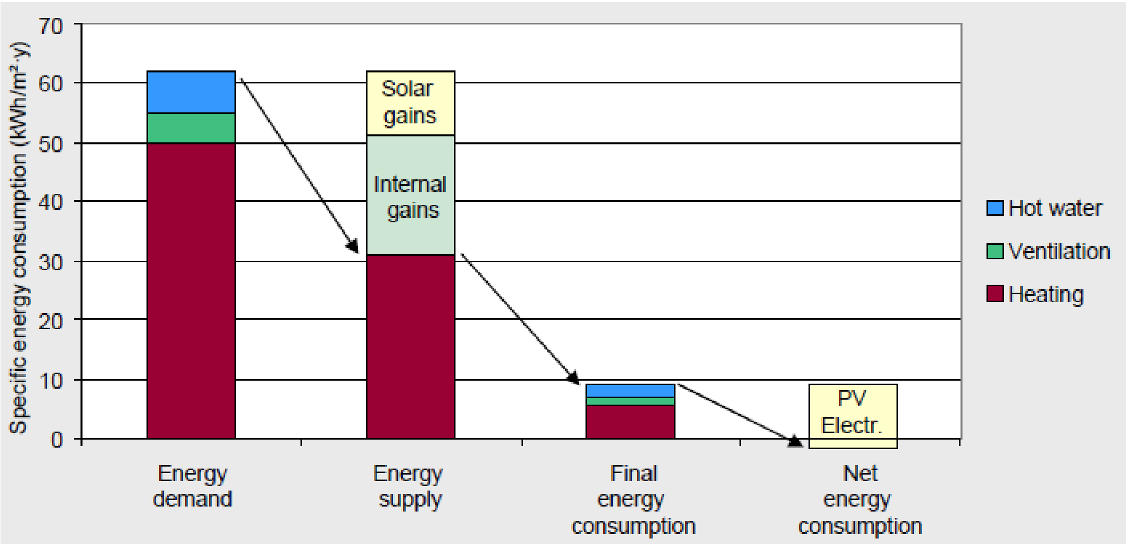

Figure 8 - Energy consumption for heating, ventilation, hot water of renovated Krummbach school building

Economic balance

In the following an approximated evaluation of the economic balance (Net Present Value). A possible observation is that without incentives and without rent increase (usually reached thanks to a space extension) is very difficult to reach a reasonable pay back time. The fact that a school does not receive any rent makes it difficult to pay back the investment, giving a very low NPV in front of the great investment outlay.

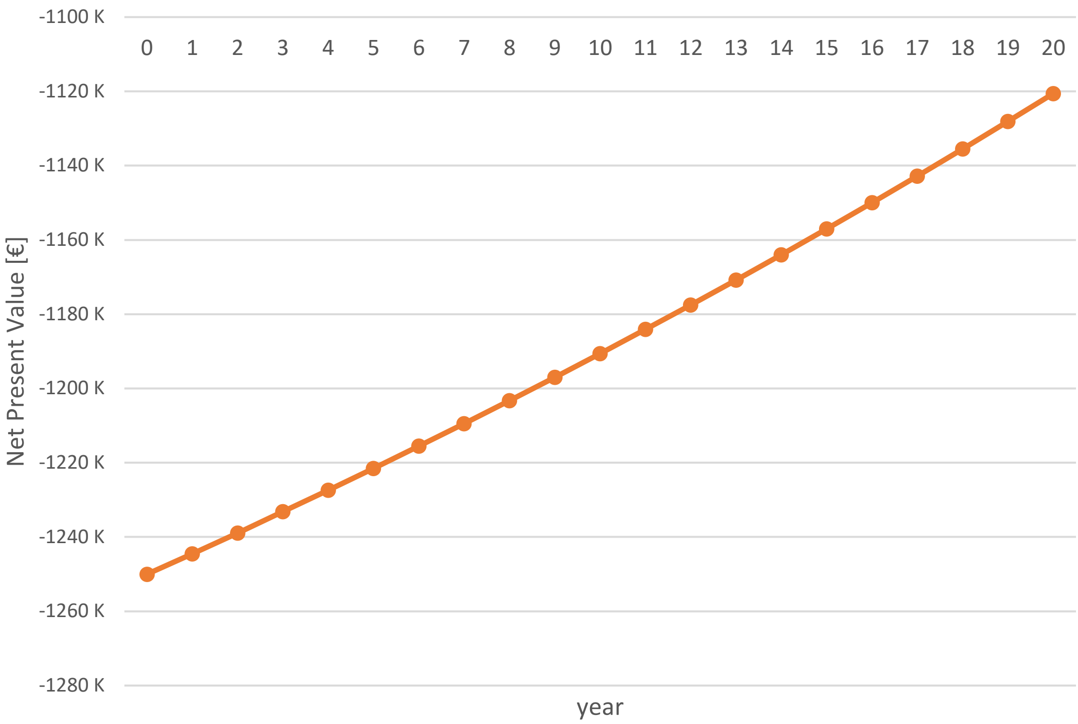

Figure 9 - View of renovated building just before completion

Case Study 2.6
Deep retrofit

Passive renovation, Roosendaal, NL

Overview

Climate

Temperate, no dry season, warm summer (Cfb)
Degree day: 3400
Altitude: 5 a. s. l.

Building details

- Owner: Erbengemeinschaft Ducret
- Location: Roosendaal, NL
- Building Type: Residential
- Number of apartments: 134
- Year built: 1965
- Size: 16080 m2
- Specific energy consumption: 137 kWh/m²·yr
- Rents (net): 6000 €/yr
- Heating costs: 1140 €/yr

Original situation

Social housing provider Allee Wonen owns all the 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 for the purposes of local industries workers. Forty years of use had an impact on the housing conditions, which was maintained only with gradual improvements and normal maintenance. The owner and the inhabitants expressed their interest for energy requalification.

The renovation was planned in such a way that the tenants shall stay in their houses for the whole period of renovation, reducing the discomfort period. Which means a fast and non-intrusive renovation process on the large number of apartments. It is a crucial challenge for the two architect firms and energy consultants that were appointed to develop the passive renovation, while aiming at the same low energy demand for space heating and domestic hot water, and also for an architectonical variety of the district.

Efficiency Measures

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

Data of renovated building

- Year of renovation: 2011
- Number of apartments: 134
- Heated floor area: 16080 m²
- Total heating energy incl. hot water: 38.0 kWh/(m²·yr)
- Heating + DHW energy savings (per m2): 72 %
- Specific electricity consumption: 29 kWh/(m²·yr)
- Installed heating capacity: 3.5 kW
- Spec. heating capacity: 30 W/m2
- Rents: 6780 €/yr
- Total investment: 25.000 € per house
- Heating costs: 335 €/yr

Figure 1 - overview of the area Kroeven in Roosendaal

Two approaches

Approach 1 resulted in two test houses, showing how the assets can be insulated using 200 mm external EPS insulation and a façade with plaster rendering, window frames with passive house quality 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 consists of one test house demonstrating how the complex can be insulated using a new 350 mm timber frame element with cellulose insulation, using 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 from local material. This second approach has been applied in 134 houses from 2010 to 2011 and is the one considered here.

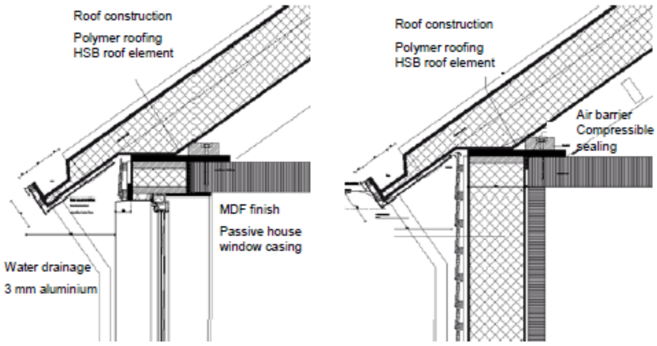

Figure 2 – cross section of the prefab roof renovation

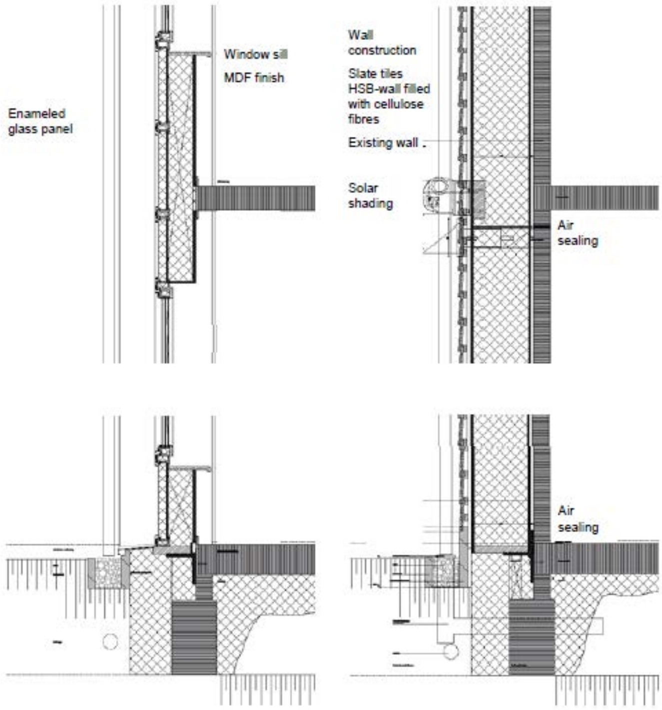

Figure 3 - Wall and basement prefab renovation

Modernization proposal

Façade

The renovation of Kroeven's complex 505 consisted, as a first step, of the demolition of the outer leaf of the cavity wall. The second phase was to insulate the perimeter around the houses with EPS insulation, and to create the foundation for the prefabricated timber elements. The new prefabricated timber elements are 360 mm wide and contain cellulose fibre insulation of 350 mm. The U-value is 0.11 W/(m²·K). Thermally broken windows with triple glazing have been factory mounted on the prefabricated wooden frames. The U-value of the frame is 0.87 W/(m²·K), the U-value of the glazing 0.5 W/(m²·K) with a g-value of 0.47. The new cavity between the inner leaf and the timber element is sealed around the window frames to avoid thermal bridges. Eventually, battens were mounted on site to allow the installation of natural slate tiles. The external tile, in this way, provides the building with a ventilated façade.

Figure 4 - real section of the timber frame. The external slates and the cellulose insulation are visible,together with the new roof and triple glazing windows

Roof solutions

The roof elements are 360 mm wide (similar to the walls' one), and are covered with a PVC roofing material. The U-value stands at 0.10 W/(m²·K). Solar collectors were installed for the preheating of domestic hot water already in the factory, so that the whole prefab roof would come ready for mounting on site

Also ventilation supply and exhaust ducts together with the air supply and exhaust for the gas heated equipment have been preinstalled in the timber frame.

Figure 5 - prefab timber frame roof module with solar panel

Heating and ventilation

Heating and ventilation supply is provided by a compact heating system, designed by Brink Climate Systems, which includes all components in one unique system:

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

Due to the limited height of the attic, the compact system has been divided in two parts (heat recovery unit and the other components) and placed one next to each other as shown in figure. The living room has one new radiator to replace two large ones. The flow in the bedroom radiators has been reduced to adapt to the new heating demand, and the user installed thermostatic valves for better controlling of room conditions. Fresh air is now provided by a ventilation unit, which also treat the exhaust air from kitchen and bathroom.

Figure 6 - combined heating, ventilation and DHW system

Hot and grey water
DHW is provided by storage tanks which are fed by the 5 m^2 solar thermal collectors installed on the roof, even if a gas boiler is preserved.

Construction process

The newly installed prefabricated elements are produced by VDM, company based 250 km away from the renovation site of Roosendaal. The process of renovating 134 units has been considered with attention and the flow of work optimized in order to allow the renovation of 4 houses per week. The elements have been transported on one truck per home which travelled in the night-time and installed on the next day. In this way, the tenants experienced only one day when there was no roof and no windows, reducing the discomfort at the minimum level.

At the day of mounting everything was put in place: the prefab elements and also the compact heating and ventilation system was craned into the attic. The whole process from start to completion took only six weeks, at a very high rate. Before the timber frames were mounted, gardens were partially cleaned and the external cavity leaf demolished, as explained before. Then, the perimeter was insulated and the foundations for the new elements was adapted. After this, the external tiles for the ventilated façade were applied.

Figure 7 -Ttransprtation phases of the prefab element

Performance data and energy consumption

In the framework of the new EU Commission funded FP7 project "E2ReBuild" monitoring will take place. Also national research and demonstration programmes help supporting the monitoring works.

Airtightness was assessed with a blowerdoor test to be of 1.0 ach at 50 Pa, an optimal value.

The energy consumption of the renovated houses is expected to change significantly after the renovation. Space heating demand will reduce to a calculated 25 kWh/(m²·y) for a mid-terrace house and to around 30 kWh /(m²·y) for an end terrace. If confirmed, these values are 80% better than the current performance. Hot water demand will reduce by 50% to 60% due to the roof installed solar thermal collectors, also thanks to the higher energy efficiency.

In the end, 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 with the increasing energy prices. The future-proof of elements is a key factor for a sustainable building stock.

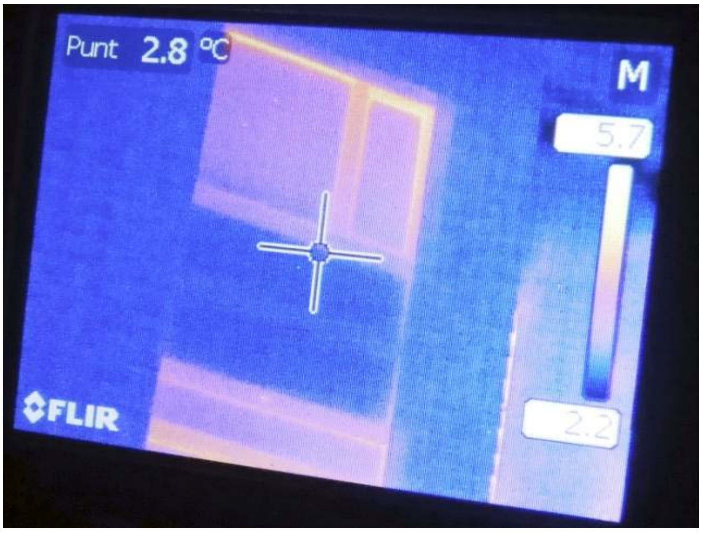

Figure 8 - the energy performances were evaluated with thermal cameras

Renovation costs

If the total intervention costs is smeared on the 134 apartments, the cost for each unit amounts at 107.500 €, and the additional cost for energy efficiency is of only 25.000 €.
The prefabrication approach helps reducing heavily costs, the tenants accept to pay a slightly higher rent, which equal the energy savings along one year. Moreover, the renovation project brings an higher value in case of future market evaluation.

Future improvements

Future improvements in the system can be possible going towards a higher degree of integration in the timber frame elements. In addition, alternative solutions for the new cavity filling between the existing wall and new prefabricated elements are being investigated.

References

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

Economic balance

In the following an approximated evaluation of the economic balance (Net Present Value). A possible observation is that without incentives and without rent increase (usually reached thanks to a space extension) is very difficult to reach a reasonable payback time. In yellow the case in which only the extra cost for energy efficiency is considered, in which the “anyway” measures are excluded. This perspective gives a completely new point of view, which push the owner to add energy efficiency when other renovation works are already scheduled.


20 K
K
-20 K
-40 K
-60 K
-80 K
-100 K
-120 K
Net Present Value [€]
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
year
NPV complete investment
NPV (only extra cost for efficiency)