Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Umwelt, Verkehr, Energie und Kommunikation UVEK

Bundesamt für Energie BFE

Final report 19th December 2011

AN INNOVATIVE PREFABRICATED RETROFIT SYSTEM FOR LOW ENERGY RENOVATIONS - CASE STUDY: APARTMENT BUILDING

SEGANTINISTRASSE 200, ZURICH

Initiator of work:
Bundesamt für Energie BFE
Forschungsprogramm Energie in Gebäuden
CH-3003 Bern
www.bfe.admin.ch

Engaged instutution:
kämpfen für architektur ag
badenerstrasse 571
CH-8048 Zürich
www.kaempfen.com

Author / co-authors:
Nadja Grischott, Architect FH MAS EnBAU, kämpfen für architektur ag,
Beat Kämpfen, M.A: UCB, dipl. Architect ETH/SIA, kämpfen für architektur ag,
beat@kaempfen.com
René Naef, Dipl. El.-Ing HTL, NDS Energie, naef energietechnik.
naef@naef-energie.ch

BFE-Department Leader: Andreas Eckmanns
BFE-Programme leader: Charles Filleux
BFE-Project leader: Mark Zimmermann
BFE-Contract- and project numbers: SI/500348 / 103118

The author of this report bears complete responsibility for its content and conclusions

Summary and conclusions

The project at Segantinistrasse, a typical apartment building from the 1950s, provided the ideal opportunity to test the prefab retrofit system which was developed as part of the ccem-retrofit research project [2]. In summary the system met the following expectations:
compared to a conventional exterior finishing system the prefab method proved to be an efficient construction method, providing a degree of precision crucial to achieving a tight building envelope. It was demonstrated that the prefab retrofit construction is a feasible method for transforming the vast stock of energy-wasting residential buildings into net zero energy balance buildings.

It is, however, important to point out that careful planning is instrumental and labour-intensive: The Segantinistrasse project showed that issues such as site access, scaffolding system, and early involvement of all stakeholders in the planning process are the keys to ensuring a successful project. Above all, the building size itself determines largely whether or not prefabrication can become a cost effective alternative to conventional construction methods. Only sufficient element repetition and large-scale production provide the economy of scale to make the case for prefabrication. Thus although the Segantinistrasse project was very interesting for training purposes, it was rather toosmall for an efficient implementation of the retrofit method.

Table of Contents

1. The Segantinistrasse project

1.1. Description of the existing building

The three-storey apartment building (see Figs. 1-10) is located in a prime location[1] at Segantinistrasse 200 in Zürich-Höngg. Located close to the city centre and the Hönggerberg, a popular recreational area, the site offers ideal living conditions. The building sits on a south-facing slope overlooking the entire city. A small river adjacent to the property and a large amount of greenery enhance the attractiveness of the neighborhood. All in all there are two 3-bedroom and two 2-bedroom apartments on the upper floors and an additional 3-bedroom ground floor apartment with access to the garden. The building dates from 1954 and has largely kept its original form and condition typical of buildings of this era. Only the south façade has been renovated and the heating furnace replaced one time. The small kitchens and bathrooms with outdated appliances no longer conform to current living standards.

The exterior walls are load bearing, as is the internal wall in the middle of the floor plan (see Fig. 1). The exterior walls are of 32cm-thick masonry construction finished with a mineral stucco which has been well-maintained. Without thermal insulation the exterior envelope does not comply with current building regulations. The ceilings are reinforced concrete and the extremely lightweight roof structure is in good condition. Where the concrete balcony slabs have been damaged, exposed rebar shows signs of corrosion. In addition, steel railings are partially rusted and the fiber cement balcony balustrades are weather-worn and need to be replaced (see Fig. 7). Most of the windows date from 1954, with only a few having been replaced in recent years. The interior floor finishes have mostly been replaced as single isolated interventions, while original kitchens and bathrooms have never been upgraded to modern living standards. The central heating and radiators are original except for the oil furnace, which was replaced in 1983. Domestic hot water is provided by individual electric boilers in each apartment.

Project data before renovation	
Location	Segantinistrasse 200, Höngg CH-8049 Zürich
Altitude	506 m above sea level
Heating degree days	229 Kd
Year of construction	1954
Number of apartments	5
Heated floor area	458 m^2
Heating energy (incl. hot water)	80’140 kWh/a (average measured 2002-2007)
Specific energy consumption	175 kWh/m^2a (measured)
Rents (net)	65’000 €/a
Utility costs	12’000 €/a

[1] Highest property rating according to ZKB evaluation

Fig. 1 Typical floor plan of existing building

Fig. 2 Ground floor plan

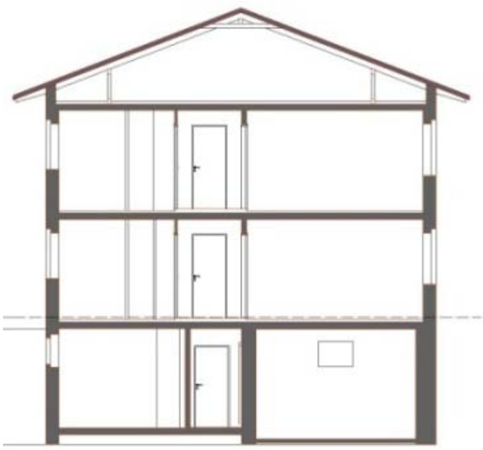


Fig. 3 Section of the existing building

Fig. 4 Location

Fig. 5 Existing northwest façade with building entrance

Fig. 6 Existing southwest façade

Fig. 7 Existing balcony balustrade with signs of corrosion

Fig. 8 Existing southeast façade

Fig. 9 Existing kitchen

Fig. 10 Existing bathroom

1.2. Goals of the renovation project

History

Peter Rieben and his daughter Sara bought the building in 2006 and at the beginning of the project had been living there for almost two years. Convinced of the necessity to refurbish the building in a comprehensive and environmentally responsible way, they approached our firm kämpfen für architektur ag, known for its expertise in sustainable architecture, to provide them with a concept study. The initial goal was a "soft" renovation, and only after long discussions about economy and ecology was it decided to undertake a "fundamental" comprehensive renovation.

The project at Segantinistrasse presented itself as an ideal demonstration project for the international research project Annex 50[1], incorporating the project's aims of finding efficient and sustainable solutions for building refurbishments. Enthusiastic and open to innovation the clients asked us to proceed. After a project team consisting of various consultants was assembled (see Appendix 1), planning started in 2007 and the building retrofit was successfully completed by the end of 2009.

Key project objectives

The main goal of the project was to transform the apartment building, with its poor comfort level and excessive energy consumption, into a Minergie-P house with a substantially modernized living standard. Additionally, if financially possible, a photovoltaic roof should be added to achieve a net zero energy balance for space heating, domestic hot water and ventilation.

Item	Objectives, Targets
Specific energy demand	30 kWh/m^{2}a (as per MINERGIE®-P limiting value)
Non-renewable energy demand	Net zero energy balance
Air exchange rate for existing structure	1.5 h^{-1}
Air exchange rate for rooftop apartment	0.6 h^{-1}
Daylight	Optimization
Construction time	≤ 6 months[2] for the complete renovation
Added gross floor area	Max. permitted by applicable zoning law
On site measuring	3D laser scanning
Overall costs for the renovation	Max. 60% of the costs of a new building
Costs for insulation of the façades	Cost efficiency approximately that of EIFS[3]

[2] In comparison, a conventional system with an Exterior Insulating Finishing system (EIFS) would take approximately 2 months

[3] Exterior Insulating Finishing System („Kompaktfassade"), the most economic standard solution currently available

The comprehensive building renovation concept applied the following core strategies:

- Drastic reduction of energy consumption[4] by reducing thermal transmission and ventilation losses through a highly insulated and airtight building envelope, and utilizing renewable energy for the residual energy demand for heating and domestic hot water (see Fig.13,29).
- Prefabricated retrofit system [2]: Prefabrication of insulated timber façade panels with integrated ventilation ducts (see Fig. 32-34) for controlled air exchange[5] and pre-installed high performance windows[6].
- Increasing rental value by adding a rooftop apartment (see Fig. 13,22), and increasing the size of the existing apartments by enlarging the living and balcony spaces (see Fig.18,19,20-22).

Specific objectives

1. High thermal performance
   Super insulation, no thermal bridges

2. Airtight building envelope
   Air tightness meeting the requirement of a new building, = 0.6 h^{-1}

3. Optimization of daylight conditions
   Increasing the area of glazing on the south façade

4. Efficient and rapid building process
   As some tenants had to stay in their apartments the construction process should not exceed 6 months

5. Utilization of advanced measuring technologies (3D laser scanning)

6. Optimization of floor plans (enlargement of balconies and living spaces)
   Modernization of apartments

7. Upgrading to modern living standards (kitchens, bathrooms and mechanical fixtures)
   As all fittings were original replacement was necessary in any case

8. Optimized planning (coordination between planners, consultants and contractors)

9. Quality control

10. Cost effectiveness
    The overall costs should not exceed 60% of those of a new building.

---

[4] 30 kWh/m^2 limiting value as per MINERGIE®

[5] Air renewal with heat recovery unit

[6] Wood/Metal triple-glazed windows, Häring Fenster und Fassaden AG

Project plans

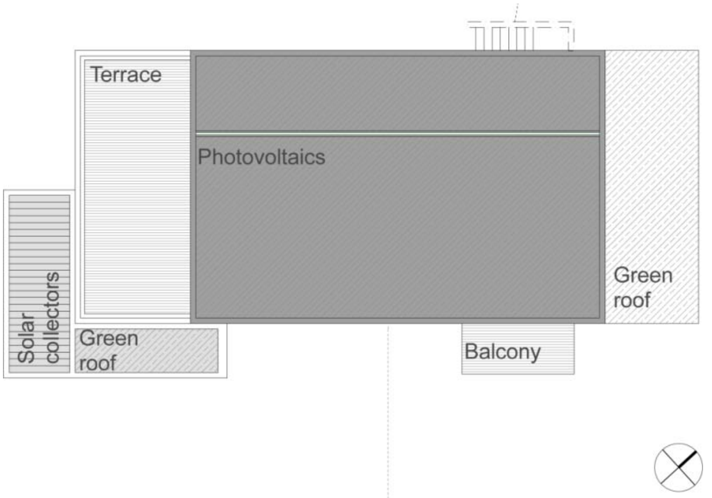


Fig. 11 Birds-eye view of rooftop

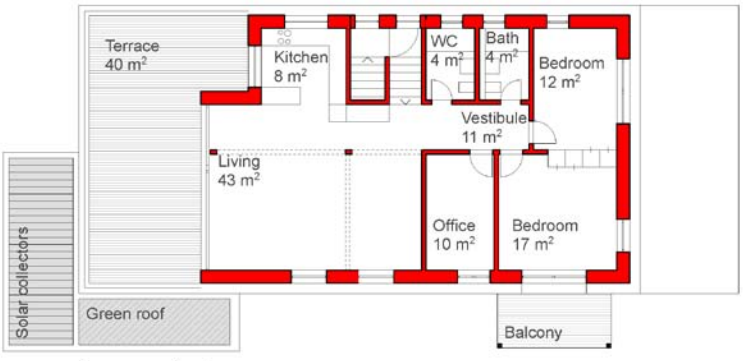


Fig. 13 Floor plan of rooftop apartment

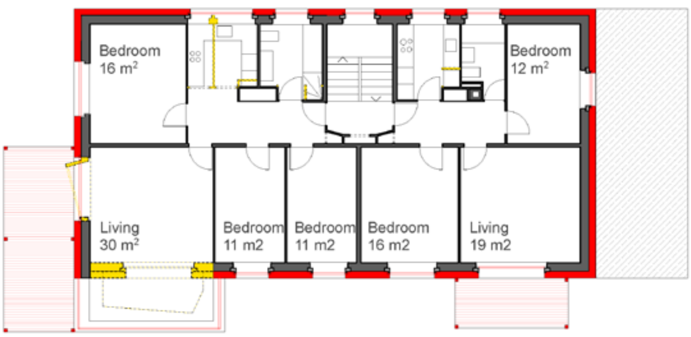


Fig. 14 Upper floor plan

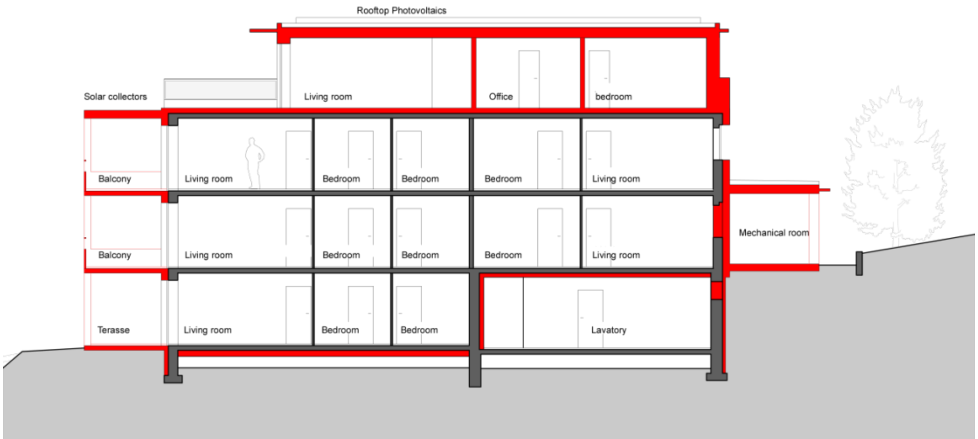


Fig. 15 Longitudinal section with scope of renovation

Fig. 16 Northwest façade showing partition of prefab panels

Fig. 17 Southwest façade showing partition of prefab panels

2. The retrofit construction method

2.1. Key data

Project data after renovation		**After**	**Difference**
Year of renovation		2009 - 2010	
Number of apartments		5 + 1 rooftop apartment	1 additional apartment
Heated floor area		657m^2	+ 43%
Heating energy (incl. hot water)		9’656 kWh/a	- 88%
Specific energy consumption		17.2 kWh/m^{2}a	- 90%
Heating energy savings per m2		90%	
Rents (net)		120’000 €/a	+ 85%
Utility costs		3’000 €/a	- 75%
Rent increase per m2		39%	
U-values W/m^{2}K	**Before**	**After**	
Exterior wall	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 kW/m^{2}a			
Air infiltration rates (h^{-1})	(1.5)	0.5	
	(0.6)	0.4	
Space + WW heating (primary energy)	175	14 (Minergie-P)	- 92%
Added rental area			
Gross floor area (m2)	380	517	+ 36%

2.2. Building additions and interior upgrades

It was clear from the outset of the project that interventions had to go beyond simply restoring the existing structure. To make it financially attractive for the building owner, it was essential that the renewal had to create added value. This was achieved by adding rental area and by upgrading the apartments to modern living standards.

- The existing roof was removed to make room for a rooftop apartment with a large roof terrace (see Fig. 18).
- The living rooms were enlarged by partially demolishing an exterior wall and creating a new building envelope (see Fig. 20-21).
- The original balconies were torn down and replaced with more generous, covered balconies (see Fig.23). To prevent thermal bridging, the balcony slabs are supported independently of the existing building structure.
- Existing kitchens and bathrooms were entirely upgraded to conform to current living standards. New appliances and sanitary fixtures were installed throughout.
- As the basement was rather small, an additional storage room was added to the building.

Fig. 18 Renovated apartments with generous balconies

Fig. 19 Renovated building with rooftop apartment

Fig. 20 Demolition work to enlarge living-rooms

Fig. 21 Interior view of new living-room

Fig. 22 new roof terrace

Fig. 23 new balcony

Fig. 24 new attic apartment living room and roof terrace

2.3. Exterior façades

Based on plans provided by the architect and measurements gained by accurate laser 3D scanning[7], the prefab panels were manufactured complete with air ventilation ducts already integrated and were shipped to the site ready for assembly (see Fig.25). The panels were then mechanically anchored to the existing exterior walls, leaving a gap in between to accommodate the unevenness of the existing construction (see Fig. 26). This gap together with the stud spaces was filled with loose fill cellulose insulation[8]. High performance windows and balcony and entrance doors were installed on site (see Fig. 27-29). Gaps along the perimeter of all openings such as windows or ducts were sealed (see Fig. 32). Finally, a stucco finishing system was applied to the whole exterior envelope except for the extension on the southwest corner and the attic storey, which were clad with horizontal timber slats (see Fig. 18). The materialization differentiates between existing and added elements.

Fig. 25 Prefab timber panels being lowered with a crane

Fig. 26 Panels being positioned and installed

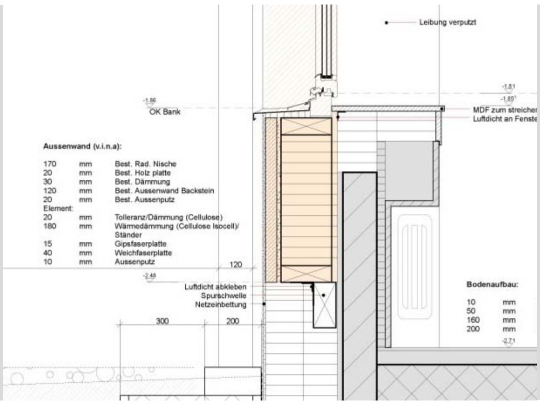


Fig. 27 Window detail extract

Fig. 28 Window header and jamb during construction

[7] Applied measuring method developed by the Fachhochschule Nordwest (FHNW), department for geomatics.

[8] Loose fill cellulosic insulation, Isofloc AG

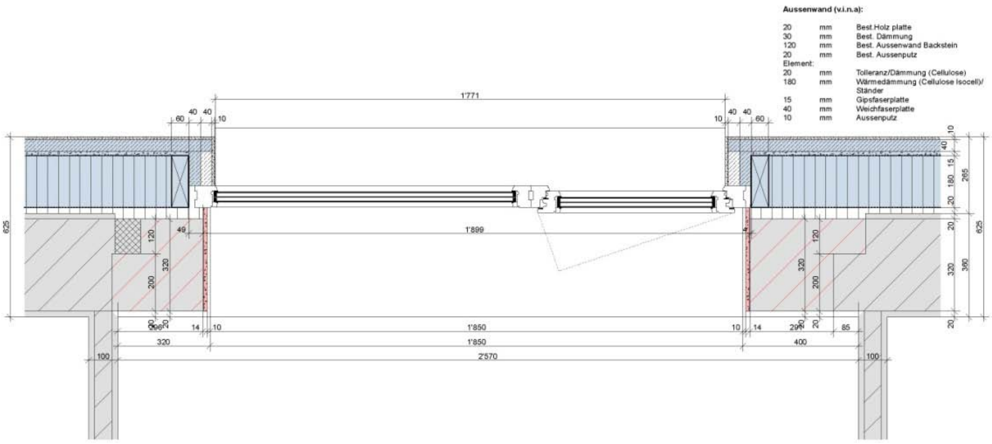


Fig. 29 Kitchen window detail

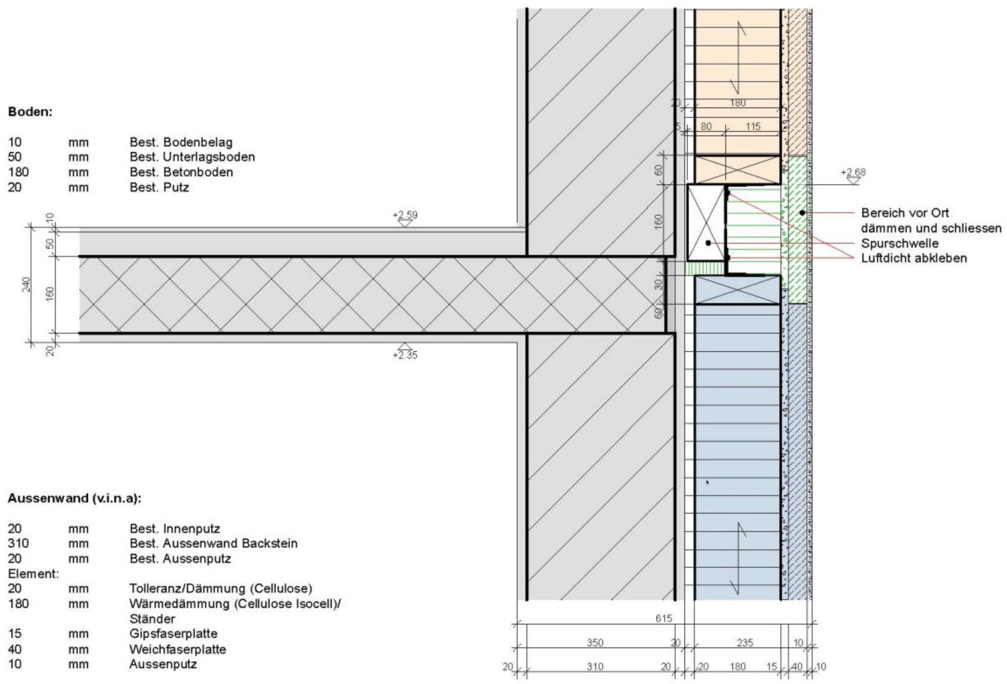


Fig. 30 Detail of external wall construction

2.4. Integration of mechanical ventilation and electrical wiring

Achieving a zero-energy retrofit building is particularly challenging compared with new-build construction. In this building the inadequate oil furnace, electrical boilers and distribution network were all decommissioned to make room for an entirely new heating system based on an intelligent combination of different energy sources: a ground source heat pump was installed to cover the majority of the energy required for space heating (see Fig. 36). The pump is complemented by vacuum tube collectors on the roof which provide roughly 7% of the energy for space heating and cover 75% of the domestic hot water demand (see Fig. 38). Two boilers, each with a capacity of 1,600 litres, provide a constant supply of hot water. 115 m^2 of photovoltaic panels (see Fig. 39) installed on the attic roof feed electricity into the public grid, which in turn provides a sufficient electricity supply to power the circulation pump and fans for controlled air renewal. Due to the lost attic space on the roof and the limited space in the basement, it was decided to build an extra mechanical plant room in the back of the building for the ground source heat pump and the heat recovery equipment. As there was also no space in the apartments for ventilation equipment, an innovative air duct distribution system was designed. In order to avoid any demolition work to create duct spaces inside the building, the ducts were run within the new façade layer (Fig. 31-32). However, to reduce the number of necessary penetrations of the wood framing it was decided to run the horizontal ducts along the edge of the 2nd floor where the attic storey is slightly recessed. This concept brought with it the advantage that for the most part only vertical ducts had to be run in the stud spaces of the prefabricated panels.

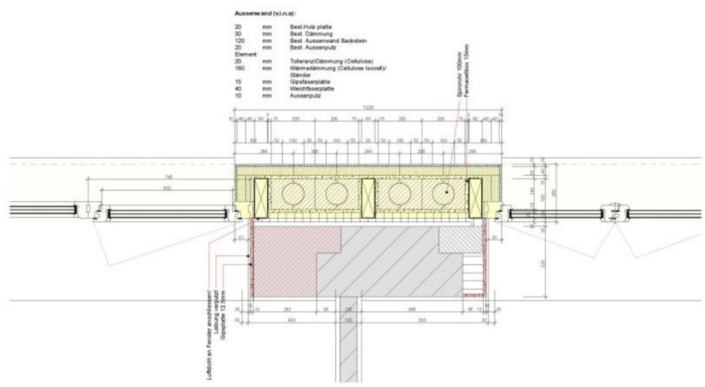


Fig. 31 Ventilation ducts built into insulated prefabricated timber external wall panels

Fig. 32 Layout of ventilation ducts southeast façade

Fig. 33 Ventilation duct fittings at panel joints

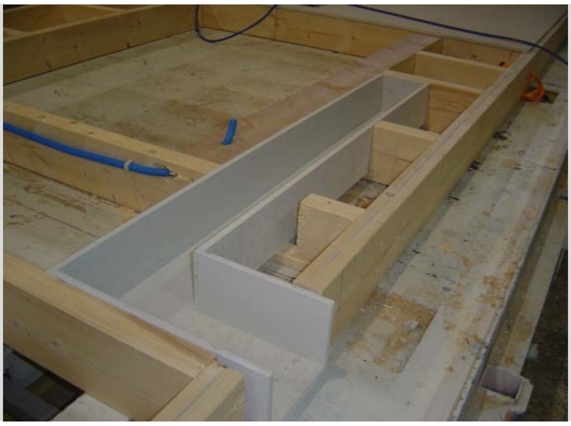


Fig. 34 Fire-rated ventilation duct enclosure

Fig. 35 Air supply outlet above window header

Fig. 36 Bore hole for heat pump

Fig. 37 Rooftop photovoltaic panels

Fig. 38 Vacuum tube collectors on the roof of a balcony

3. The energetic aspects of the renovation

3.1. Summary

The existing 1950s house with an estimated annual heating requirement equivalent to 7,000 litres of heating oil was transformed into a zero heating-energy building. The electricity requirement for the heat pump and ventilation system was a little higher than anticipated, but the improved performance of the photovoltaic system (with around 25% greater yield than expected) was able to compensate for this. The electricity requirement for heating and ventilation totaled 15,080 kWh/a for the year measured, and 12,152 kWh/a according to Minergie calculations. The measured consumption data for heat production compare well with the values set as project objectives. The power required for the ventilation system is relatively high, with the centralized ventilation 'Monoblock' for the existing apartments from ground floor to 2nd floor requiring 580W of electricity for its operation. The ventilation system in the attic apartment operates with a lower airflow rate and has an input power of 20W.

The measured Annual Energy Performance Factor (JAZ ‚Jahresarbeitszahl') of the ground source heat pump stands at just 2.4. A reading of only 2.2 was recorded during the winter measurement period over January and February 2011. The reason for this is presumably that the heat curve has been set too high. The heat curve should be checked and reset for the winter period 2011/2012. During the summer period a JAZ of 3.4 was recorded for the production of hot water. The temperature measurements recorded over winter 2010 (Fig.54) show that only under very few operating conditions does the input temperature of the ground source fall below 5°C. With the heating system's anticipated supply temperature of 45°C, the COP value should be around 3.6 which equates to a JAZ of a little over 3. A JAZ of 3.7 was recorded in the latest measurement period (18.11.11 to 2.12.11).

Assuming a better adjustment of the heat curve and reduced annual use of ventilation systems it is possible to further significantly reduce the electricity requirement for building systems. As all bathrooms and kitchens have windows (which can be used for ventilation), and as the building is in a very quiet location, it is recommended that the ventilation system be used much less during the summer, or even completely switched off.

The photovoltaic system yields 16,605 kWh/a electricity, which represents an increase of around 29% compared with the estimated yield of 12,880 kWh/a.

3.2. Existing energy system and performance

Energy reference area:
The energy reference area (EBF) is calculated using the project floor plans (in accordance with SIA 380/1)

- ground floor	95.5 m^2
- 1st floor	181.5 m^2
- 2nd floor	181.5 m^2
Total	**458 m^2**

Building envelope (existing building)

- The building envelope dates for the most part from 1954
- Cold roof with cold attic space
- Double-glazed windows installed 1955; some windows renewed around 1980; single glazed entrance door
- 6cm Styropor external insulation on the southwest facade (from around 1990)
- Uninsulated heating pipes in the cellar

Building services:

Heating	Oil heating
Hot water	Each apartment has an electric boiler fitted into the kitchen units
Heat distribution	Old radiators, sometimes with thermostat valves

The graph below shows the house’s heating oil use over recent years.

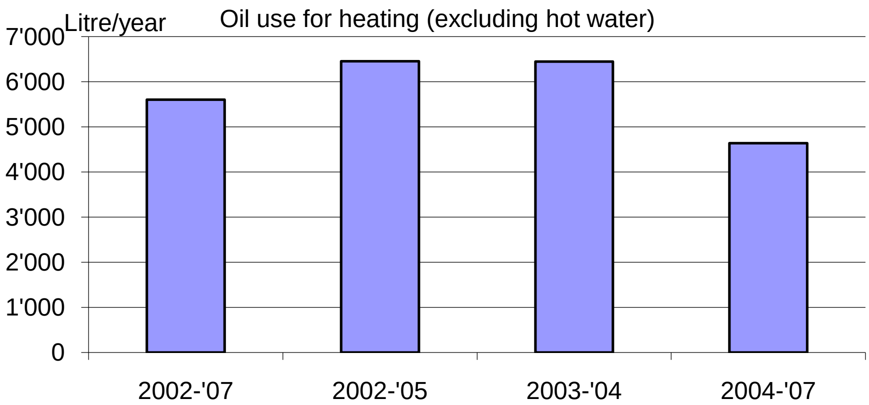


Fig. 39 Heating oil use for heating exclusive of hot water (winter 2005/2006 was unusually warm)

Assuming a boiler efficiency of around 85% gives a mean annual energy use of around 70,600 kWh for heating.

Mean energy use	70'600 kWh for heating, 154.1 kWh/m^2a
Energy use for hot water (SIA)	9'540 kWh
Total mean energy use	80'140 kWh (heating and hot water), 175 kWh/m^2a

Fig.40: double-glazed kitchen window

Fig.41: double-glazed living-room window

Fig.42: radiator without thermostat valve

Fig.43: boiler built into kitchen fixtures

Fig.44: oil-run boiler for heating (not including hot water)

Fig.45: uninsulated basement ceiling and heating pipes

3.3. Energetic improvements

Energy schema

The new energy system combines a ground source heat pump with vacuum tube solar thermal collectors. For the existing apartments a central ventilation system is located in the external extension while the attic apartment has its own ventilation system. Photovoltaic panels are installed on the flat roof.

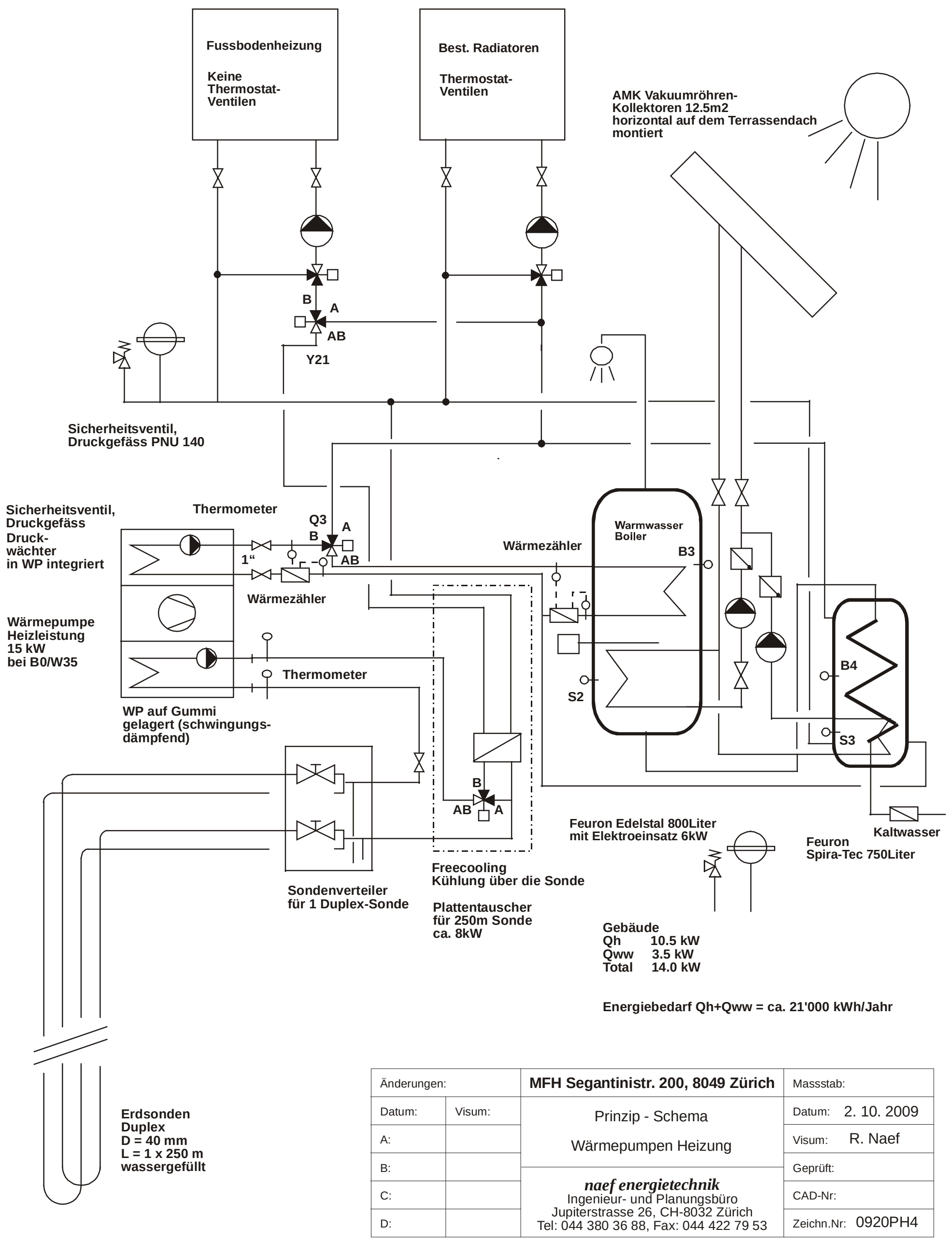


Fig. 46 : Heating schema: Ground source heat pump, hot water storage and hot water Spira-Tec

Heat distribution

In the existing apartments heat is distributed as previously using radiators. This meant that the floor construction did not have to be changed. New underfloor heating in the kitchens and the extended living-rooms was linked into the existing heating system serving the radiators. The new attic level was also provded with underfloor heating, and can also be cooled by 'freecooling' using the same system.

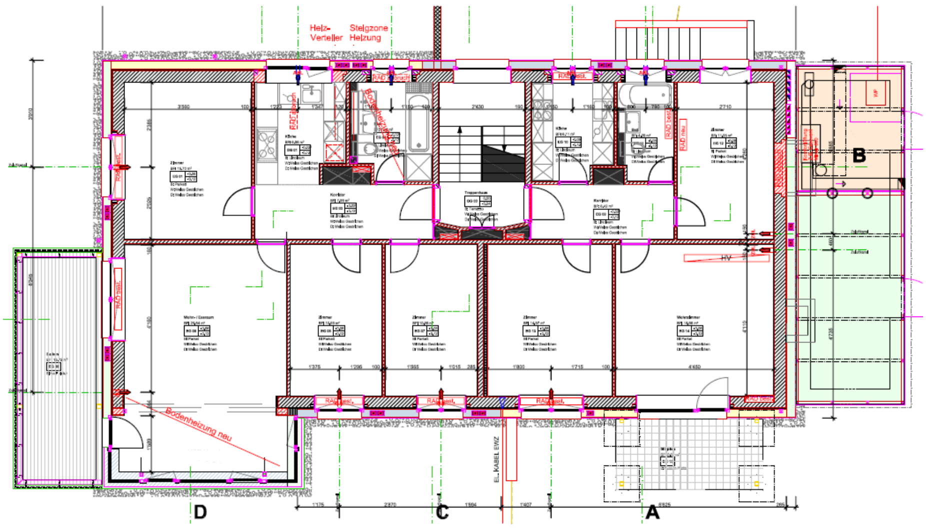


Fig.47: typical floor plan showing extension for heat pump and ventilation system for the existing apartments

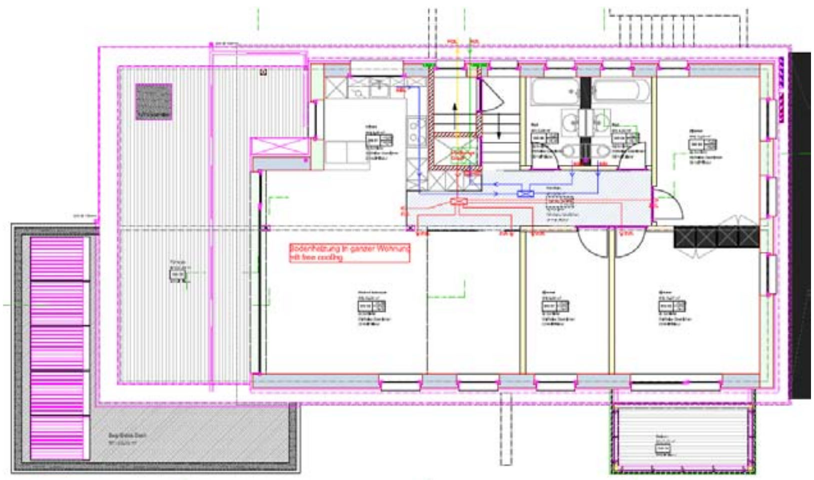


Fig.48: attic storey with decentralised ventilation unit located in the stairwell

Ventilation system

In principle the house is divided into a ‚supply air side' (southeast façade) and an‚exhaust air side' (northwest façade). One rectangular channel per apartment runs from the centralized ventilation unit in the extension to the bottom of the attic storey. Thus a circular distribution network is created, from which further distribution pipes descend vertically to serve the individual rooms.

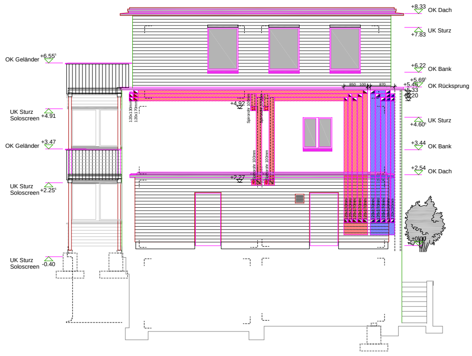


Fig.49: distribution of fresh air and removal of exhaust air via the insulated northeast and southwest facades

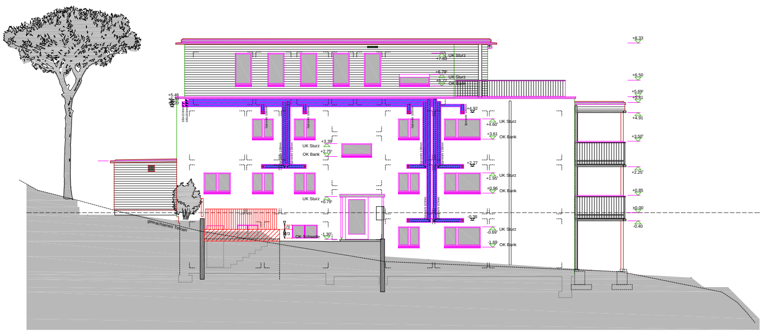


Fig.50: circulation of exhaust air via the insulated northwest facade

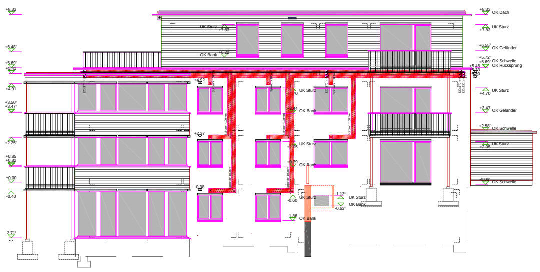


Fig.51: distribution of fresh air via the insulated southeast facade.

3.4. Calculations and measurements

Building envelope: existing building

External walls	0.18 W/m^2K (a few facade elements 0.52 or 0.55 W/m^2K)
Terrace	0.15 W/m^2K
Floor to unheated space	0.18 W/m^2K (some areas 0.15 or 0.22 W/m^2K)
Windows	0.85 bis 1.07 W/m^2K (Triple-glazing U-Value 0.70 W/m^2K)

Heating requirement: existing building

Heating requirement Project value Qh 92 MJ/m^2a, or 25.6 kWh/m^2a (Standard air change rate)
Effective thermal outdoor air flow rate 0.36
Heating energy requirement Minergie Qh 66 MJ/m^2a, or 18.3 kWh/m^2a

Building envelope: new-build

External walls	0.13 W/m^2K (a few facade elements 0.52 or 0.55 W/m^2K)
Flat roof	0.11 W/m^2K
Windows	0.85 bis 1.00 W/m^2K (3 Triple-glazing U-Value 0.70 W/m^2K)

Heating requirement: new-build

Heating requirement Project value Qh 88 MJ/m^2a, or 24.4 kWh/m^2a (Standard air change rate)
Effective thermal outdoor air flow rate 0.34
Heating energy requirement Minergie Qh 62 MJ/m^2a, or 17.2 kWh/m^2a

Key data from Minergie-certification information

Energy reference area	656.9 m^2	
Heat production: heating	CTA 15es	JAZ 3.1 (Minergie standard value)
Heat production: hot water	CTA 15es	JAZ 2.7 (Minergie standard value)
Solar thermal collectors AMK OPC 15	12.5 m^2, yield according to Minergie:339 kWh/m^2a	
Photovoltaic system 3S Laminat 230W	16.1 kWp, 800 kWh/kWp	

Primary energy demand: building envelope	31.0 kWh/m^2a,	calculated 25.3 kWh/m^2a
Limit value Minergie-P	30.0 kWh/m^2a,	calculated -2.3 kWh/m^2a

The engineering firm Naef Energietechnik was commissioned to monitor the energy performance of the completed apartment building at Seganitinistrasse 200 to verify if the measured results match the planning goals.
Measurements taken over the years 2009 and 2010 show that the electricity consumption of the ground source heat pump is 10’757 kWh/a which is slightly higher than the target amount of 9’656 kWh/a (Consumption 7’390 kWh/a + 2’266 kWh/a for auxiliary equipment). The discrepancy is most likely due to different assumptions with regard to room temperatures. The effective temperature has been recorded as more in the range of 21°C - 22°C as opposed to the standard value of 20°C from SIA 280/1. Thus the effective electricity consumption was duly accounted for. The JAZ (‘Jahresarbeitszahl’, the measured Annual Energy Performance Factor) for heating and hot water was measured as only 2.4 during the measurement period (2.12.10 to 18.11.11). During the reading period (9.3.11 to 22.11.11) the JAZ was 3.4 and significantly higher than the reading from the reading of the winter period 2010/2011, when a JAZ of only 2.2. was recorded (period 7.1.11 to 9.3.11). The cause of this is assumed to be that the heat curve has been set too high, resulting in a very low JAZ.

During the measurement period the hours of sunlight were slightly higher than the annual mean value (1’665 per year compared with 1’600). Thus the energy yield of the photovoltaic system is, with 17’983 kWh/a somewhat higher than was calculated for Minergie certification. An electricity requirement of 5’256kWh was calculated for the ventilation systems. This is somewhat higher than the expected Minergie value of 2’496 kWh. The measured electricity consumption of the ground source heat pump and for ventilation is 14’056 kWh/a and are therefore slightly below the measured energy output of the photovoltaic system with 16’605 and 17’983 kWh/a for the two measured time periods respectively.

Item	target	measured	difference
Energy reference area	656.9 m^2		
Energy demand for space heating Q_h (therm. exterior-LW 0.36)	17.2 kWh/m^2		
Energy demand domestic hot water (SIA)	20.8 kWh/m^2		
Energy demand for space heating Q_h (therm. exterior-LW 0.36)	11’299 kWh/a		
Energy demand domestic hot water (SIA)	13’685 kWh/a		
Energy demand space heating and domestic hot water	24’984 kWh/a		
Output photovoltaic system	4’204 kWh/a		
Energy demand space heating and hot water from heatpump	20’780 kWh/a	23’206 kWh/a	+ 10.5%
Ground source heat pump electricity demand	3’580 kWh/a		
Ground source heat pump electricity demand warm water	3’810 kWh/a		
Electricity demand for auxiliary equipment (fan)	2’266 kWh/a		
Electricity demand ground source heat pump	9’656 kWh/a	9’824 kWh/a	+ 2%
Electricity demand ventilation EG to 2. OG		5’081 kWh/a	
Electricity demand ventilation attic		175 kWh/a	
Electricity demand for ventilation equipment	2’496 kWh/a	5’256 kWh/a	+ 53%
Electricity demand for heating and ventilation	12’152 kWh/a	15’080 kWh/a	+ 19.5%
Output photovoltaic system (July 2010 – June ‘11)	12’880 kWh/a	17’983 kWh/a	+ 39%
Output photovoltaic system (Dec. 2010 – Nov. ‘11)	12’880 kWh/a	16’605 kWh/a	

Measurements during the first year of operation

Monitoring of the building began on November 20th 2009 using battery operated measuring equipment. The following graphs illustrate the key findings (fig. 49-62). Temperature measurements were taken at the "monoblock" of the ventilation system and at the ground source heat pump loop.
With low outside temperatures the inlet flow temperature of the ground source heat pump is approximately 6.5 C°, and only on a few days is a short temperature swing to a minimum of 3.8C° likely to occur (fig.51).
Based on an average inlet flow temperature of 8°C and a 35C° inlet flow temperature for heat distribution, one can expect a COP value of approximately 5.3 according to the manufacturer's specification.
With domestic hot water at 50°C and a loop temperature of 5°C, the COP value is around 3.2.

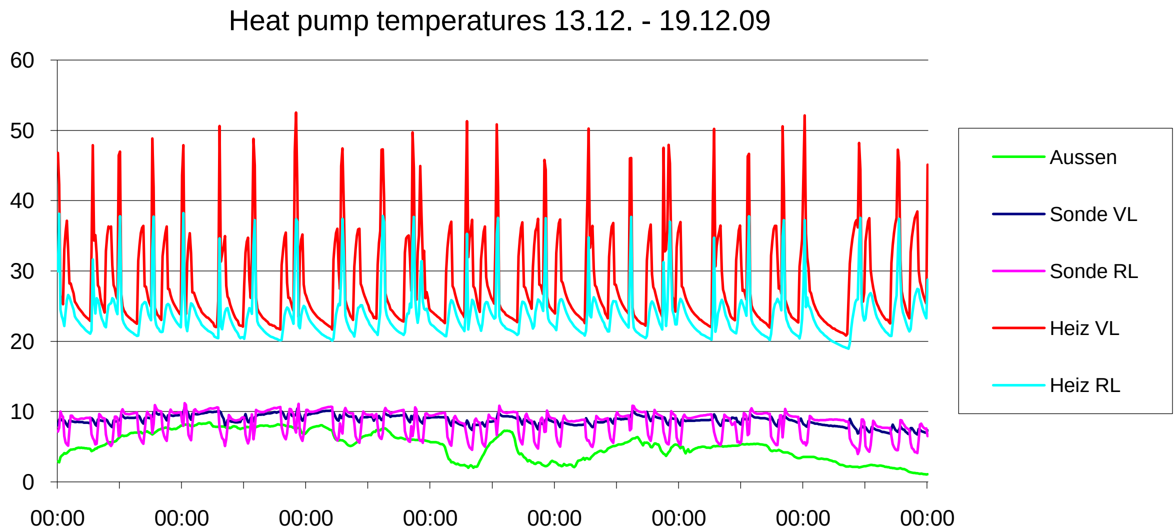


Fig. 52 Ground source heat pump temperatures at loop and temperature of heat dissipation

The heating of water to above 50°C can be seen clearly from the peaks of the red curve on the graph.

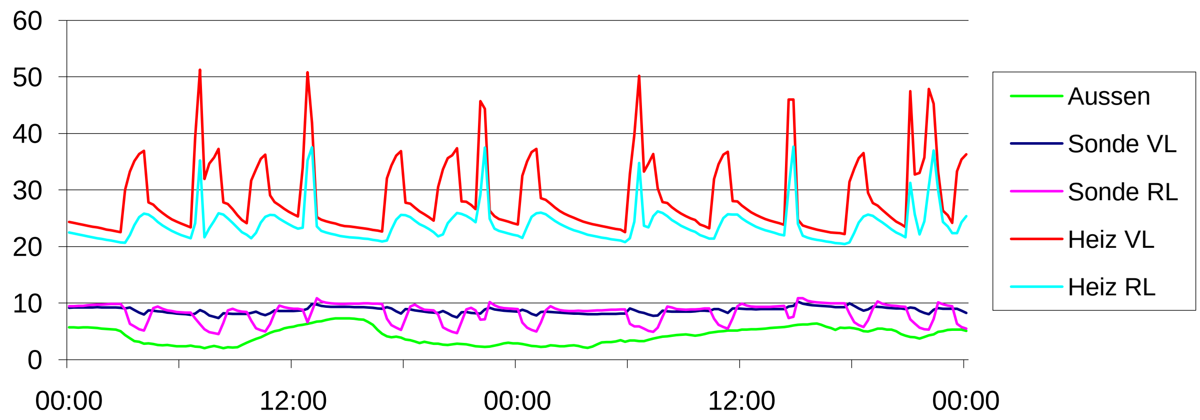


Fig.53: ground heat source temperature and heat emitted by the heat pump

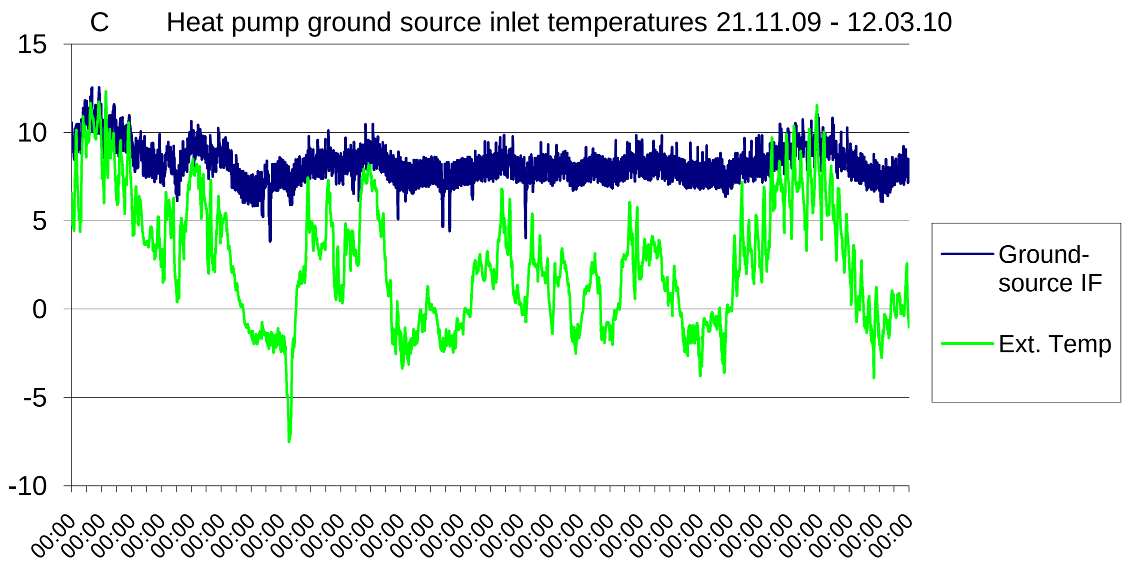


Fig.54: Ground heat source inlet temperature for the winter period 2009/2010

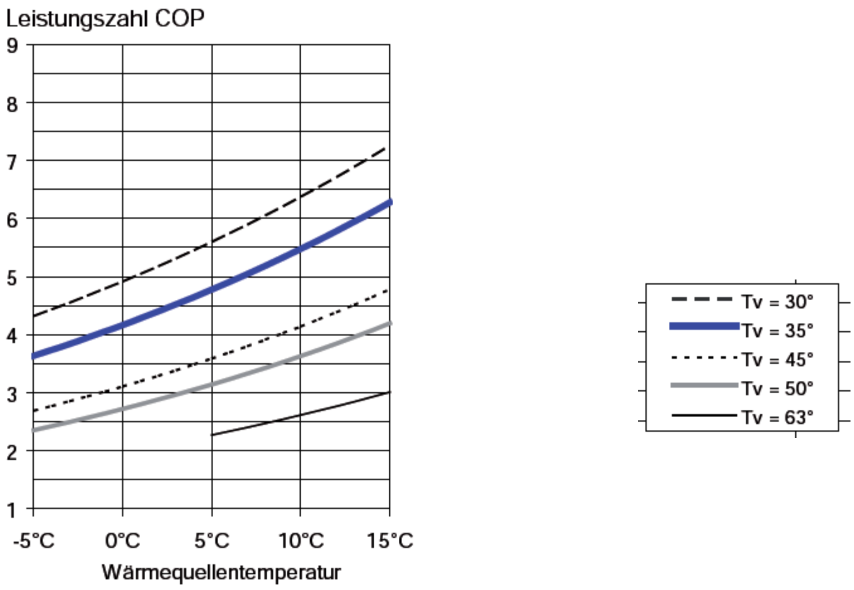


Fig.55: Efficiency rating for the CTA 15es heat pump, with 8°C ground source temperature and 35°C supply temperature COP ca. 5.3

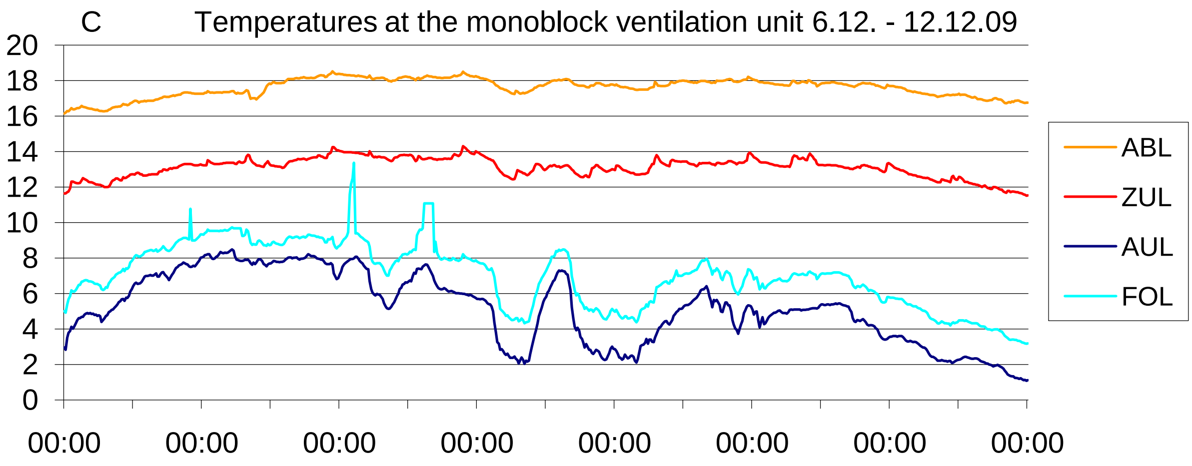


Fig.56: temperatures recorded at the Monoblock of the centralised ventilation system

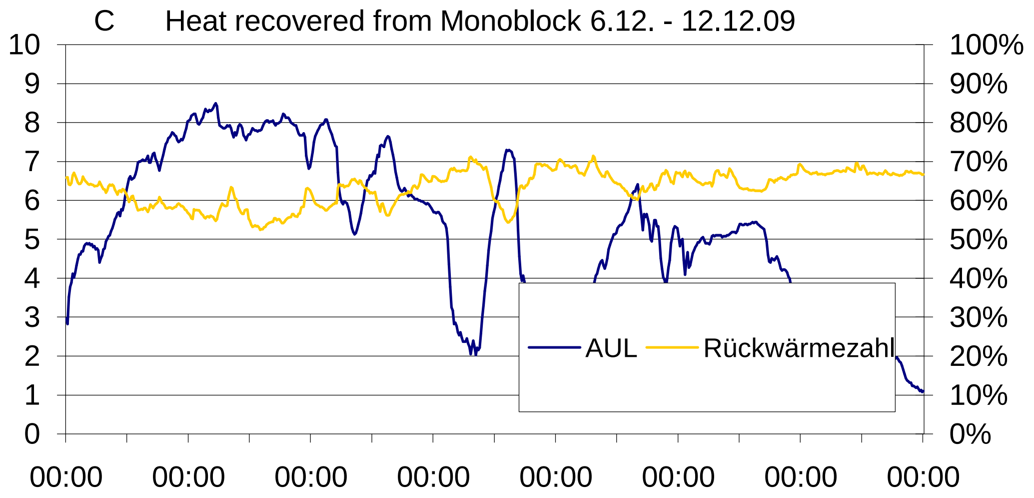


Fig. 57: the return heat of the heat recovery unit lies between 52% and 70% during the second week of measurement in December

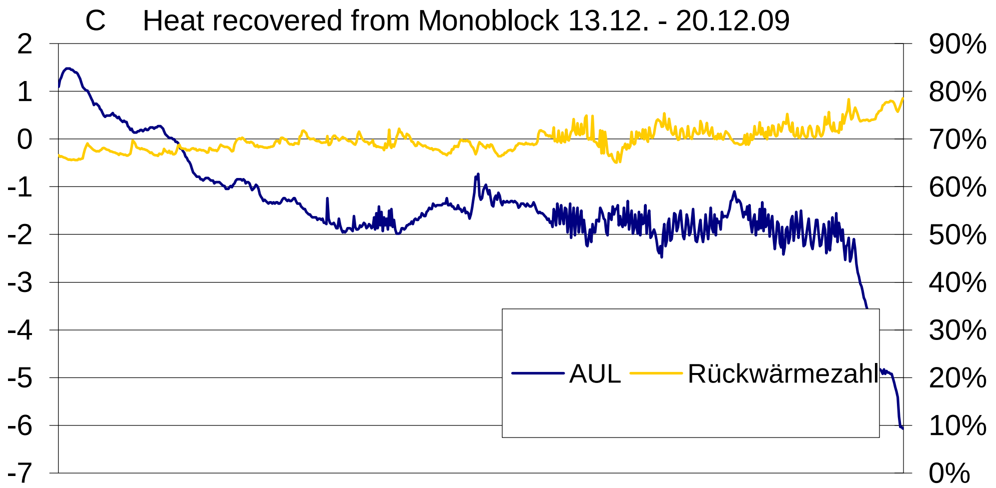


Fig. 58: with cold external temperatures the recovered heat is significantly higher (between 66% and 78%) in the third measurement week of December

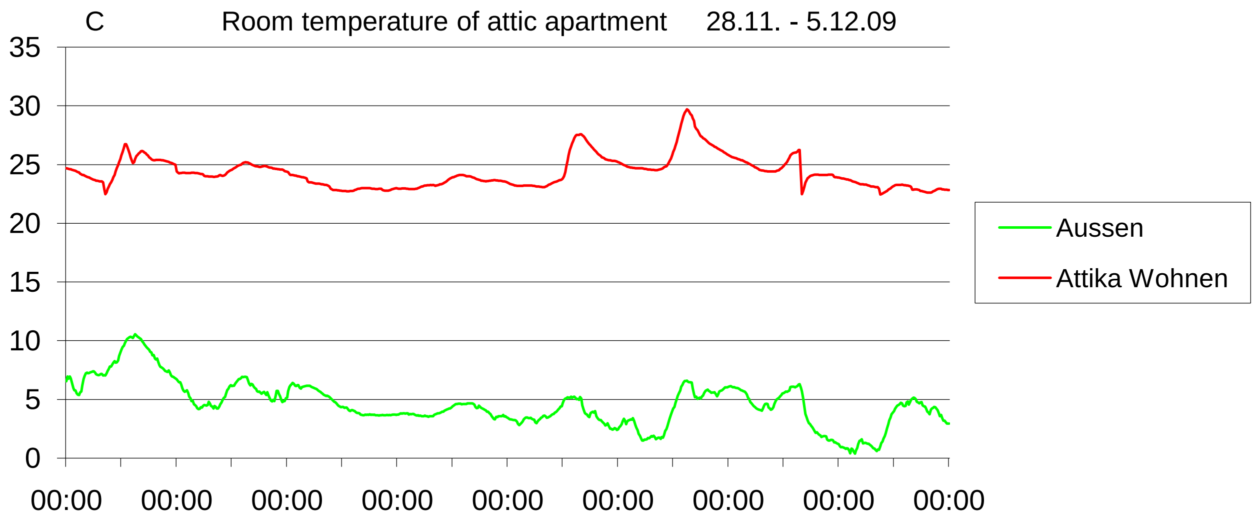


Fig.59: days with greater amounts of direct sunlight can be clearly seen from the temperature curves for the attic living-room

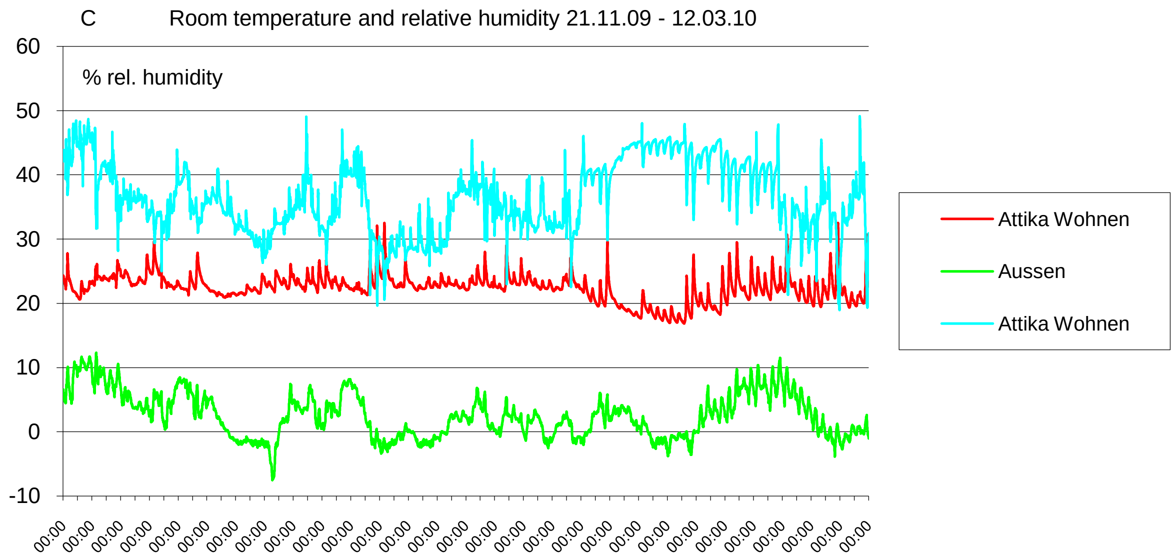


Fig.60: room temperature and relative humidity in attic apartment living-room

During cold periods the relative humidity sinks in the living-room of the attic apartment to below 30% (fig. 60, light blue curve). As the ventilation unit for the attic apartment is adjusted to operate with a lower airflow rate (Level 1 with an airflow rate of around 60 m^3/h, with an input power of 20 W) the relative humidity remains at around 35% during the winter period.
In the attic apartment (and presumably also in the apartments below) the room temperature lies at around 21°C - 22°C. This increases the heating requirement with regards to SIA 380/1 stated values.

The lower room temperatures during the holiday periods and the steep peaks caused by passive solar gain can be clearly seen in the above graph (fig.60)

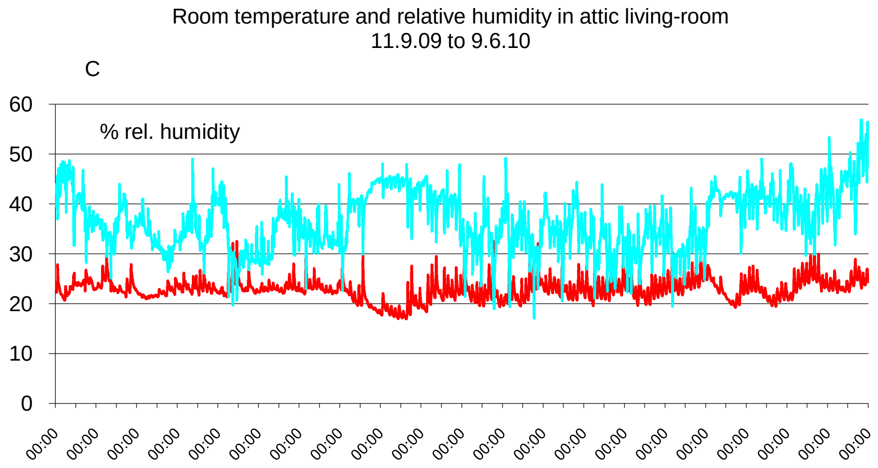


Fig.61: Room temperature and relative humidity in attic living-room

Thanks to the increased energy yield of the photovoltaic system the goal of achieving a zero heating-energy building through renovation was achieved despite a slight increase in the electricity requirement for the heat pump and ventilation systems.

Assuming a better adjustment of the heat curve and reduced annual use of ventilation systems it is possible to further significantly reduce the electricity requirement for building systems. As all bathrooms and kitchens have a window (which can be used for ventilation), and as the building is in a very quiet location, it is recommended that the ventilation system be used much less during the summer, or even completely switched off.

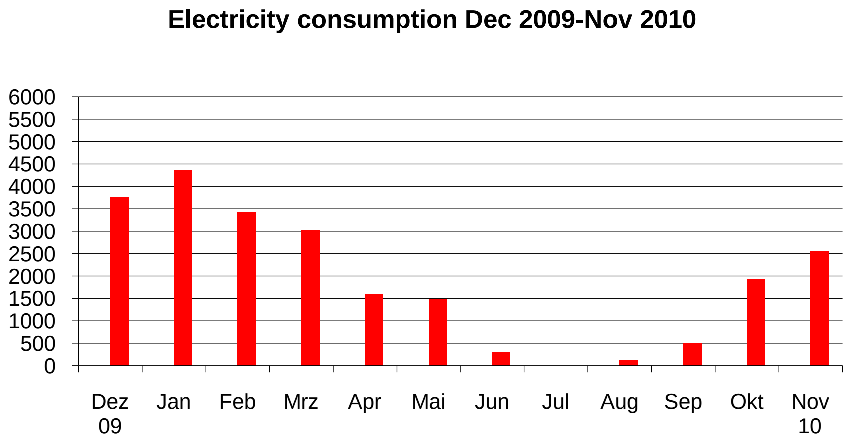


Fig.62: heat pump electricity use for heating and hot water = 9'374 kWh/a

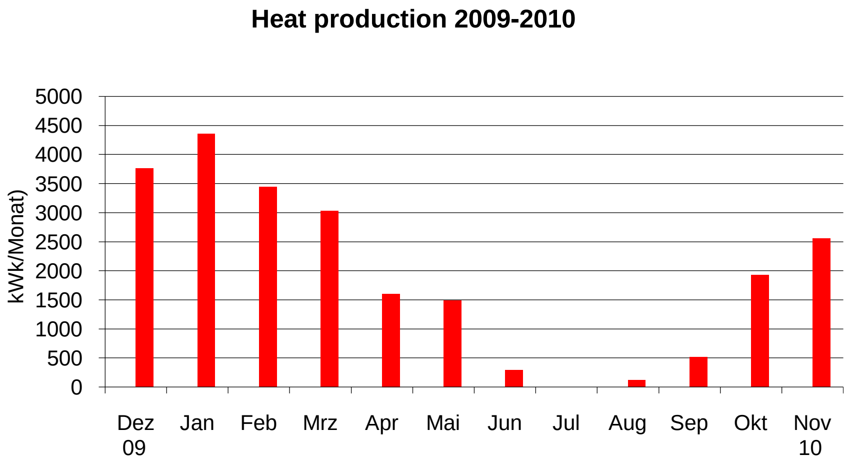


Fig.63: Heat production for heating and hot water using the heat pump = 23'073 kWh/a

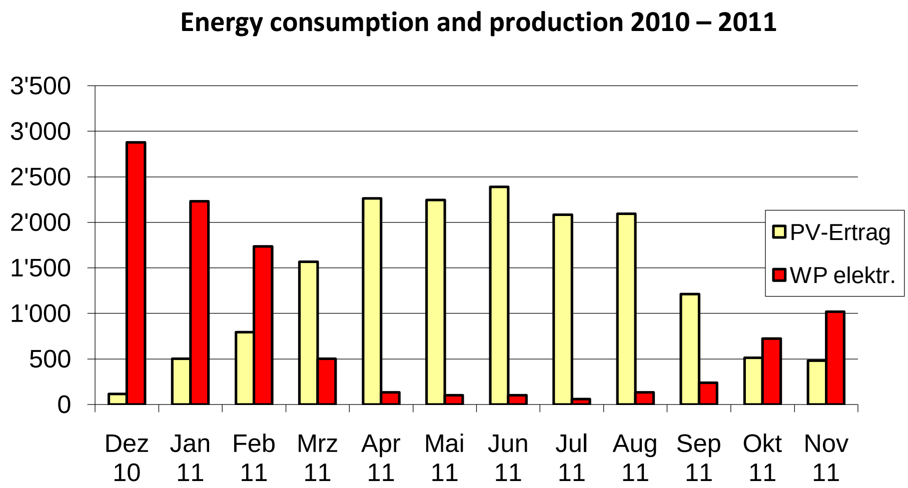


Fig.64: photovoltaic system electricity yield compared with heat pump electricity requirement

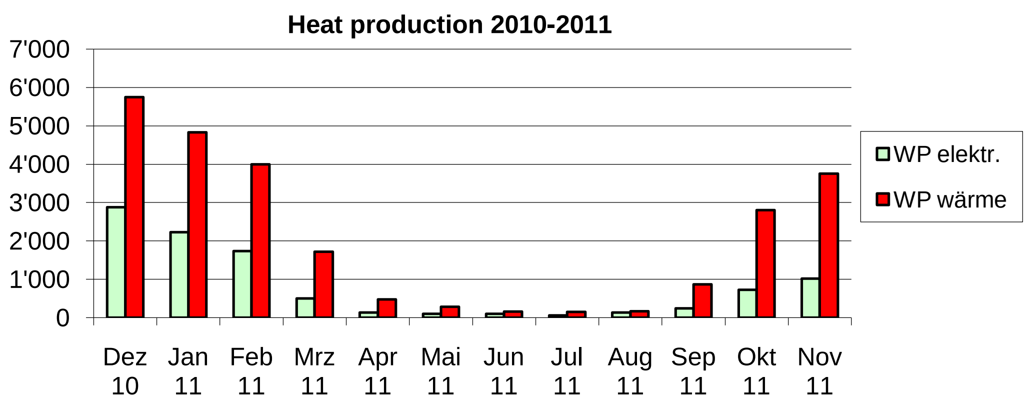


Fig.65: heat pump: electricity use compared with heat production

4. Conclusions and follow-up project

4.1. Follow-up project: Retrofit apartment house, Salvatorstrasse, Zurich-Oerlikon

Shortly after the Segantinistrasse project our firm kämpfen für architektur received another commission for a comprehensive building refurbishment. The building located in an urban context[9] was similar in scale and type to the Segantinistrasse project. Built in the 1940s the building's energy efficiency was poor. Though structurally sound, the exterior walls were barely insulated and the heating system needed to be replaced. Given these circumstances it was evident to us that the project was an ideal candidate for the prefab retrofit system we had utilized for the first time for the Segantinistrasse project. Thanks to the valuable experience of this system gained at Segantinistrasse we were able to optimize the planning and construction process at Salvatorstrasse, resulting in a shorter construction time and reduced costs.

Key aspects of the project were:

- Renovation resulted in a larger house than would have been possible with a new-build
- The large beautiful garden could be retained
- By horizontally extending the house, small 3 room apartments could be transformed into modern, generous 3.5 room apartments.

Two things learned from our experience of both projects deserve particular mention:

Firstly, instead of measuring the entire building using a 3D laser scanning method (which provided us with a vast amount of data not usable for our purposes), we just measured a certain number of key points. In conjunction with built-in tolerances this proved to be both sufficiently accurate and much more efficient.

Secondly, in this project the ventilation devices could be placed in the attic. As the air is preheated, the ducts are much shorter and the distribution of air is simpler.

It is, however, important to point out that despite the improvements made to the prefab retrofit system, the limited size of the project did not achieve a sufficient economy of scale to be able to fully exploit the advantages of prefabrication.

[9] Apartment building Salvatorstrasse 33, Zurich-Affoltern

Project plans: Salvatorstrasse 33

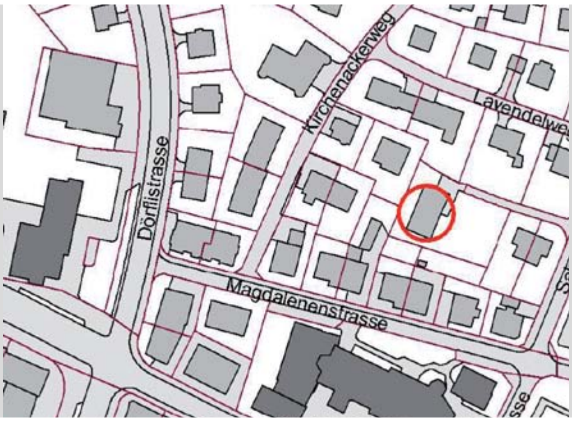


Fig. 66: Site plan

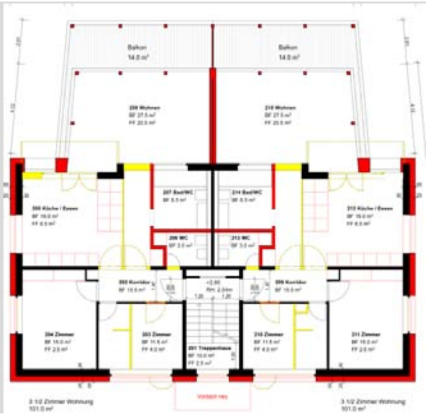


Fig. 67: Typical floor plan (new in red)

Fig. 68: South façade with addition

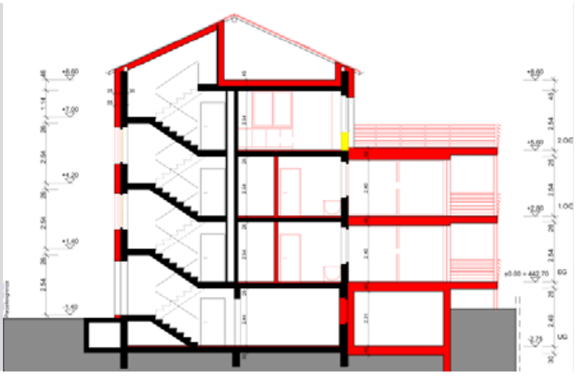


Fig. 69: Building cross section (new in red)

Fig. 70: East façade with addition

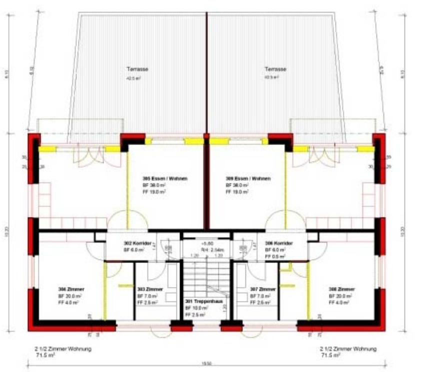


Fig. 71: Attic apartment plan (new in red)

Photos before renovation and under construction

Fig. 72: East façade before renovation

Fig. 73: East façade with cut of balcony slabs

Fig. 74: Manufacturing of framed façade panels

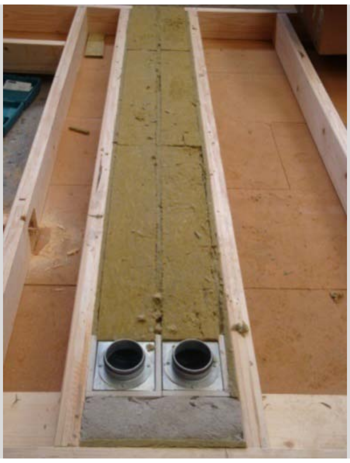


Fig. 75: Integrated ventilation ducts wrapped in insulation

Fig. 76: Addition in wood construction

Fig. 77: East façade during construction (December 2010)

Photos of the completed building


Fig. 78: East façade after renovation and extension


Fig. 79: Balconies on the east facade


Fig. 80: new kitchen and living rooms


Fig. 81: new balcony


Fig. 82: rooftop photovoltaics


Fig. 83: balcony detail

4.2. Lessons learned

The main goal of the renovation was to transform the apartment building, with its poor comfort level and excessive consumption of energy, into a net zero energy balance building with a substantially modernized living standard.

With regards to its overall performance, the completed building meets our goals. It is important, however, to emphasize that the success of the project was not a consequence of any single measure but rather a result of a combination of intelligent interventions: It was essential to first drastically reduce the overall transmission losses by increasing the insulation value and airtightness of the external envelope. The remaining heating load was then small enough to be covered by renewable energy alone.

Energy efficiency

A ground source heat pump together with rooftop thermal solar collectors and photovoltaics were installed to provide energy for space heating and domestic hot water. Taking into account the passive solar energy gains, the MINERGIE®-P [3] limit value of 30kWh/m2 was thus reached. Due to the limited space availability in the existing basement, a one-storey building at the northeast of the building was constructed to accommodate the ground source heat pump and air exchange equipment for the controlled ventilation system (see Fig. 19,36).
The integration of the air ducts into the prefabricated panels posed a greater challenge: Due to strict fire-rating regulations, the ventilation ducts had to be enclosed in gypsum fiber boards[10]
(see Fig. 34). Increasing the overall duct dimensions could only be accommodated at the expense of thermal insulation, resulting in thermal bridging. Another option would have been to increase the overall panel thickness.
This would, however, have conflicted with the requirement for optimal daylight levels: increasing the overall wall thickness creates deeper window recesses, thereby reducing the incidence of natural daylight. The effects of reduced light incidence are further compounded by the reduced glazing ratio and light transmittance (g-value) of the retrofit windows. The only solution available was to add new windows where feasible.

[10] Gypsum board, fire resistance rating EI 30, 15mm thick board, Fermacell GmbH Schweiz

Prefabrication method

The case study showed that the expectations of the prefab retrofit system could only be partially met:

On the positive side, prefabrication ensured that panel dimensions were so precise that the panels fitted together like a puzzle. Tight fitting joints prevent air leakage and are essential for minimizing energy losses and humidity infiltration. Initially the panels were to be shipped already complete with insulation. However, in close collaboration with the timber manufacturer, it was decided to fill the compartments between the studs with loose fill insulation after the panels were installed on site. This proved to be more efficient and ensured that the cavity between the panel and the existing exterior walls were filled at the same time.

Differing from the retrofit method proposed by EMPA and FHNW, we think that prefab elements must be as large as possible, with their size limited only by transport. The handling of elements, and especially their joining, is in this way made much easier. Either something is carried out completely on site or in shop, but prefabrication must be as stringently controlled as possible.

The efficiency we intended to gain by measuring the entire building with a 3D scanner did not manifest in the project. The digital data turned out to be difficult to translate into a format practical for manufacturing purposes. In any case the high degree of dimensional precision was not necessary as the system was designed in a manner to absorb tolerances common in construction.
The negative side of the case study had less to do with the retrofit system in itself but rather with planning and coordination issues:
A tight schedule due to a set deadline for vacating the apartments left planning time insufficient for detailing an untested prefab retrofit system, thereby resulting in compromises and incomplete detailing.

To meet the deadline the manufacturer had to press ahead with the panel production even though the windows were not yet delivered. This meant that the windows were installed after the prefab panels were assembled and the window frames had to be anchored in a less favorable position with respect to thermal bridging and air tightness.

A final issue relates to the economy of scale: Prefabrication can only be economical when the prefabricated units are manufactured on a large scale. The extra effort put into machinery, transport and additional planning time can otherwise not be justified and a conventional retrofit system such as an Exterior Insulation Finishing System (“Kompaktfassade) will be more cost competitive.
Another justification for prefabrication is its advantage to substantially reduce the construction time on site and reduce the disruptive effects on the building occupants. Ideally the building could remain occupied during the whole construction.

For the Segantinistrasse project, the building size and the fact that the renovation included also major interior renovations, which precluded building occupancy, were the main reasons that the advantages of the implemented retrofit system were only partially exploited. However, it is important to mention that the case study provided the unique opportunity to verify the proposed prefab retrofit system and the findings as outlined in this report will be essential to further developing the prefab retrofit system.

Rental value

Most current building renovations only address isolated building components such as roofs, façades or heating systems. Optimal results cannot be achieved by single renovation measures and new problems could arise, including local condensation or overheating. A look at the real estate market, however, shows that private building owners are typically not able to come up with the financing required for a comprehensive renovation. Rather they resort to a piecemeal approach, regardless of the long-term disadvantages.

A cost intensive retrofit only pays off if the property value is substantially increased after the renovation.

With the Segantinistrasse apartment building, the optimization of floor plans by measures such as enlarging living spaces, providing more generous balconies and upgrading the interiors, and above all the addition of the rooftop apartment were key to making the investment an attractive option to the building owner.

References

[1] IEA ECBCS Annex 50: "Prefabricated Systems for Low Energy Renovations of Buildings", Annex text, Nov. 6, 2006
[2] CCEM-CH Project: Advanced energy-Efficient Renovation of Buildings, Empa, Feb. 28, 2006
[3] MINERGIE® Verein, Reglement zur Nutzung des Produktes MINERGIE®-P nach Norm SIA 380/1: 2007 und 2009

5. Appendices

5.1. Appendix A: Documentation for IEA ECBCS Annex 50

5.2. Appendix B: Documentation for SIA 2040

5.3. Appendix C: Participants

Contractors for exterior envelope:

- General contractor	Max Bissig AG, Zurich
- Scaffolding	Roth Gerüste AG, Regensdorf
- Engineered façade panels	Bächi Holzbau AG, Embrach
- Windows	Häring Fenster und Fassaden AG, Frenkendorf
- Roofer	Fröhlich Dach AG, Glattbrugg
- Exterior stucco finish	Isotop AG, Zürich
- Sun shading	Griesser AG, Aadorf

Engineers:

- Structural engineer	Ergin Telli, APT Ingenieure GmbH, Zurich
- Timber construction	Andreas Burgherr, Timbatec Gmbh, Holzbauingenieure, Zurich
- Mechanical engineer	René Naef, Naef Energietechnik, Ingenieur und Planungsbüro, Zurich

Consultants as part of Annex 50:

- Planning	Andreas Gütermann, Amena AG, Winterthur
- Energy measurements	René Naef, Naef Energietechnik, Zurich
- Thermographic imaging and blower door test:	Christoph Tanner, QC-Expert, Dübendorf

National research institutes:

- EMPA, Building Science and Technology Lab — Mark Zimmermann (Project manager)
- Lucerne University of Applied Sciences and Arts, CCTP — Prof. Dr. Peter Schwehr (Co-Leitung)
- University of Applied Sciences Northwest Switzerland Prof. Dr. Reinhard Gottwald Institut (FHNW), Institute, Surveying and Geomatics
- University of Applied Sciences Northwest Switzerland Prof. Armin Binz / René Kobler (FHNW), Institute Energy and Buildings
- Lucerne University of Applied Sciences and Arts — Prof. Gerhard Zweifel

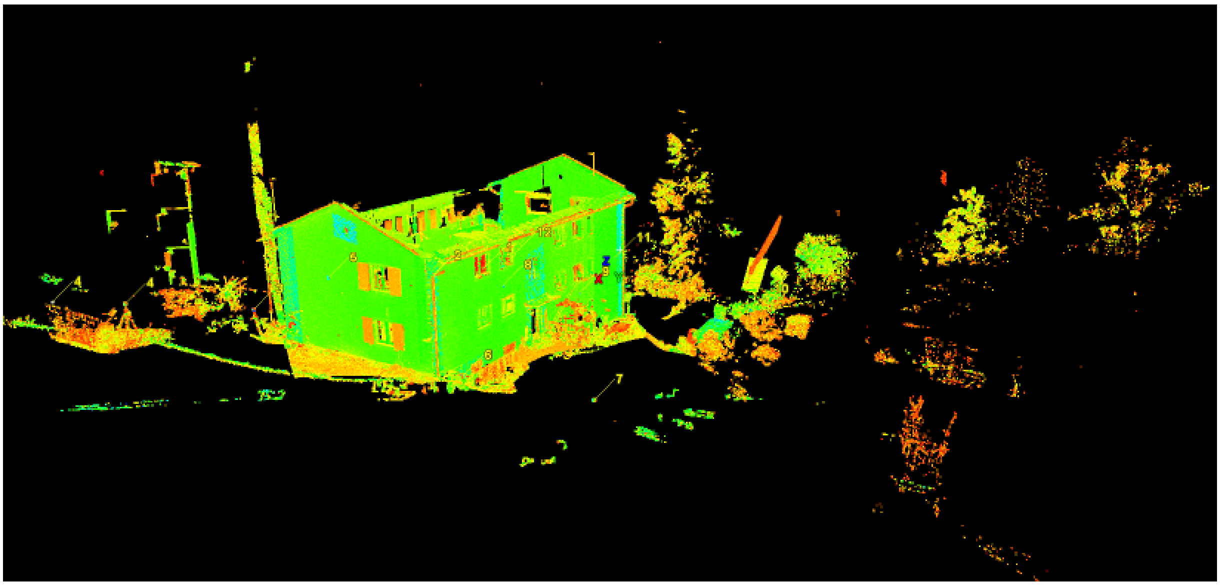
Participants in the Retrofit-project team:

- Bächi Holzbau AG, Embrach
- Isofloc AG, Bütschwil
- Flumroc AG, Flums
- Roth Gerüste, Regensdorf

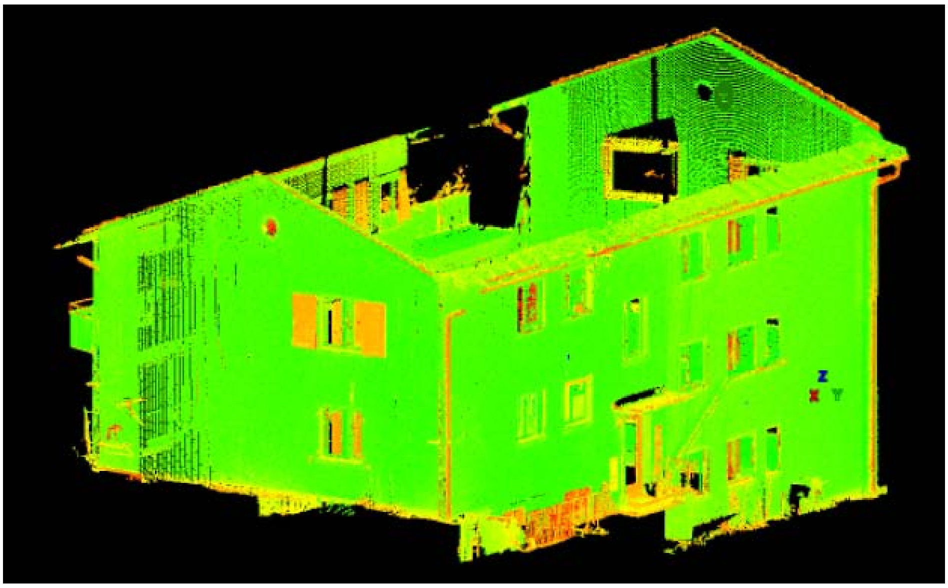
5.4. Appendix B: Digital survey

Digital 3D building survey

(measurement carried out by the University of Applied Sciences Northwest Switzerland FHNW)



Point clusters combined from six different testing positions



Processed point cluster (around 26 million points, coloured according to intensity)

5.5. Appendix C: Lectures and publications

Lectures (held by Beat Kämpfen)

2008

- Tag der Technik: im Zeichen effizienter Energienutzung – Winterpullover für alte Gebäude
- CCEM-retrofit: Advanced Energy Efficient Renovation of Buildings – Wir sanieren und bauen für die Zukunft
- Novatlatis Bauforum: Nachhaltige Umbauten

2009

- Task 37: Advanced Housing Renovation with Solar and Conservation, Subtask B, Canada, Niagara on the Lake
- Von der Energieschleuder zum Nullenergiehaus, Grundsätze-Beispiele, Herbstseminar Best Pratice, 2009, Bern
- Von der Energieschleuder zum Nullenergiehaus, Energieapero Luzern, 2009 Luzern
- Verbesserung der Energieeffizienz, Holzbautagung, 2009, Biel

2010

- Gebäudezyklen der gebauten Umwelt, Lignum/Pro Holz Luzern, 2010 Rain
- Energie und Nachhaltigkeit im Bauen, Institutionelle und Professionelle Bauherrschaft, IPB, 2010
- Refurbishment: from Minergie to Zero Energy. Is it possible? International Energy Agency, IEA, Paris 2010
- München: Energieeffiziente Gebäudeerneuerung mit Holzbauelementen, Symposium TU
- München: Holzbaulösungen für die Gebäudemodernisierung, 2010, München
- Gebäudeintegrierte Photovoltaik, Nationale PV-Tagung, 2010, Winterthur
- Energieeffizienz und Nachhaltigkeit, Seminar Nachhaltigkeitskompetenz für, 2010, Winterthur
- Von der Energieschleuder zum Nullenergiehaus – 2 Beispiele, Europäischer Kongress für energieeffizientes Bauen mit Holz, 2010, Köln
- Bauen mit der Sonne, swisssolar, 2010, Zürich

2011

- Seminar zu innovativem Holzbau, Winterthur
- Futurbuilt seminar, Oslo
- Poznan, Polen
- Nachhaltiges Immobilienmanagement, Bern

Publications

Retrofit and additions – Apartment building Segantinistrasse 200, 2009

2009

- Forum Holz I Bau Garmisch 09: Von der Energieschleuder zum Nullenergiehaus – zwei aktuelle Beispiele, Internationales Holzbauforum (IHF) 2009, Biel

2010

- Schweizer Energiefachbuch 2010, Nachhaltig Planen, Bauen und Betreiben: Upgrade eines 0815-MFH auf Minergie-P, KünzlerBachmann Medien AG, St. Gallen
- Nachhaltig Bauen - im Kanton Zürich: Von Energieschleuder zum Plus-Heizenergie-Haus, 3/2010, Gerber Media, Zürich
- COVISS, Das unabhängige Magazin für Architektur, Kontur und Farbe: Architektur im Sonnenlicht, Solare Energie möglichst gut ausnützen, 8/2010 Dezember 2010, Eigensatz Verlags GmbH, Luzern
- NZZ am Sonntag: Mit Holz frisch eingepackt, Ausgabe 5. September 2010
- Von der Energieschleuder zum Nullenergiehaus – 2 Beispiele, Europäischer Kongress für energieeffizientes Bauen mit Holz, 2010, Köln

2011

- CONFORT (Japan), Renovation in the age of energy-efficiency, Ausgabe 08/2011
- Umwelt Journal, Von der Energieschleuder zum Haus der 2000 Watt Gesellschaft, Ausgabe 4/2011

Visits

The building has been visited in the past year by students from Switzerland, architects and engineers from Scandinavia, Japan, Germany etc. – probably a total of more than 1’000 persons.

Prizes

Swiss Solar Prize 2011

From the 50's to zero energy balance. Residential building in Zürich, Switzerland.

Owners:
Peter Rieben,
Markus and Sara Rieben

Location of the building
Segantinistrasse 200,
CH -8049 Zürich

Construction year: 2009

Architects:
kämpfen für architektur ag, Zürich
Beat Kämpfen,
dipl. Arch ETH/SIA, M.A. UCB
Collaborater: Nadja Grischott

Energy engineer:
René Naef, Zürich

In Switzerland and all other European countries a huge mass of residential buildings have been built from the fifties to the seventies. After 40 to 60 years, these buildings have to be modernised completely. Floor plans have to be adjusted, constructions to be repaired and the energy consumption has to be reduced drammatically. This project shows, that buildings with an energy consumption of about 228 kWh/m2a can be transformed to a zero energy bilance (no energy for heating, hot domestic water and ventilation). State of the art technical equipment (ground source heat pump, solar collectors and photovoltaics) is combined with a most advanced building envelope and the use of passive solar energy. At the same time the floor plans are adjusted to todays habits and a more luxurious apartment is added on top. A new experimental prefabricated facade system in timber construction was used here, so that these transformations can be realised in a short building period. The input of embedded gray energy was also minimised, the pay back time of the energy input is less than ten years.

Key technologies

- Large prefabricated timber elements
- Air-ventilation system
- Ground-source heat-pump 260m deep
- Vacuum solar collectors 12.5 m2
- PV- system 15 KWp

Living room in the added apartment on top…. *and in the renovated ones*

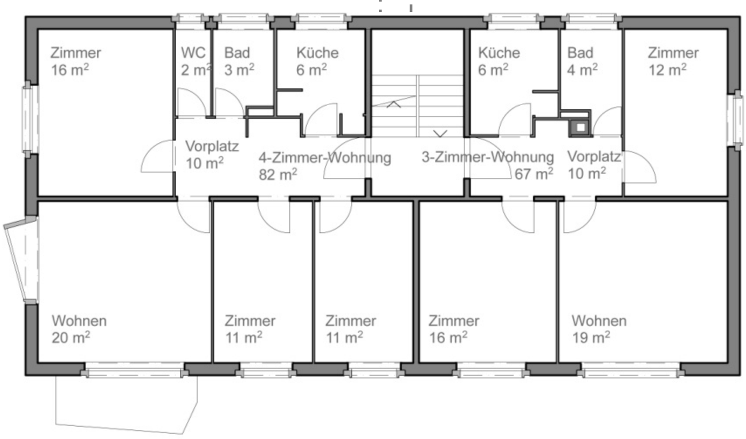
Background

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 has been replaced once. The building fabric was in good shape; the main facades and the wall in the middle are the load bearing structure. The external walls are 32cm deep and are not insulated. The exterior mineral plaster is still well-preserved.

The ceilings are reinforced concrete slabs; the light weight roof structure is also in good condition. Balconies and handrails were weather-beaten during the years and had some rust damage that has corroded through the armouring. Most of the windows still date back to 1954 and only some have been replaced in recent years; they all have a standard double-glazing. The floor coverings inside have mostly been replaced, while kitchens and bathrooms are still in original condition. The oil-heating dates back to 1983 and the heat supply runs due to the radiators; the decentralized water heating works with an electric boiler.

Above: view of the former southwest façade

Above: formers northwest façade and north façade with the entrance



Typical floor plan of the existing building

Project data of building before renovation

Location	Zürich
Altitude	506 m
Heating degree days	229 Kd
Year of construction	1954
Number of apartments	5
Heated floor area	477m²
Total heating energy (incl. hot water)	110’000
Spec. energy consumption	228 kWh/(m²·a)
Rents (net)	65’000 €/a
Additional costs	12’000 €/a

Renovation concept

View of renovated building

Design data for renovated building

Year of renovation	2009-10
Number of apartments	6
Heated floor area	655m²
Total heating energy (incl. hot water)	25'000 kWh/a
Spec. energy consumption	38 kWh/(m²·a)
Heating energy savings (per m²)	81%
Installed heating capacity	15.8 kW
Rents (net)	120'000 €/a
Additional cost	3'000 €/a
Rent increased per m²	39 %

Summary of the renovation

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

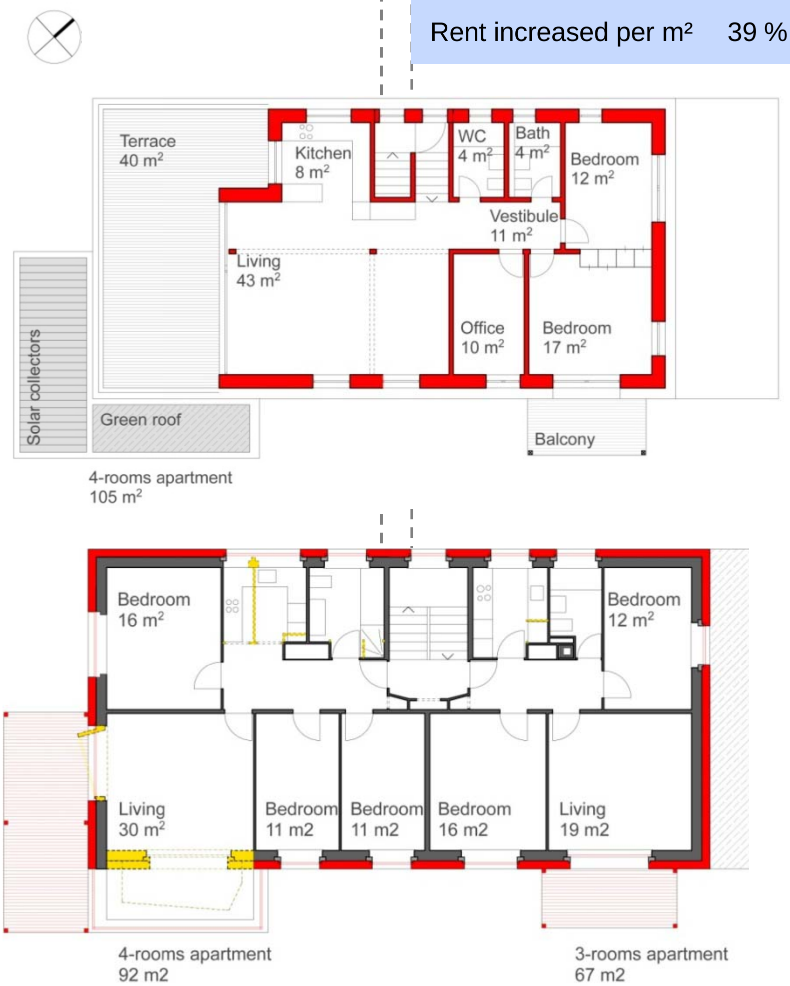
Renovation of the building envelope in Minergie-P standard, with preservation of the architectural quality.

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 kitchens and bathrooms

The rebuilding is to be carried-out with taking care to recycle the existing structures and materials, in order to minimize the consumption of grey energy.



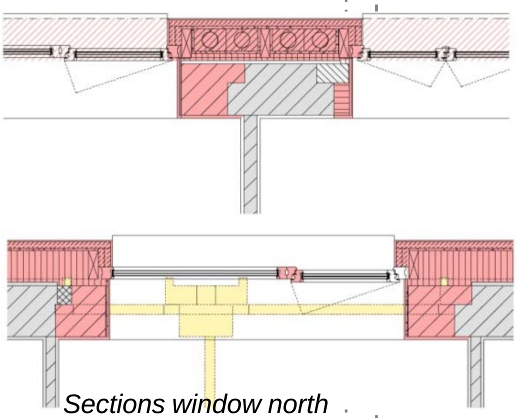
Floor plans showing the changes of renovated building

Renovation design details

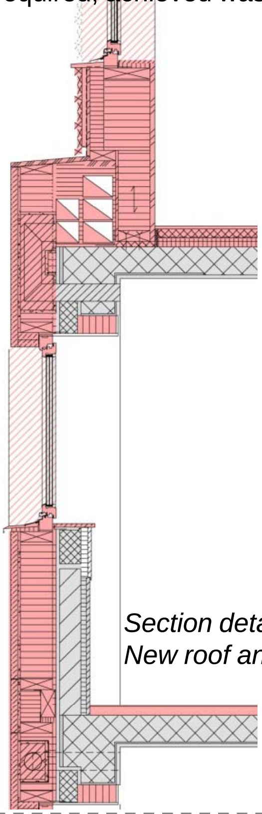
Façade Solutions

The construction of the façade was a big challenge. First the Fachhochschule Nordwestschweiz FHNW took exact 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 his own measures. The new, large scale elements in timber construction had to fit the imprecise and curved old walls. Because of this problems cellulose insulation was used in order to fill all the gaps. The connections between the new windows and the old wall is tighten by a plasterboard and sealing tapes. The airtightness is excellent. For the existing part it 1.5 (h-1) was required, the measurements were 0.5 (h-1). For the attic 0.6 (h-1) was required, achieved was 0.4 (h-1).

Demolition of the existing facade



Sections window north

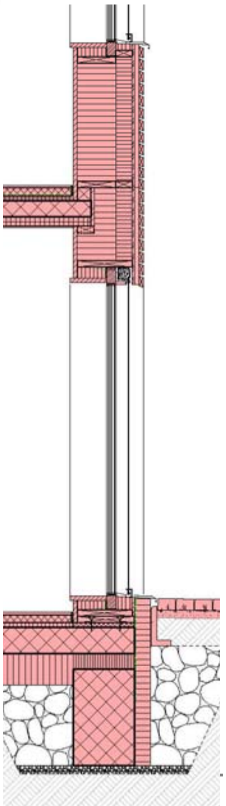


Section detail: New roof and façade

Wall construction ***U-value: 0.18 W/(m²·K)***
(interior to exterior)

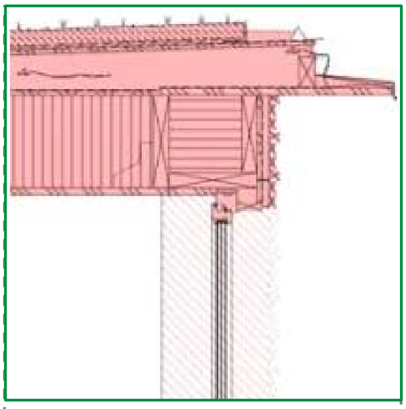
Interior plaster	**10 mm**
Exterior brickwall	**320 mm**
Exterior plaster	**20 mm**
+ Prefabricated element	
Tolerance / Thermal insulation (cellulose)	**20 mm**
Insulation (cellulose Isocell/pillars)	**180 mm**
Wood softboard	**40 mm**
Exterior plaster	**10 mm**
Total	**600 mm**

Section detail: Living room extension

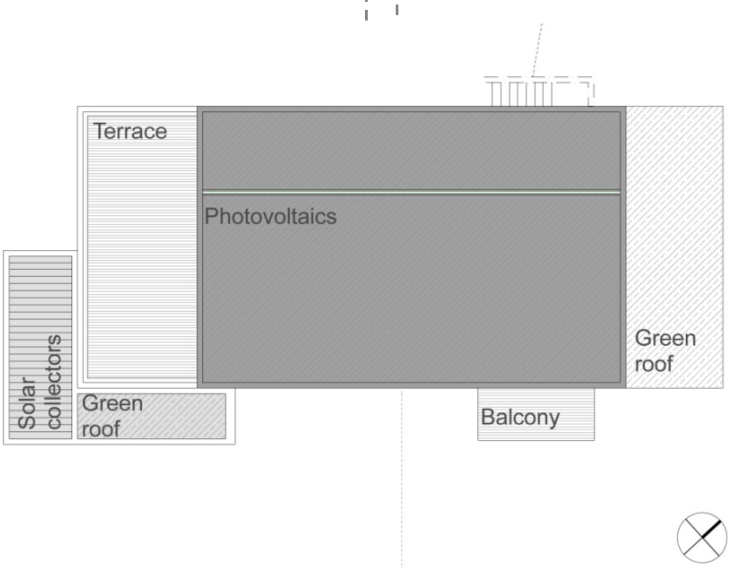


Renovation design details

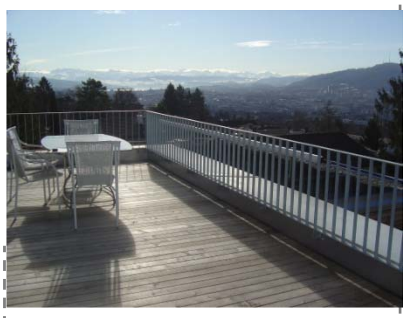
Roof Solutions



Section detail of the new roof



Solar collectors 12,5 m2



Terrace

Roof construction ***U-value: 0.11 W/(m²·K)***
(interior to exterior)

Three-layer slab	**27 mm**
Thermal insulation / Rafters	**360 mm**
Three-layer slab	**27 mm**
Air space /	
Three-layer slab	**200 mm**
Double polymerbitumen seal	**10 mm**
Recycled rubber mat	**7 mm**
Substrat geomembrane	**60 mm**
	691 mm

Photovoltaic surface 115 m2

Renovation design details

Ventilation system

To get ideal ventilation conditions in the rooms, the ventilation tubes are integrated in the new elements of the façades. The air reaches the rooms from the above of each window.

So the ventilation system does not consume any valuable interior space. The interior room dimensions are not affected. A suspended ceiling is not required.

The integration of the ventilation tubes into the prefabricated elements was a big technical and constructive challenge.

Ventilation: North-east façade

Ventilation: South-east façade

Heating and hot water installations

The space-heating and the hot domestic water supply are produced by a geothermal heat-pump and by vacuum solar collectors on the roof of the balcony. 75% of the hot water and 7% of the energy for the space heating comes from the sun. On the upper roof a PV-system will be installed with an area of around 115m2 and an energy production of 15 KWp.

To bring all the new technical equipment in the old basement of the house was impossible. So, a small building was added on the north-east side of the house for placing the head pump and the ventilation devices. In the laundry room are the two boilers with 1'600 liters each to store the gained solar-energy.

260m deep of boring for the ground source

Construction process

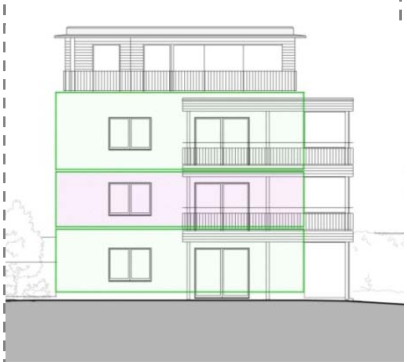
The prefabrication of the façades with the timber elements are a very new building methode, which has not been applied in Switzerland till now. For this reason this project was taken in the ‘Annex 50’ program’s pilot- and demonstration-project.

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

At the end of construction, the air supply system and the electric conduits were placed in the prefabricated elements before they were installed in the building.

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

Prefabrication: North-west façade



Prefabrication: South-west façade

Performance data

Increase of thermal insulation

The level of the thermal insulation , measured by the U-value, has been increased extremely due to new and inventive solutions of the building envelope. So, much less energy is needed to achieve a high comfort level.

Renovation costs

SURFACE INCREASE / ADDITIONAL VALUE

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 are1.800.000 CHF.
The contributions from the government are110.000.- CHF.

Monitoring system

At the moment some data are being collected in order to have enough results to make a valid measurement of the energy savings (electricity, heating, etc) after the renovation.

The winter season 2009-2010 has been the first one. It will need more time and data to have reliable 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 kW/m2a	Before	After	Reduction
Space+water heating (primary energy)	154	30 (Minergie-P standard)	81 %

Renovation (m2)	Before	After	Increase
Rentable area available	380	517	136 %

Summary

Renovations with this deep intervention have to generate an additional value. This additional value has to cover most of the costs for the renovation. At the end the building became a new building.

That means from an aesthetic point of view, the living comfort and the new technologies are like in a new house. For the next renovation in this way, we see the potential in optimizing the building-process, the distribution-system of the ventilation and the construction of the elements.