School building renovation for sustainable second life

Owner:
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Architect:
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Contractor prefab modules:
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Report:
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Supported by:
SFOE, CTI, CCEM
Location:
Krummbach-Geuensee
Renovation: 2011

Key technologies

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

Background

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

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

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

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

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

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

Figure 2: North view of the school building before renovation

Project data of building before renovation

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

Figures by Empa if not mentioned differently

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

Renovation concept

Renovation strategy

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

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

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

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

PV-modules were installed on the roof.

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

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

Design data of the renovated building

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

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

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

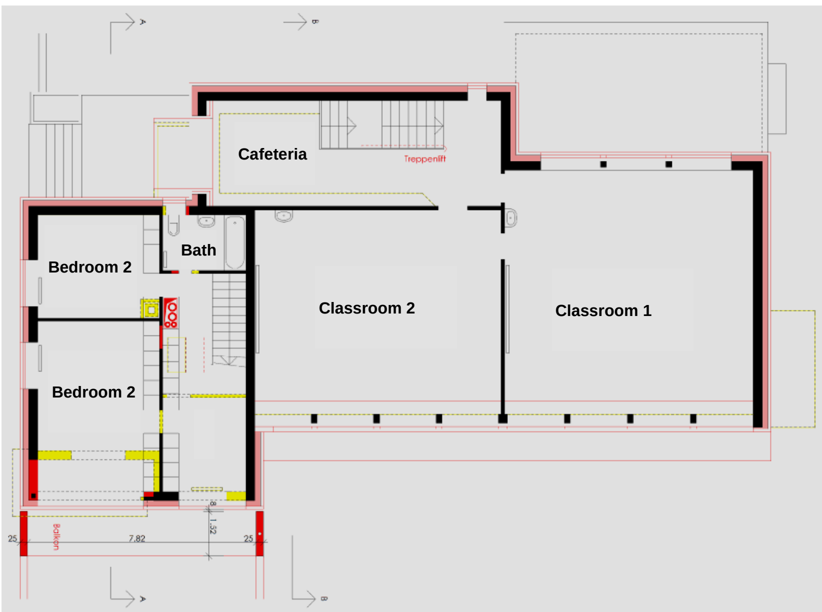


Figure 6: 1st floor plan of school building with caretakers apartment (left). Red: new construction / building envelope, yellow: removed construction (source: Bruno Thoma)

Renovation design details

Façade solution

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

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

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

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

Envelope construction:

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

Roof solution

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

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

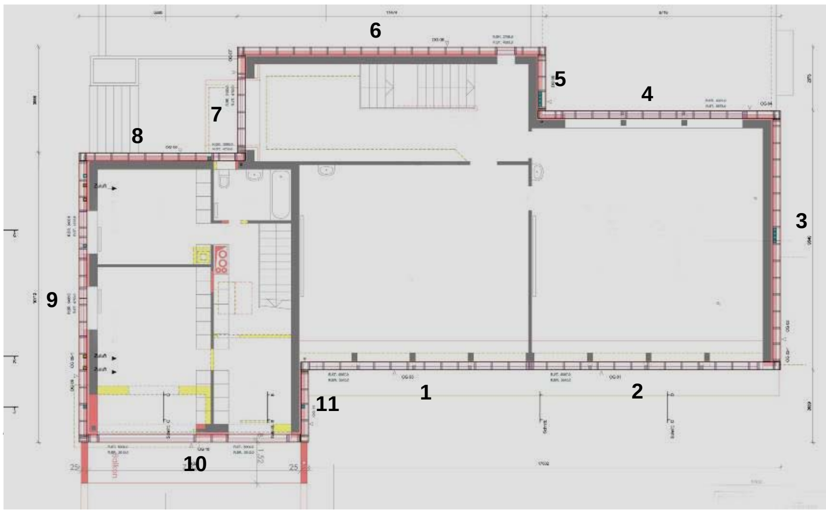


Figure 8: 1st floor plan of school building with modules 1 – 11 (source: Renggli HolzbauWeise)

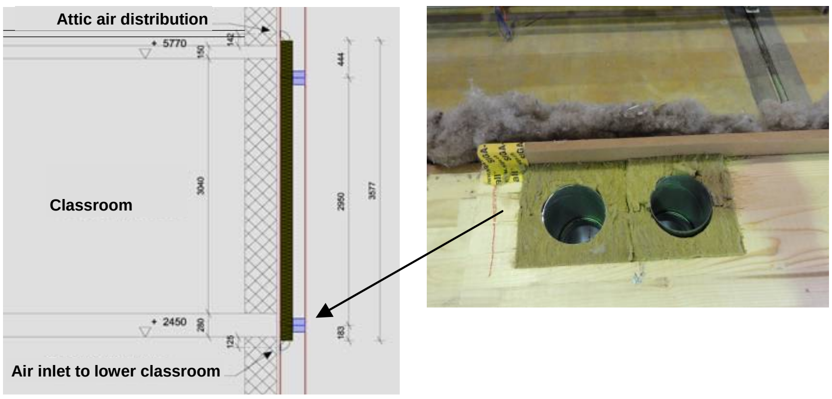


Figure 9: Wall section with integrated ventilation pipes

Heating system and hot water

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

PV system

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

Controlled ventilation

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

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

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

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

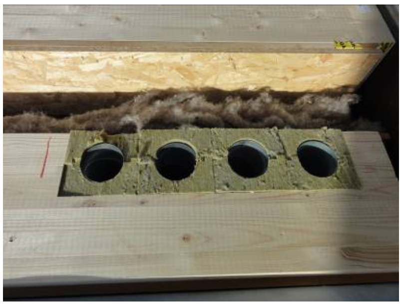


Figure 11: The ventilation ducts are fire protected with specially designed mineral wool sections.

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

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

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

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

Construction process

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

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

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

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

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

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

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

Figure 16: Prefabrication of modules in factory

Figure 17-18: Module delivery on site

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

Figure 21: Mounting of the second module row

Performance data

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

Energy bill

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

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

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

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

Renovation costs

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

Technical data

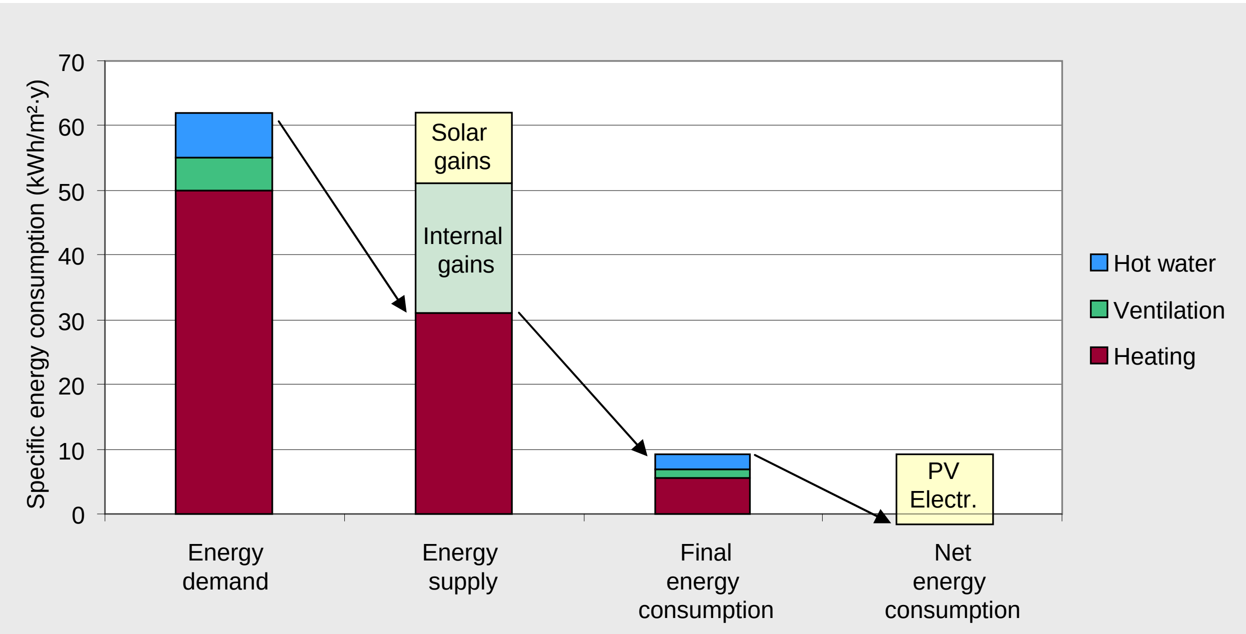
U-value walls	0.12 W/(m^2·K)
U-value windows	0.88 W/(m^2·K)
g-value windows	60%
U-value roof	0.16 W/(m^2·K)
U-value floor	ca. 0.35 W/(m^2·K)

Energy consumption

Transmission	50 kWh/(m^2·y)
Ventilation	5 kWh/(m^2·y)
Internal gains	11 kWh/(m^2·y)
Solar gains (without PV)	20 kWh/(m^2·y)
Heating demand	24 kWh/(m^2·y)
COP heat pump	4.35
Heating energy	5.5 kWh/(m^2·y)
Ventilation energy	1.4 kWh/(m^2·y)
Hot water demand	7 kWh/(m^2·y)
COP heat pump	3.13
DHW energy	2.2 kWh/(m^2·y)
Pumps	0.2 kWh/(m^2·y)
PV produced electricity	10.5 kWh/(m^2·y)
Total energy consumption	-1.2 kWh/(m^2·y)

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

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



Summary

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

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

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

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

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

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

Figure 25: View of renovated building just before completion

Practical experience

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

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

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

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

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

Alexander Ritz, owner

Acknowledgment

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- SFOE Swiss Federal Office of Energy
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