SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Conservation compatible energy retrofit technologies

Part IV: Documentation and assessment of energy and cost-efficient **HVAC-systems** and strategies with high conservation compatibility

IEA SHC TASK 59 | EBC Annex 76
Renovating Historic Buildings Towards Zero Energy

Conservation compatible energy retrofit technologies

Part IV: Documentation and assessment of energy and cost-efficient **HVAC-systems** and strategies with high conservation compatibility.

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IEA SHC Task 59 | EBC Annex 76: Deep renovation of historic buildings towards lowest possible energy demand and CO_2 emission (NZEB)

Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

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IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

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- Solar District Heating (Tasks 7, 45, 55)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
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- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
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To reach the objectives of SHC Task 59 the IEA SHC implementing Agreement has collaborated with the IEA EBC Implementing Agreement at a "Medium Level Collaboration", and with the IEA PVPS Implementing Agreement at a "Minimum Level Collaboration" as outlined in the SHC Implementing Agreement's Policy on Collaboration.

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1.1 Introduction Ventilation & Heating

Historic building restoration and renovation requires sensitivity to the cultural heritage, historic value, and sustainability (i.e., building physics, energy efficiency, and comfort) goals of the project. Heat recovery ventilation can contribute to the mentioned goals if ventilation concepts, and airflow distribution is planned and realized in a minimally invasive way. Compared to new buildings, the building physics of historic buildings are more complicated in terms of hygrothermal performance. In particular if internal insulation is applied, the need for dehumidification is needed for robust and risk-free future use, while maintaining the building's cultural value. As each ventilation system has to be chosen and adapted individually to the specific building, the selection of the appropriate system type is not an easy task.

The integration of a heating system also presents a challenge in the renovation of historic buildings. Existing heat sources such as tiled stoves or open fireplaces do not provide sufficient and uniform heating for the entire living space, in addition to the safety problems related to fire protection and indoor air quality. In order to integrate modern heating systems into the historical building substance, it is necessary to ensure that the distribution is as invisible as possible and to choose heating systems that are adapted to the situation.

1.2 Content of the report

This report is basically divided into three chapters. The first chapter (chapter 2.1) contains solutions and information for the integration of ventilation systems in historic buildings. Chapters 2.2 and 2.3 deal with solutions for heat distribution and heat production.

The fourth part of this report contains an evaluation method for the integration of ventilation systems in historical buildings. For this purpose, the assessment categories according to EN 16883 were taken as a basis and adapted in detail for ventilation systems. In order to illustrate the detailed assessment, one solution was tested using the adapted assessment criteria and is included in the last chapter of this report.

2 Building services and HVAC: Energy efficient solutions with low impact on the historic value of the building.

2.1 Ventilation systems

2.1.1 Overview of Solutions

Category	Measure	Best practice example	Author
Improvement of airtightness	Airtightness thanks to detailed planning and OSB - Board	Hof Neuhäusl, Austria	Alexander Rieser (UIBK)
	Airtightness thanks to detailed planning and vapour retardant layer	Giatlahaus, Austria	Alexander Rieser (UIBK)
	Airtightness thanks to detailed planning and vapour retardant layer	Ansitz Kofler, Italy	Alexandra Troi (EURAC)
Flow control types	Cascade / Extended cascade ventilation system	-	Info sheet
	Active overflow system	-	Alexander Rieser (UIBK)
Cent. ventilation system – suspended ceiling	Classical cent. vent. with suspended ceiling	Villa Castelli, Italy	Alexandra Troi (EURAC)
	Classical cent. vent. with suspended ceiling	Feldbergstraße – Basel, Switzerland	Cristina Polo López (SUPSI)
	Classical cent. vent. with suspended ceiling	Single family house – Bern, Switzerland	Cristina Polo López (SUPSI)
	Classical cent. vent. with suspended ceiling	Magnusstraße – Zürich, Switzerland	Cristina Polo López (SUPSI)
Cent. ventilation system – ducts integrated in the floor	Cent. ventilation system – ducts integrated in the floor	Ansitz Kofler, Italy	Alexandra Troi (EURAC)
	Cent. ventilation system – ducts integrated in the floor	Doragno Castle, Switzerland	Cristina Polo López (SUPSI)
Decentralized ventilation system at apartment level	Decentralized ventilation system with at apartment level	Ryesgade, Denmark	Kirsten Engelund Thomsen (SBI)
	Decentralized ventilation system with Monoblocks	Kindergarten Chur, Switzerland	Cristina Polo López (SUPSI)
room by room Ventilation system	Push pull System	Bochumer Hütte, Austria	Tobias Hatt (EIV)
	Window integrated system – Climawin	-	Jørgen Rose (SBI)
Ceiling through system	Ceiling through system	Farmhouse Trins, Austria	Pavel Sevela (UIBK)
Facade integration of air ducts	Façade integration of air ducts	-	Alexander Rieser (UIBK) / Arnulf Dinkel (ISE)
Air supply via chimney / shaft	Air supply via chimney / shaft	-	Rainer Pfluger (UIBK)

2.1.2 Improvement of airtightness

2.1.2.1 General Information about airtightness

Before installing a controlled ventilation system in an existing building, it is important to ask whether the building meets the requirements for airtightness. Unfortunately, today even new buildings do not automatically comply with the required limit values. Why is building air tightness so important in both old and new buildings? Building leakage not only improves sound insulation, but also helps to prevent moisture damage. Limiting the room air humidity, which is permanently ensured by controlled ventilation, can be a very important factor in this respect.

Due to the reduced infiltration losses, air-tight construction pays for itself in the resulting savings in heating energy consumption. Comfort ventilation with outdoor and exhaust air in balanced operation (equal volume flows) is pressure-neutral, i.e., the internal pressure of the building is equal to the ambient pressure. However, changes in the air flow (ingress and egress of air through leaks in the building envelope) occur due to wind pressure or density differences (temperature difference between inside and outside). These leakage volume flows are not conducted via the heat exchanger of the ventilation unit, so the heat recovery is not effective for this part of the building air change. The leakage volume flows thus contribute directly to increasing the ventilation heat losses. This reduces the amount of heat recovery in the ventilation heat losses and thus also the cost-effectiveness. According to DIN 18599-2, a basic minimum requirement for the air tightness of buildings with ventilation and air-conditioning systems related to the n_{50} value (pressure test result at 50 Pa) is a value of 1.0 1/h.

2.1.2.2 Airtightness thanks to detailed planning and OSB – Board

Author: Alexander Rieser (UIBK)

What is the solution?

Airtightness is an important parameter for the quality of a building. If it is sufficient, it stops warm humid air penetrating through cracks and gaps into the construction, condensing there and leading to moisture damage. An airtight level also prevents drafts and the associated energy loss. The convective entry of warm humid air into the insulation layer is a major problem, especially in the case of interior insulation, because this moisture transport mechanism transports much more moisture than pure diffusion. Such an entry would be fatal, especially with diffusion-tight interior insulation systems. At the "Neuhäusl" farm, the airtightness of the walls was achieved by an OSB board. All joints were glued and sealed with a designated airtight adhesive tape. The connections to the floor, the ceilings and the windows were sealed with care. Through exact planning and meticulous execution, an n50 value of 0.51 1/h could be achieved at the "Neuhäusl" farm.

Why does it work?

The production of the airtight level using OSB boards has become established especially in timber frame construction. However, it is important to pay attention what kind of OSB boards are used. Not all OSB boards are equally airtight. This is largely attributable to the type and quantity of glue used. In the EU research project "3EnCult", various OSB boards were tested. The results varied widely. In principle, OSB-4 boards achieved better results than OSB-3 boards. There were considerable differences between the producers. Only a few products achieved the targeted area-related air permeability q50 of a maximum of 0.1 m³/(m²h). It should be noted that even with the boards that had a worse airtightness an airtight level and the associated values according to the Blower Door Test (n50 < 0.6 1/h) can be achieved. Nevertheless, the space for possible leaks due to connections etc. is significantly reduced. More detailed information can be taken from the report in the link below. Another important aspect is how to deal with penetrations of the airtight layer. In the "Neuhäusl" farm, all installations were placed in the internal walls in order to ensure an airtight level free of penetrations. Also, the integrating ceilings and walls were included in the concept and a penetration of the airtight level was avoided. The rafters and purlins of the visible roof truss posed a challenge. There, the penetrations could not be avoided. For this reason, the cracks in the beams were drilled to the core with an 8 mm drill and pressed out with a permanently elastic special rubber (e.g., Dörken Delta Than). In the link below, further possibilities for handling beam heads are presented, but the method of injection sealing has proved to be the best.

Pros and Cons

The Pros are the easy processing of the OSB panels, the surface is robust against mechanical damage and due to the hard surface, gluing the joints is easier compared to foils. Another advantage is that the airtight layer can also be used as a moderate vapour barrier. The Cons are the big quality differences between manufacturers and that due to the limited size of the panel material, many joints must be glued subsequently.

Best practice example

Hof Neuhäusl – https://www.hiberatlas.com/de/hof-neuhaeusl--2-130.html

figure 1: airtight layer with glued OSB boards, © DI Hans Peter Gruber

figure 2: detail of the ceiling, © DI Hans Peter Gruber

figure 3: connection to floor, © DI Hans Peter Gruber

figure 4: Blower Door test, © DI Hans Peter Gruber

figure 5: © DI Hans Peter Gruber

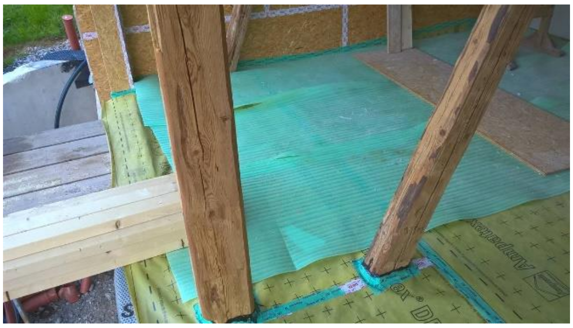


figure 6: Connection to the beams, © DI Hans Peter Gruber

2.1.2.3 Airtightness thanks to detailed planning and vapour retardant layer – Solution A

Author: Alexander Rieser (UIBK)

What is the solution?

Airtightness is an important parameter for the quality of a building. If it is sufficient, it stops warm humid air penetrating through cracks and gaps into the construction, condensing there and leading to moisture damage. An airtight level also prevents drafts and the associated energy loss. The convective entry of warm humid air into the insulation layer is a major problem, especially in the case of interior insulation, because this moisture transport mechanism transports much more moisture than pure diffusion. Such an entry would be fatal, especially with diffusion-tight interior insulation systems. In the case of the "Giatlahaus", the airtight level in the area of the walls was achieved by using a polypropylene foil (Ampatex® DB 90). All joints were glued and sealed with a designated airtight adhesive tape. The connections to the floor, the ceilings and the windows were made with great care.

Why does it work?

In connection with diffusion-retarding interior insulation systems, vapour barriers in form of foils are used in many cases. These foils can vary strongly in their properties (diffusion resistance, moisture-adaptive properties, etc.). The installation of this vapour barrier layer also creates an airtight layer. All connections to other components must be made very carefully and professionally to avoid convective moisture entry into the insulation layer. Especially with foils, the processing instructions of the individual manufacturers must be observed. Expansion joints and overlaps must be carried out according to the manufacturer's instructions, as otherwise stresses and in the worst case even gaps can form in the airtight layer due to component movements. All connections must be made with suitable products depending on the type of substrate. Ideally, the products of one manufacturer are used to ensure that the construction works within the system. Especially penetrations (pipes, cables etc.) and corner connections are often poorly executed. Special cuffs and processing techniques guarantee a faultless finish here as well.

Pros and Cons

One of the main advantages of using foils for airtight layers is their simultaneous use as a vapour barrier. Depending on the type of foil, different Sd - values (equivalent air layer thickness) can be achieved. Furthermore, there are also foils where the Sd - value can vary depending on the boundary conditions (moisture-adaptive foils). They can help the construction to dry out during the summer months, compared to static foils or panels, and at the same time reduce diffusion in winter. Due to the relatively large format, rapid assembly can be carried out for large areas. Also, the low weight facilitates the installation compared to e.g., OSB boards. However, foil installation must be practiced and requires a comprehensive knowledge of the correct processing. Especially on soft insulation, gluing the joints and making corners requires a little more practice. The mechanically low resistance is also often a problem, especially on the construction site. However, holes and cracks can easily be repaired with adhesive tape. To protect the foil, a facing shell is usually applied to the inside. On the one hand, this facilitates the assembly of installations and, on the other hand, serves as mechanical protection for the future users.

Type of data available

The solution is practically tested and has been implemented in countless projects and verified by blower door measurements.

Best practice example

Giatlahaus– https://www.hiberatlas.com/de/giatla-haus--2-212.html

figure 7: vapour barrier and airtight level with Ampatex DB 90 above an internal insulation with sheep wool, © Madritsch und Pfurtscheller Architekten

figure 8: © Madritsch und Pfurtscheller Architekten


figure 9: © Madritsch und Pfurtscheller Architekten


figure 10: especially the details must be executed with great care, © Madritsch und Pfurtscheller Architekten

figure 11: © Madritsch und Pfurtscheller Architekten

figure 12: © Madritsch und Pfurtscheller Architekten

2.1.2.4 Airtightness thanks to detailed planning and vapour retardant layer – Solution B

Author: Alexandra Troi (Eurac), Eleonora Leonardi (Eurac)

What is the solution?

To reach a continuous air-tight layer at Ansitz Kofler, the vapor barrier on the walls was (i) well connected to the vapor retarder on the roof, (ii) turned around the border of the lean concrete in the floor, and (iii) well connected with tape to the window sub-frame and other openings. All electric and hydraulic ducts and cables were installed on the inner side of the vapor barrier in order to prevent punctures. To check the tightness of the vapor barrier and to discover any leaks, a preliminary blower door-test was done before the application of wooden battens and plaster boarding. The final Blower Door test following European Standard UNI EN 13829, procedure B, resulted in a very good value of n50= 0,66/h (for comparison: 0.6 needed for PH certification, 1.0 for EnerPHIT). The new windows are obviously also part of the measures to guarantee airtightness. Details on the connections can be found in the External Wall sections and the windows of the best practice example "Ansitz Kofler".

Why does it work?

Increasing the airtightness was in this specific case a "side effect" of other measures: new windows to reduce heat losses and insulation of the envelope - where for the ceiling and the parts with interior insulation anyway a moisture barrier resp. retarder was needed. Increasing the airtightness was reached by planning and implementing well the details - especially at connection points.

Pros and Cons

Pro: Avoiding damage in the construction due to (humid) indoor air penetrating into the (cold) construction. Energy saving Con: Compared to the airtight layer with board materials, special attention must be paid to the connections and transitions of the foils. The processing is somewhat more complex and complicated. It is however mainly a question of well-planned and implemented details rather than considerable additional parts. What might be an issue: if the overall air tightness is increased without guaranteeing proper ventilation indoor air quality might decrease and the increased humidity might condensate on cold walls (not in this case, as the envelope is insulated, and there is a ventilation system ...) Experience in this and other cases has shown, how important it is to do a first Blower Door test already in the construction phase, when weak points can be recognized and corrected - in this specific case e.g. a chimney not visible in the plans was found, which would have compromised the air-tightness and brought humid air to cold areas .

Type of data available

Blower Door Test and comprehensive documentation of the overall intervention in the master thesis of Hannes Mahlknecht (see below)

Is there any related publication?

A. Troi, H. Mahlknecht, M. Rametta, R. Lollini, M. Benedikter (2011) "Ansitz Kofler in Bolzano/Italy: Energy retrofit to near passive house standard and towards zero emission for heating and cooling". *International Conference on Energy Management in Cultural Heritage*, 6-8 April 2011, Dubrovnik, Croatia: Programme Summary.

H. Mahlknecht (2009) “Refurbishment and monitoring of an historical building. A case study”. Master thesis, *Free University of Bozen-Bolzano*.

Best practice example

Ansitz Kofler – https://www.hiberatlas.com/en/ansitz-kofler--2-25.html

figure 13: Air-tight connection to the window frame (c) Manuel Benedikter

figure 14: Battens for installation layer, which avoids penetrating the vapour barrier with pipes and cables (c) Manuel Benedikter

figure 15: © Vapour barrier on the walls and its connection to the vapour retarder in the ceiling (c) Manuel Benedikter

figure 16: Blower Door test with smoke test, done during construction phase (c) Manuel Benedikter

figure 17: Air-tight connection thanks to concrete screed on the floor (c) Manuel Benedikter

2.1.3 Flow control types

2.1.3.1 Cascade ventilation system and extended cascade ventilation system

The principle of the cascade ventilation has established itself as a standard system for the air distribution within the dwellings. The supply air is introduced into the bedrooms or living room via a duct network and the respective supply air outlets. The air flows through the corridor and is discharged in the functional rooms (exhaust rooms, e.g., kitchen, bathroom, and toilet). For the air routing from the supply rooms via the corridors into the exhaust rooms, overflow openings must be provided between the rooms (e.g., door gaps at least 10 mm high or overflow openings in the door leaf or in the door frame).

In many layouts, it is even possible to dispense with the supply air outlet in the living room if the supply air from the bedrooms can overflow through the living room. This so-called "extended cascade ventilation" enables on the one hand a simplification of the duct network (reduction of investment costs by approx. 8 %) and on the other hand, due to the lower total volume flow, the energy requirement for the fans and thus the operating costs are reduced by approx. 15 %.

2.1.3.2 Active Overflow

Author: Rainer Pfluger (UIBK)

What is the solution?

With the concept of "active overflow system", the entire supply air is brought into the corridor or living room. This area practically functions as a "fresh air reservoir" and distribution zone. From there the air is conveyed into the living rooms by means of active overflow. The return flow also takes place back into the distribution zone; this is mixed air. The exhaust air is discharged via rooms such as the bathroom, toilet, and kitchen.

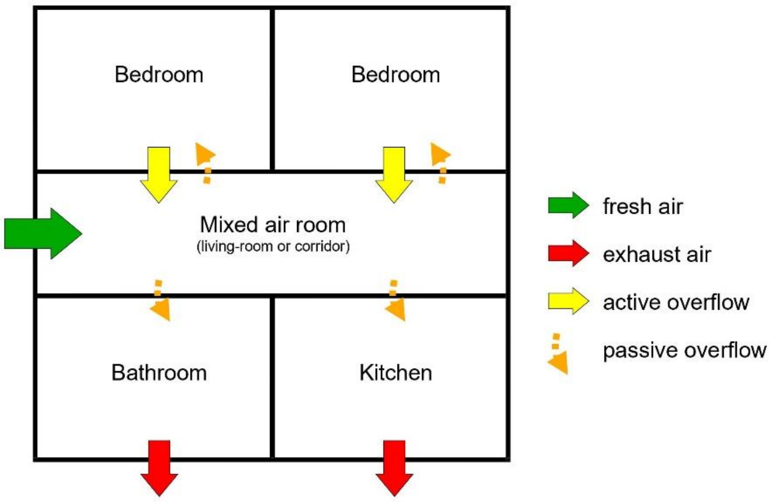


figure 18: concept of active overflow systems, according © Elisabeth Sibille's

Why does it work?

Thanks to the active overflow system, sufficient fresh air is transported from the distribution zone into the bedrooms and living rooms. The return flow is passive via sound-absorbing overflowers. The passive overflow elements should be designed in such a way that they create a pressure drop of maximum 1 to 2 Pascal. Otherwise, a slight overpressure is generated in the common rooms which can lead to building damage. (Warm humid air is pressed into leakages of external wall components and can condense there). In case of leaky buildings (historical buildings) it is recommended not to blow fresh air from the "mixed air room" into the bedrooms. Instead, the exhaust air should be extracted from the bedroom and the fresh air should flow in through passive overflow openings (Figure 2). Blowing in can cause overpressure in the bedrooms and moist warm air can be forced into the construction, which can lead to condensate and damage. The great advantage of this ventilation system is that a suspended ceiling can be completely renounced. Despite the barely visible distribution of fresh air, every room is ventilated and also exhausted. Therefore, the same advantages of a conventional comfort ventilation are achieved with the active overflowers.

Pros and Cons

One big advantage is that there is no suspended ceiling required and a minimal installation of ducts. A disadvantage is if the pressure drop of the passive overflow valves is too high, building damage is possible.

Type of Data available

The solution was presented and investigated in the course of Elisabeth Sibille's dissertation. Furthermore, a system was implemented at the Brünnengut mansion in Bern (Switzerland).

Additional information

Pfluger Rainer (2019) - Domestic ventilation in existing buildings. Highly efficient and cost-effective solutions for the modernisation of old buildings.

Elisabeth – Sibille (2015) - Optimized integration of ventilation with heat recovery in residential buildings through the implementation of innovative air distribution strategies and prefabricated components Page 30

figure 19: Active overflow system as a so-called "Verbundlüfter" by the company Erich Keller integrated into the door leaf in the listed manor house Brünnengut in Bern (Switzerland).

2.1.4 Centralized ventilation system with suspended ceiling

2.1.4.1 Classical central Ventilation with suspended ceiling – Villa Castelli

Author: Alexandra Troi (EURAC)

What is the solution?

Mechanical ventilation system with heat recovery centralized at each floor, with suspended ceiling. It guarantees a pollen-free, healthy indoor environment and improve the comfort indoor for the users. It controls the air humidity in the rooms, given that the building is lying in a zone closed to the lake. A set of CO_2 sensors regulates automatically the air exchanges, and the heat exchanger allows a further reduction of the building energy demands. The mechanical ventilation system is centralized at each floor, in order to guarantee the independency of each flat. Thus, three centralized comfort ventilation units with 480m³/h per unit and a heat recovery of 87% (according to the passive house certificate) were installed.

Why does it work?

Compatibility with conservation: Integrating the distribution ducts in the ceiling allows to hide them, nevertheless adequate floor-to-ceiling heights are required.

Moisture safety: With ventilation systems high indoor humidity which might induce condensation within the construction at any weak point is avoided.

Energy improvement: A central system for controlled ventilation with heat recovery ensures not only that the necessary exchange of air takes place automatically but also that the incoming air from outdoors is warmed by cooling the exhaust air (the “Air-to-Air Heat Exchanger” recovers up to 85 percent of the heat from outgoing air).

Description of the context

Villa Castelli is a listed building from the 19th century located at the riverside of Lake Como (Italy). The owners set the ambitious goal of renovating the Villa, which had belonged to the family for about 140 years, to the lowest possible energy demand while maintaining the original use of the rooms and the external appearance. The renovation achieved a 90% energy demand reduction and a significant increase in comfort, demonstrating that also a listed building can become nZEB.

Pros and Cons

The pros of the solution are that the mechanical ventilation systems with heat recovery provide better air quality, lower humidity and no condensation. Keeping slight under pressure avoids that warm, humid interior air enter via cracks into the construction (causing moisture issues there). Another advantage is that the constant supply of warm air through the heat recovery system can reduce energy costs because the environment temperature is kept constant, this provides greater comfort in cold climates. The disadvantages of the system are that mechanical ventilation systems with heat recovery do require that filters and fans must be kept clean to ensure effective operation (additional maintenance costs). That the heat recovery work efficiently a good level of airtightness must be achieved in the rooms where it is installed, this can lead to additional costs. Since heat dispersed from ceiling ducts reaches the upper air first, the HVAC system has to work harder to push the heat lower into a room. It is always necessary to check the space availability for the mechanical systems and to control the dimension of the air ducts.

Is there any related publication?

P. Penna, O. Stuffer, A. Troi, V. Carì (2019) “Villa Castelli - Transformation of Historical Building into Nearly Zero Energy Building”, *Applied Mechanics and Materials*, vol. 887, pp 148-155.

Troi, O. Stuffer, V. Carì (2018) "Villa Castelli: Sanierung mit Innendämmung auf nZEBStandard. Nutzerüberlegungen zur Nachhaltigkeit", *Denkmal und Energie*, pp 161-175.

V. Carì, O. Stuffer, E. Lucchi (2014) “Risanamento conservativo sulle sponde del lago”, *Casa&Clima* n°51, pp 44-52.

Best practice example

Villa Castelli – https://www.hiberatlas.com/de/villa-castelli--2-23.html

figure 20: Horizontal ventilation distribution / piping, © Valentina Cari

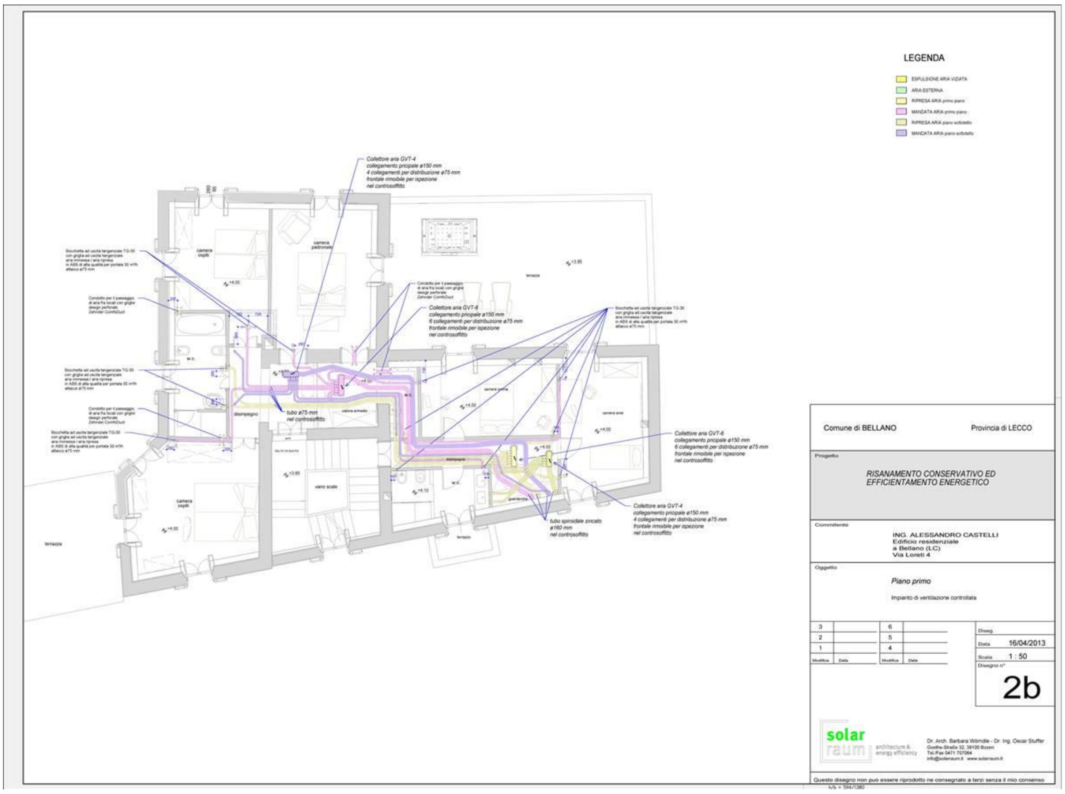


figure 21: Ventilation plan, © Solarraum GmbH

figure 22: *Ventilation outlets on the wall just below the ceiling, © Valentina Cari*

2.1.4.2 Classical central Ventilation with suspended ceiling - Feldbergstraße

Author: Cristina Polo (SUPSI)

What is the solution?

A centralized ventilation with heat recovery, typical of the Minergie buildings, was added to the building. The main pipes pass through technical compartments near the staircase area. Minergie® Certification for low energy consumption buildings is the Swiss brand that certifies the sustainability of new or redeveloped buildings. To achieve the Minergie® certificate specific attention was paid to control of the air change throughout the year and to good performances and verification of summer thermal comfort. This certificate implies a limitation of additional costs up to a maximum of 10%, compared to conventional buildings.

Why does it work?

The intervention for ventilation was done entirely internally without repercussions on the façade. The air intakes pass in the subsoil of the court. The 100-year-old apartment buildings on Feldbergstrasse in Basel, Switzerland is a 6-storey residential building with 12 apartments. The building is an apartment-block designed around an internal court. In this type of nineteenth-century institutional and residential block as well as the twentieth century perimeter block in the old part of Basel, the central yard could be communal or private courtyard surrounded by a group of buildings. Many central courtyards had specialised utilisations e.g., workshops and ground floor dwellings backyard, or have served only as ventilation wells. Several requirements of the cityscape commission for façade and roof design had to be met mainly in the front facade towards the street.

Description of the context:

Two more than 100-year-old apartment buildings on Feldbergstrasse are being renovated to produce more energy than they use for heating/hot water, ventilation and auxiliary energy. The 12 apartments did not meet today's comfort requirements. Accordingly, the apartments were poorly rented or stood empty. The need for maintenance was high.

Pros and Cons:

The solution is very simple: starting from the basement, in the central area are placed the main vertically ducts and the distribution at the floor is horizontally through lowered ceilings in the corridors. No external intervention on the façade was carried out. Controlled ventilation systems are mandatory for residential buildings that are certified in accordance with the rules of the Minergie building standard to achieve high energy efficiency. Since a tight building envelope prevents the gradual loss of warm air, ventilation systems compensate for this with a continuous, controlled exchange of air

Type of data available

Several data are available in the architect's web page and projects documentation: Viridén + Partner AG, https://www.viriden-partner.ch/mehrfamilienhaeuser

The project was awarded with the Swiss solar prize in 2009.

Additional information

http://www.viriden-partner.ch/plus-nullenergiehaeuser?lightbox=dataItem-is05dqmd

https://www.hiberatlas.com/smartedit/projects/67/G-09-08-20 Viriden_5.pdf

Swiss solar prize 2009, https://www.solaragentur.ch/dokumente//G-09-08-20%20Viriden.pdf

Best practice example

Feldbergstraße – https://www.hiberatlas.com/de/residential-and-commercial-building-feldbergstrasse-basel--2-67.html

figure 23: Execution of pipes during the works ©V+P

figure 24: Execution of pipes during the works ©V+P

figure 25: Execution of pipes during the works ©V+P, Viridén + Partner AG

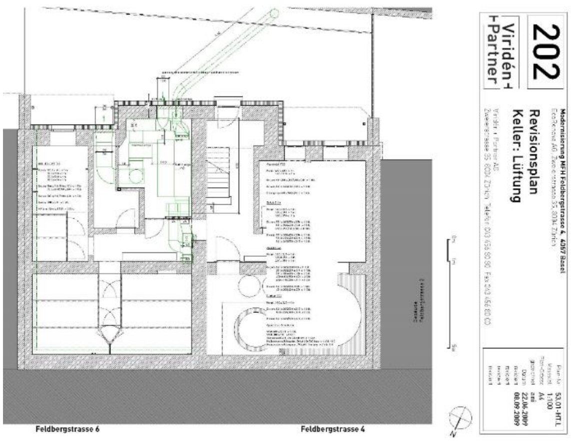


figure 27: Ventilation plan, ground floor ©V+P, Viridén + Partner AG

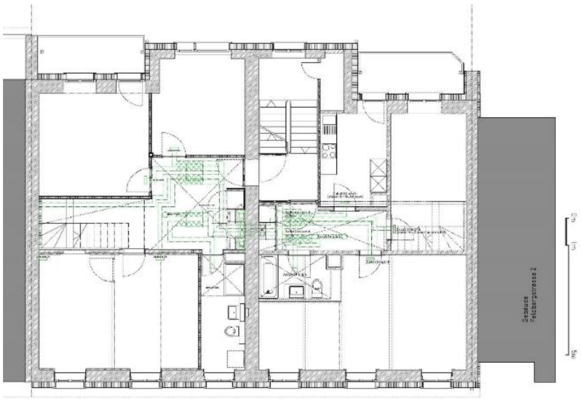


figure 26: Ventilation plan first floor ©V+P, Viridén + Partner AG

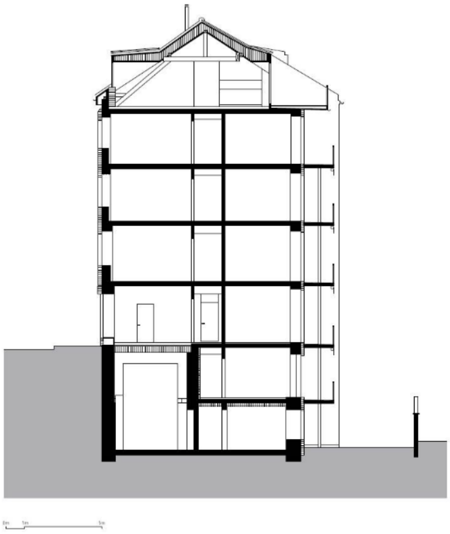


figure 28: Cross section ©V+P, Viridén + Partner AG

figure 29: Court view ©V+P, Viridén + Partner AG

2.1.4.3 Classical central Ventilation with suspended ceiling – Single family house, Bern

Author: Cristina Polo (SUPSI)

What is the solution?

A comfort ventilation system with heat recovery of the company Zehnder (https://www.international.zehnder-systems.com/products-and-systems/comfosystems) has been installed.

Why does it work?

On the top floor, the supply air is routed via the screed into the built-in cupboards: apart from the inconspicuous supply air grilles in the cupboard walls (usually behind furniture), no architectural intervention in the rooms (pipes) is necessary. This will avoid the visual impact of technical installations.

Description of the context

The building is a detached single-family house, a two-floors neo-baroque construction with a mansard rooftop and is dated 1898. The general situation of degradation and the need to minimize energy demand collide with the important aspect of historic buildings preservation. The challenge is to achieve maximum results in both fields, opting for several high efficiency interventions, but at the same time with minimum aesthetic impact. As usual at road forks and corner houses in the Kirchenfeld district, according to the Kirchenfeld-Brunnadern building inventory, the house was designed with special care: the south-east corner of the house is characterized by a corner covered with the mansard roof. The house is listed in the cantonal building inventory and classified as worthy of protection (highest protection level). For this reason, any changes must obtain the approval of the Department of Historic Monuments.

Pros and Cons:

In addition to the minimum architectural intervention, there are no audible ventilation noises. Controlled ventilation allows to achieve high energy efficiency. Since a tight building envelope prevents the gradual loss of warm air, ventilation systems compensate for this with a continuous, controlled exchange of air. The positive effect of controlled ventilation systems is that no moist air accumulates in the rooms; the risk of mould is eliminated. And because fresh air can flow in automatically from outside, the quality of the room air is permanently guaranteed. Furthermore, the heat contained in the exhaust air from a controlled living space ventilation system is systematically recycled improving energy efficiency. In contrast, there is no longer any need for manual and natural ventilation. Practice even shows that without a ventilation system, manual natural ventilation is usually too long, so that unwanted heat loss increases.

Type of data available

Winner of the Swiss Solar Prize 2014, "B" category for building's retrofit. INTERREG case study for cultural-protected building's retrofit.

https://www.hiberatlas.com/smartedit/projects/174/Beschreibung des Gebäudes und der Solaranlagen_20161030.pdf

Additional information

https://www.hiberatlas.com/smartedit/projects/174/Beschreibung%20des%20Geb%C3%A4udes%20und%20der%20Solaranlagen_20161030.pdf

Article and video published in Hausinfo, a neutral online information platform on all topics relating to the house, published in German and French (Ed. GVB Services AG and the Homeowners Association Switzerland, HEV): "Architecture report: Energy-producing roof despite monument protection". The article contains information on the products and the technical plans used in the building refurbishment.

Available at: https://www.hausinfo.ch/de/home/gebaeude/architekturreportagen/hutterli-bern.html

In 2014, the building owners received a Swiss solar award for their commitment to improving the energy balance of their building. Link:

https://www.solaragentur.ch/sites/default/files/g-14-10-03_hutterli_roethlisberger_solpreiskatsan.pdf

Best practice example

Single family house, Bern– https://www.hiberatlas.com/en/single-family-house-bern-switzerland--2-174.html

figure 30: Services tubes vertical distribution © M. Hutterli

figure 32: Services tubes horizontal distribution © M. Hutterli

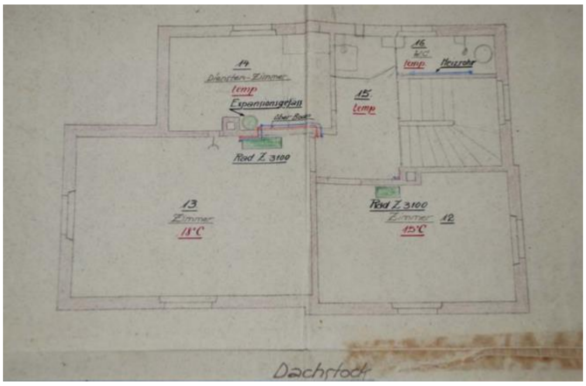


figure 31: System distribution scheme (attic floor, attic) © M. Hutterli

figure 33: Indoor spaces after refurbishment © M. Hutterli

2.1.4.4 Classical central Ventilation with suspended ceiling - Magnusstraße Building, Bern (CH)

Author: Cristina Polo (SUPSI)

What is the solution?

A centralized ventilation with heat recovery, typical of the Minergie buildings, was added to the building. Minergie® Certification for low energy consumption buildings is the Swiss brand that certifies the sustainability of new or redeveloped buildings. To achieve the Minergie® certificate specific attention was paid to control of the air change throughout the year and to good performances and verification of summer thermal comfort. A central air treatment unit in the basement serves all apartments. Individual air volume regulation in the apartments is not possible. A basic point of the Minergie concept is that mechanical ventilation not only guarantees good air quality, that also saves energy with the heat recovery unit, but without manual ventilation allowing the adjustment device to be easily accessible in the apartment without individual devices. The outside air is drawn in from the passage facade to the courtyard at a height of approx. 2.5 m from the floor.

Why does it work?

The apartments are accessed via two separate climbing zones. The fine distribution takes place in the toilet / bathroom and corridor ceilings. In the new roof section, individual supply and exhaust air pipes with plastic pipes were inserted into the wooden elements. The air enters the room via an outlet grille over the doors. In the wet rooms, it is drawn off again via poppet valves. Inside the apartment, the air circulates through the newly made door slots. The exhaust air is returned to the air treatment unit through insulated pipes and ducts made of galvanized sheet steel and blown out through a light shaft in the courtyard facade.

Description of the context

The two street-side facades are subject to preservation requirements and therefore could not be changed. Otherwise, the attic and the court side. Here the roof with eaves could be broken off and put back in the form of prefabricated wooden elements. In this context, the roof could be raised on the courtyard side.

Pros and Cons

The solution is very simple: starting from the basement, in the central area are placed the main vertically ducts and the distribution at the floor is horizontally through lowered ceilings in the corridors. No external intervention on the façade avoiding visual impacts of ducts or technical installations. Controlled ventilation systems are mandatory for residential buildings that are certified in accordance with the rules of the Minergie building standard to achieve high energy efficiency. Since a tight building envelope prevents the gradual loss of warm air, ventilation systems compensate for this with a continuous, controlled exchange of air.

The positive effect of controlled ventilation systems is that no moist air accumulates in the rooms; the risk of mould is eliminated. And because fresh air can flow in automatically from outside, the quality of the room air is permanently guaranteed. Furthermore, the heat contained in the exhaust air from a controlled living space ventilation system is systematically recycled improving energy efficiency. In contrast, there is no longer any need for manual and natural ventilation. Practice even shows that without a ventilation system, manual natural ventilation is usually too long, so that unwanted heat loss increases

Additional information

https://www.hiberatlas.com/smartedit/projects/88/Baubeschrieb Magnusstrasse_7.pdf

The Magnusstraße residential building in Zurich, Switzerland, is a cooperative housing at fair prices. The apartment building in Zurich needed a complete modernization. After renovation, the building meets the Minergie standard was awarded with the Swiss Solar Prize 2007 and Watt d'Or 2008.

Swiss solar award 2007 documentation: https://www.solaragentur.ch/dokumente//M-07-09-21Magnusstrasse.pdf

Several information is available in the architect's web page and projects documentation: Viridén + Partner AG, https://www.viriden-partner.ch/mehrfamilienhaeuser

Best practice example

Magnusstraße– https://www.hiberatlas.com/de/apartment-building-magnusstrasse-zuerich--2-88.html

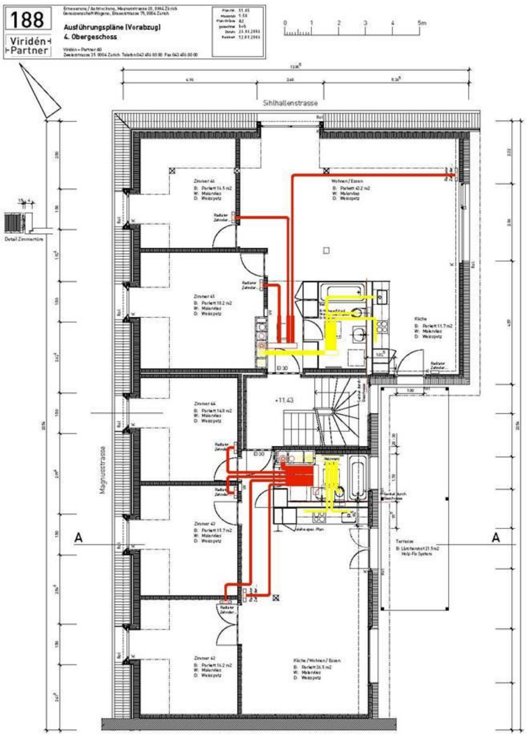


figure 34: Ventilation plan of the 4th floor ©V+P

figure 35: Ventilation unit during the works ©V+P

figure 36: Ventilation unit during the works ©V+P

figure 37: Execution of pipes during the works ©V+P

2.1.5 Centralized Ventilation system with ducts integrated in the floor

2.1.5.1 Central Ventilation system with ducts integrated in the floor – Ansitz Kofler

Author: Alexandra Troi (EURAC)

What is the solution?

Centralized mechanical ventilation system with heat recovery with ducts integrated in the floor. The ventilation unit is placed in a crawlspace above the kitchen, benefitting from the ample room height of 4m. The distribution ducts are integrated in the anyway refurbished floor, together with the hydraulic system in a concrete layer between thermal and sound insulation. Advantage from conservation point of view is the fact, that with ventilation system high indoor humidity which might induce condensation within the construction at any week point are avoided.

Why does it work?

Compatibility with conservation: Integrating the distribution ducts in the floor allows to hide them, nevertheless this measure can be adopted only if modifications to the existing floors are not restricted.

Moisture safety: With ventilation systems high indoor humidity which might induce condensation within the construction at any weak point is avoided.

Energy improvement: A central system for controlled ventilation with heat recovery ensures not only that the necessary exchange of air takes place automatically but also that the incoming air from outdoors is warmed by cooling the exhaust air (the “Air-to-Air Heat Exchanger” recovers up to 85 percent of the heat from outgoing air). Introducing an automatic summer bypass unit guarantees that the outside air almost completely bypasses the heat exchanger preventing the supply air from being additionally warmed during warm summer months.

Pros and Cons

The pros of the solution are that the mechanical ventilation systems with heat recovery provide better air quality, lower humidity and no condensation. Keeping slight negative pressure avoids that warm, humid interior air enter via cracks into the construction (causing moisture issues there). Another advantage is that the constant supply of warm air through the heat recovery system can reduce energy costs because the environment temperature is kept constant, this provides greater comfort in cold climates. The disadvantages of the system are that mechanical ventilation systems with heat recovery do require that filters and fans must be kept clean to ensure effective operation (additional maintenance costs). That the heat recovery work efficiently a good level of airtightness must be achieved in the rooms where it is installed, this can lead to additional costs. Since heat dispersed from ceiling ducts reaches the upper air first, the HVAC system has to work harder to push the heat lower into a room. It is always necessary to check the space availability for the mechanical systems and to control the dimension of the air ducts.

Description of the context

The main building of "Ansitz Kofler" was built in 1749 and had in 1769 Wolfgang Amadeus Mozart as a guest. The Orangery was added a bit later: as 30m long and 5 m wide structure with spacious and bright rooms, used for breeding tropical fruits - for which the climate in Bozen, even if south of the Alps, would otherwise have been too harsh. In 1925 the Orangery was converted to a dwelling: the windows were scaled down, and internal walls were added, forming a suite of rooms aligned with each other (so called enfilade). As typical for buildings of this age in Bozen, the bearing structure is a stone masonry, with stones of different size, taken from the rivers in the area.

Type of data available

This ventilation system is monitored by measuring temperatures and relative humidity in different positions of the system (fresh air intake, fresh air after air-to-air heat recovery, supply air after air-to-air heat recovery, return air and exhausted air). These measurements are used to evaluate efficiency of the air heat exchanger and determination of preheating and pre-cooling.

Is there any related publication?

A. Troi, H. Mahlknecht, M. Rametta, R. Lollini, M. Benedikter (2011) "Ansitz Kofler in Bolzano/Italy: Energy retrofit to near passive house standard and towards zero emission for heating and cooling

http://www.eurac.edu/en/research/technologies/renewableenergy/publications/Documents/EURAC_RenEne_Dubrovnic2011_Troi-Mahlknecht-Rametta-Lollini.pdf #

Best practice example

Ansitz Kofler– https://www.hiberatlas.com/en/ansitz-kofler--2-25.html

figure 38: Ventilation unit in the crawlspace above the kitchen, © Manuel Benedikter Architekten

2.1.5.2 Central Ventilation system with ducts integrated in the floor – Doragno Castle

Author: Cristina Polo (SUPSI)

What is the solution?

A centralized system with heat recovery has been created, with a local distribution by local. All the parts are under the floor, taking advantage of the major works carried out and the execution of an internal insulation. An electric reversible air-water heat pump powered by the photovoltaic (PV) system on the roof is used for thermal and air conditioning. Distribution is made both from radiating floors and fans bellow a raised floor (Floortech patent, deltaZERO concept), dry laid and demountable giving flexibility. DHW thanks solar thermal becomes completely free and renewable.

Why does it work?

The building has undergone many interventions, for example to remove false and non-original parts that distorted the construction, for this reason the interventions have been carried out without particular difficulties if not the usual problems of breaches and cores for the passage of the pipes. In particular, since there were no protection constraints, the interventions were aimed at enhancing the character of the building in its context. The air quality with these appliances is excellent despite reducing internal humidity. Energy efficiency for heat recovery reaches 92%. The solution is typical for refurbishment: the system starts from the basement, with horizontal ducts, the risers are inserted in the outside walls and then floor distribution boxes whit horizontal pipes.

Description of the context

The project aims to restore the soul of the castle, by demolishing the works made in the 20th century and using new glazed surfaces with a completely new concept for thermal and air conditioning achieving high standards for comfort and energy efficiency. An ancient medieval castle was converted into a private residence in 2014 where the existing building, which did not enhance the castle, has been subsequently restored in 2018. It was a part of a path bordered by fortified castles and watchtowers built at regular intervals on the way to the Alps. This private residence building, a historic not-listed building in Ticino, achieved a NZEB target using also solar renewables energy.

Pros and Cons

A work like this can be achieved at an existing building without particular difficulties or price supplements, only thanks to the fact that radical and costly interventions have been carried out.

Type of data available

Several information is published regarding this project and is available in the in the architect's web page and projects documentation, deltaZERO SA: https://www.deltazero.net/en/what-2/6-icon-projects/doragno-castle/

Maria Mazza & Stefano De Angelis Effrem, deltaZERO Architettura, Il Castello di Doragno, Restauro e sostenibilità energetica, Archi magazine, Rivista svizzera di architettura, ingegneria e urbanistica. August 004, 2020. Pages: 26-29. Publisher: espazium. ISSN 1422-5417, https://www.espazium.ch/it/archi4-20_castello

Solar web Plattform www.solarchitecture.ch: https://solarchitecture.ch/in-a-nutshell-doragno-castle/

Additional information

In the "related publication"; basement plan, ventilation appliance and pictures

https://www.hiberatlas.com/smartedit/projects/28/Ventilazione - FR_HR-MURAL 800_1.pdf

Ventilation system

https://www.hiberatlas.com/smartedit/projects/28/800.506a A3 ventilazione 1_100.pdf

Ventilation plans

Best practice example

Doragno Castle– https://www.hiberatlas.com/de/doragno-castle-rovio-ticino-switzerland--2-28.html

figure 39: Ventilation system © L. Carugo

figure 40: Ventilation pipes in the floor © L. Carugo

figure 41: Distribution in the floor © L. Carugo

2.1.6 Decentralized ventilation system at apartment level

2.1.6.1 Decentralized ventilation system at apartment level – Ryesgade 30

Author: Kirsten Engelund Thomsen (SBI)

What is the solution?

Decentralized ventilation systems placed in cupboards in the kitchen and hallway.

Why does it work?

The ventilation systems from the Danish case study "RYESGADE 30" are decentralized systems at apartment level. This means that each apartment has its own unit. The units are wall-hung and placed in cupboards in the kitchen and hallway. Each plant has fresh air intake via the facade. On one side of the stairwell, returns are managed over roof for each plant via fire insulated ducts in duct shaft. On the other side gable wall return without windows. The ventilation systems are running without any need of management. However, the system can be forced to maximum capacity by activating the cooker hood. The system is not equipped with intelligent dampers for priority of suction from cooker hood during forced operation. As the plant has a capacity of approx. 180 m^3/h, the efficiency of the cooker hood in several of the apartments is relatively limited due to inadequate suction (this can be improved using intelligent dampers).

Pros and Cons

Pros: Low electricity consumption (2.5 kWh / m^2 / year). Efficiently maintains a good indoor air quality. The system has good operational safety and "average" price compared to central ventilation plants. With regard to the operational safety, the decentralized plants in Ryesgade have clearly outperformed tests with central ventilation in the same building. The plants have also proved significantly easier to troubleshoot, since a given fault is only related to a single apartment and unit. In the case of service work, only one lease is affected at a time. Cons: More noise nuisance than central plant systems Cooker hood is not always working as planned. Comprehensive ducting for systems with heat recovery and distribution to several rooms.

Type of data available

Energy (heat and electricity) consumption is simulated before and after renovation. The system has also been monitored and measurement data are available. Measured weather data was used for the simulations in the period provided by DMI (Danish Meteorological Institute). The simulation is basically done using a heat recovery rate of 85% and an infiltration rate of 0.05 h-1.

Additional Information

A condition for using mechanical ventilation with heat recovery is that a high degree of airtightness of the dwellings can be established in connection with the renovation. Here, among other things, the experience of the passive house construction shows that when ventilation systems with heat recovery are combined with a high level of airtightness, considerable energy savings can be achieved in practice. In addition, it is important to choose heat exchanger types with high heat recovery rate ~ 90% and fans with low electricity consumption, SFP (specific fan power) value below 1.0 kJ/m^3 air. In order to achieve a high degree of user satisfaction, the systems must also have a very low noise level, preferably lower than 27 dB and there must be a plan for maintenance of the ventilation systems, e.g., filter changes etc.

https://www.hiberatlas.com/smartedit/projects/143/erfaringer fra prøvelejlighed ryesgade 30c 1tv - juni 2011.pdf

Experiences from a test apartment in Ryesgade 30 - in Danish

Best practice example

Ryesgade 30– https://www.hiberatlas.com/en/ryesgade-30-a-c--2-143.html

2.1.6.2 Decentralized ventilation system with "Monoblocks" – Kindergarten Chur

Author: Cristina Polo (SUPSI)

What is the solution?

Decentralized ventilation monoblocks were installed in the kindergartens and decentralized comfort ventilation systems with heat recovery were implemented in the new apartments. This enable operation with a high heat recovery factor that is adapted to the occupancy of the individual rooms. In summer, the devices of the kindergarten can also be used for night cooling. The ventilation decentral devices are installed in the bathrooms. In the apartments the ducts and vents are integrated in the roof. In the kindergarten the vents are in the walls of the bathrooms while the ducts are masked with a lowered ceiling.

Why does it work?

The impact on the building has been reduced to a minimum with the choice of using decentralized appliances that do not require invasive conduct. Small units were implemented to best achieve the thermal comfort regulation of the indoor spaces. Decentralized units allow air quality and a constant adjustment of the volume flow by the reduction of the average air volume and minimization of power consumption or by contrary with an automatic increase in air volume in the event of high pollutant emissions (es. a greater influx of people). Furthermore, especially in winter, the cold outside air contains very little moisture; the continuous exchange of air also ensures that excess moisture is removed. However, if significantly more air is exchanged than necessary, the air can become too dry and this monoblock units offers 2 possibilities to prevent this: the demand-oriented regulation of the amount of air by means of a CO_2 sensor or humidity recovery by means of an enthalpy exchanger.

Description of the context

The complex is divided into two structures. The residential building is characterized by the building height and the facade design as the main volume of the ensemble. The previous commercial building is deeper and due to its L-shaped geometry, forms an inner courtyard which, with its round arches and the widely projecting roof, has a high spatial quality. The specifications of the city of Chur as client were clear. The artistically valuable ensemble was to be preserved in its original expression. The earlier interventions should be dismantled, the change of use of the annex should be visible from the outside as a renewal but should be connected with the original design. And in addition: "Since Chur has been an energy town since 2011, it was necessary to incorporate the latest findings in energy and building physics into the renovation."

Pros and Cons

With the choice of using decentralized appliances that do not require invasive conduct, the impact on the building has been reduced to a minimum. The operation with a high heat recovery factor that is adapted to the occupancy of the individual rooms. In summer, the devices of the kindergarten can also be used for night cooling. Comfort ventilation not only ensures high air quality, but also the right level of room air humidity. This is based on the unacceptability of window ventilation in very cold weather and the associated low level of acceptance. Comfort mechanical ventilation systems avoid noise of the street and are therefore also playing an increasingly important role in the energy efficiency of the building and help to save heating costs. Fulfil for air hygiene and a good working or living spaces. Autonomous units of relatively low productivity but decentralized systems are more economical in operation. Each unit serves an individual area, which makes possible different temperature settings and different time schedules by zones.

Additional Information

Drexel & Weiss raumklima web page: https://www.drexel-weiss.at/produkte-und-loesungen/zubehoer/perfektes-raumklima/

This building was awarded with the Swiss Solar Prize in 2016.

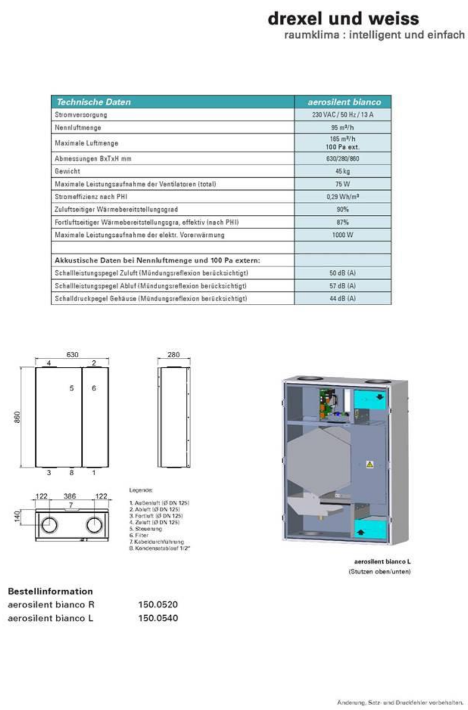
Link to Swiss solar prize data: https://www.solaragentur.ch/sites/default/files/g-16-09-22_dwhg_und_doppelkindergarten_chur_def.pdf

Link to energy-cluster.ch data: https://www.energie-cluster.ch/de/deklariert-ch/plusenergiegebaeude/schule-doppelkindergarten-chur-sanierung-(solarpreis-2016)-calandastrasse-50-7000-chur-9-3583.html

Best practice example

Kindergarten and apartments – https://www.hiberatlas.com/en/kindergarten-and-apartments-chur-switzerland--2-148.html

figure 42: Ventilation Kindergarten



drexel und weiss
raumklima : intelligent und einfach

Technische Daten	aerosilent bianco
Stromversorgung	230 VAC / 50 Hz / 13 A
Nennluftmenge	95 m³/h
Maximale Luftmenge	165 m³/h 100 Pa ext.
Abmessungen BxTxH mm	630/280/860
Gewicht	45 kg
Maximale Leistungsaufnahme der Ventilatoren (total)	75 W
Stromeffizienz nach PHI	0,29 Wh/m³
Zuluftseitiger Wärmebereitstellungsgrad	90%
Fortluftseitiger Wärmebereitstellungsgra, effektiv (nach PHI)	87%
Maximale Leistungsaufnahme der elektr. Vorerwärmung	1000 W
Akkustische Daten bei Nennluftmenge und 100 Pa extern:	
Schallleistungspegel Zuluft (Mündungsreflexion berücksichtigt)	50 dB (A)
Schallleistungspegel Abluf (Mündungsreflexion berücksichtigt)	57 dB (A)
Schalldruckpegel Gehäuse (Mündungsreflexion berücksichtigt)	44 dB (A)

Bestellinformation
aerosilent bianco R 150.0520
aerosilent bianco L 150.0540

Änderung, Satz- und Druckfehler vorbehalten.

figure 43: Ventilation Apartments

figure 44: Ventilation Plan first floor © HT-Plan

2.1.7 Room by room ventilation system

2.1.7.1 Push pull system – Bochumer Hütte

Author: Tobias Hatt (EIV)

What is the solution?

Push-Pull heat recovery systems are small ventilation units with reversing operation and regenerative heat exchanger in the outer wall. In addition to a wall opening with approx. Ø 160 mm, only one power connection is required. These electrical ventilation units change their direction every few minutes to return the heat stored in the heat exchanger when the air is blown into the room. For efficient and controlled air exchange, the units should be installed in pairs room by room so that one fan is switched to supply air mode whenever the adjacent fan is in exhaust air mode.

Why does it work?

Push-Pull heat recovery systems are suited for historic buildings because the conventional supply air distribution system (ductwork, supply air valve and silencers) can be omitted. The indoor air quality is improved, and the indoor air humidity is reduced due to the continuous air exchange. Nevertheless, high indoor noise emissions (35 dB(A)) occurs, when the system is working within the necessary airflow for good air quality. Because of the short air routing, the wind resistance and therefore the power consumption of the fans is lower compared to a central ventilation system. This leads to a low ventilation energy demand.

Description of the context:

If demand-controlled, manual ventilation can`t be guaranteed by the user and the installation of a central ventilation system is not possible, the installation of small ventilation units with reversing operation is an option.

Pros and Cons:

Push-Pull heat recovery systems are suited for historic buildings because the conventional supply air distribution system (ductwork, supply air valve and silencers) can be omitted. One disadvantage of the system is the too high indoor noise emissions (35 dB(A)) when the system is working within the necessary airflow for good air quality. Therefore, it is difficult to install such systems in quiet rooms. Other disadvantage is the visible exterior air in-and outlet. In historic buildings with a façade without intervention, those elements (min. 20x20 cm) can change the exterior appearance of the building, because there is minimum one element per room.

Type of Data Available:

Part of best practice Bochumer Huette

https://www.hiberatlas.com/smartedit/projects/92/Datenblatt_Bochumer Huette.pdf

Data sheet of best practice Bochumer Huette

https://www.hiberatlas.com/smartedit/projects/92/pendellüfter.pdf

Ecological and economical comparison of ventilation systems

Best practice example:

Bochumer Hütte – https://www.hiberatlas.com/de/kelchalm-bochumer-huette--2-48.html

2.1.7.2 Window integrated system - Climawin

Author: Jørgen Rose (SBI)

What is the solution?

ClimaWin. Room by room ventilation with heat recovery through intelligent windows.

Why does it work?

Climawin is a window solution with integrated ventilation, which means that there is no requirement for ductwork or penetration of the thermal envelope at all. The window is designed to improve comfort and energy efficiency by pre-warming the ventilation air between the two layers of glazing in the window. The window features integrated vents for controlled air intake, a frame with two layers of glazing, an automated blind, integrated electronics and wireless communication between room sensors and the windows, allowing for full control of the ventilation and daylighting levels in the building. During summer, the ventilation air can be taken directly from the outside by bypassing the "heat recovery" between the glasses, or it can operate in a mode, where air is circulated around the outside layer of the glazing removing heat from the incident solar radiation. The windows have 3 different settings; 1. In cold weather the system recovers and reuses the heat that is being lost (heat recovery) by preheating the ventilation air between the glasses in the window – this is of course most efficient for facades that receive sunlight, i.e., the sun increases the preheating. Cold air enters at the bottom of the window from the outside and the preheated air exits at the top to the indoors (see figure 1 left). 2. For hot weather or warm climates the system removes heat from the window by ventilating between the glasses. The warm air enters from the outside at the bottom and leaves to the outside at the top (see figure 1 middle). When necessary for occupant health and comfort (based on sensors as described below) the top part of the window can go into bypass mode, where outside air can go straight through the window (see figure 1 right). The window can operate in "external air curtain mode" and "bypass mode" simultaneously.

Description of the context:

Climawin can be used for situations where the existing windows can be replaced and where there are no restrictions on how the new windows look. The new windows will in turn reduce the transmission heat loss through windows and allow for energy efficient ventilation of the building.

Pros and Cons:

PROS: Low electricity consumption (most is covered by integrated PV) No space requirement for installation (no ducts, no unit) Little wiring necessary (only for indoor sensors). Efficiently maintains a good indoor air quality CONS: The openings towards the outside may carry sound/pollution to the inside. The windows are more expensive than regular windows

Type of data available:

CLIMAWIN was developed through an EU-project from October 2010 to September 2012 (https://cordis.europa.eu/project/id/262262) and therefore the solution is documented thoroughly in all details. The "CLIMAWIN – Technical Summary Report" from Aalborg University describes all the technical aspects including detailed measurements of the window performance under different circumstances.

Additional Information:

The CLIMAWIN window is not a possible solution if the windows in the building are protected or of heritage significance, however the solution does come in a variety of designs in order to better fit an existing building expression.

Technical Summary Report:
https://vbn.aau.dk/ws/portalfiles/portal/203815355/CLIMAWIN_Technical_Summary_Report.pdf

Homepage of manufacturer: https://www.enocean-alliance.org/product/rauh-climawin0/

Climawin YouTube channel: https://www.youtube.com/user/CLIMAWIN

https://www.hiberatlas.com/smartedit/projects/217/CLIMAWIN_Technical_Summary_Report.pdf

Heiselberg, P. (Ed.), Larsen, O. K., Liu, M., Zhang, C., Johra, H., Herold, L., Mendez, J., Cabral, J., Brito, N.,Zegowitz, A., & Heusler, I. (2013). CLIMAWIN: Technical Summary Report. Department of Civil Engineering,Aalborg University. DCE Technical reports, No. 160

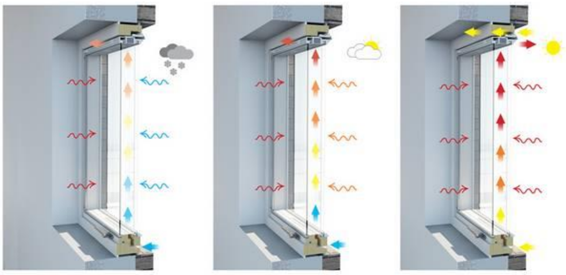


figure 45: Visualization of ventilation modes of the ventilation window. (a) winter (b) spring/autumn (c) summer (Source: ventilationsvinduet.dk).

figure 46: Three different designs of the window are available (source: ventilationsvinduet.dk)

2.1.8 Other Solutions

2.1.8.1 Ceiling through system – Farmhouse Trins

Author: Pavel Sevela (UIBK)

What is the solution?

A new ventilation system was installed. Each dwelling is supplied by one heat recovery unit. The flow regime is cascade ventilation.

Why does it work?

The air ducts were mounted within the ceilings, in order to avoid any visual impact of the historic interiors. The design of the supply air outlet was adapted to the historic wooden ceiling. An additional way to minimize the air ducts was the use of cascade ventilation. The air passes over from bedrooms and living rooms via the corridors to the bathrooms and kitchen. When the heating system was changed to floor heating, the originally negative pressure driven ventilation through leakages is substituted by mechanical ventilation to ensure the dehumidification and good air quality. The high heat recovery rate guarantees draft free supply air and the counterflow heat exchanger ensures high energy efficiency for heat recovery.

Pros and Cons:

The ductwork does not influence the visual aspect of the interiors. Individual unit for each dwelling has the advantage to get rid of any additional effort for fire protection. The highly efficient heat recovery assures high comfort and reduction of ventilation losses. The use of one unit per dwelling has the disadvantage of more duct work and more costs compared to a central system.

Description of the Context:

The building is located in Trins, a picturesque municipality in the district of Innsbruck-Land in the Austrian state of Tyrol on the Gschnitzbach. Since the early 1600 agriculture has been the most important economic sector for the 1300 parishioners but since commuter found out about the perfect situated hideout the municipality is in constant change.

As a result of the growing population in urban centre the population in Trins also increased. Living space is often being created through demolition and new building. The Mayrhof demonstrates an inverse trend and shows how a modern multigenerational home can be built in accordance with traditional architecture and innovative technological concepts. A special focus has been laid on the external appearance so that the design plays with its former functions and fits in the surrounding architecture.

Additional Information:

One of the internal elements with historic value was the rustic living room, that consisted of decorated wood paneling on the walls and ceiling. The wood paneling was dismounted and remounted. This way modern HVAC systems were implemented without damage of historic value. Another solution that was implemented is the downpipe venting valve. Normally this is done by a duct through the roof with problems of thermal bridges, air tightness and destruction of historical elements. This way is solved within the thermal envelope (see concept).

Best practice example:

Farmhouse Trins - https://www.hiberatlas.com/en/farm-house-trins--2-40.html

figure 47: Ventilation Unit, © Michael Flach

figure 48: Supply air opening © Michael Flach

2.1.8.2 Façade integrated ventilation system

Author: Alexander Rieser (UIBK), Arnulf Dinkel (ISE)

What is the solution?

The integration system consists in different prefabricated components. At first a two-layered insulation system made of mineral wool integrates air ducts in the façade. The first layer is composed of preformed insulation boards in which the air ducts can be easily clicked in. The air ducts are made of galvanized steel and the connection pieces of the ductwork are equipped with sealing rings to avoid leakages and enable an easy mounting process. Figure 1 and Figure 2 show the concept of the prefabricated insulation boards with the possibility to integrate ventilation ducts: Red are the exhaust air channels and blue the supply air channels. They all will be conducted to the roof where the ventilation units with the heat exchanger are located. The second main component of the system is the insulation frame for the installation of the windows in the insulation layer. This frame is slightly deeper since the air inlets and outlets have to be integrated between the existing wall and the window. To integrate the air inlets and outlets, prefabricated boxes have been designed and implemented in the same material as the installation frame.

Why does it work?

About the air inlets in the prefabricated box integrated in the new windows the supply and exhaust air will get into the apartments. The air ducts are made of galvanized steel and the connection pieces of the ductwork are equipped with sealing rings to avoid leakages and enable an easy mounting process. After placing the Air in- and outlets in the window frame elements the first layer of the insulation boards will be connected. Afterwards the ducts are installed, the remaining gaps are fulfilled with fitting elements of mineral wool. After the installation of the air ducts, a layer of mortar has been applied on the first insulation layer to equalize the surface and facilitate the sticking of the second insulation layer. After that, a second layer of insulation will be installed. The façade integrated air duct lead ventilation air to the ventilation systems with heat recovery place in the attic. As the attic is a non-heated zone, all air ducts in this room have been insulated with 80 mm mineral wool. Sound attenuators have been installed to avoid the noise of the fans to disturb the tenants.

Pros and Cons:

The solution is a flexible refurbishment system for different building geometries and a minimally invasive installation is possible. The mounting is quick and relatively simple. Furthermore, there is also an individual choice of technology and materials (fire protection). Due to the high level of part prefabrication, a high-quality standard is achieved, and a subsequent upgrade is possible. The unfamiliar handling of the system must be mentioned as a disadvantage. Since this type of ventilation is new, a certain period of adjustment must be planned for the craftsmen. However, after a period of acclimatisation, the craftsmen have become very familiar with the new system.

Additional Information:

article on the ISE Fraunhofer Institute website:

https://www.ise.fraunhofer.de/en/research-projects/retrokit-toolboxes.html

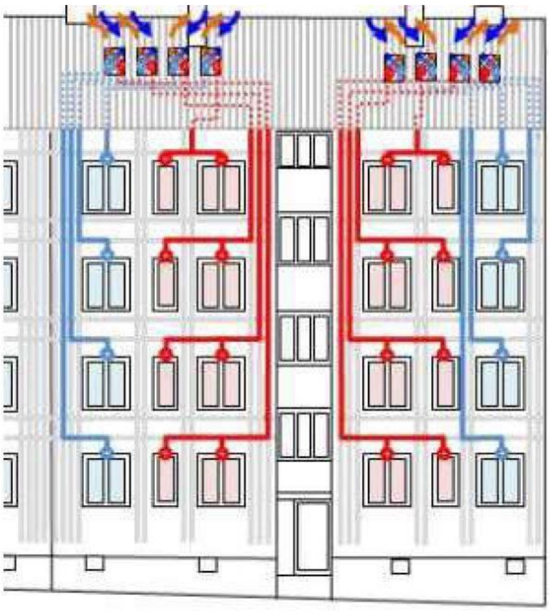


figure 49: © Fraunhofer Institut, Indicated location of the installation channels in the front of the house

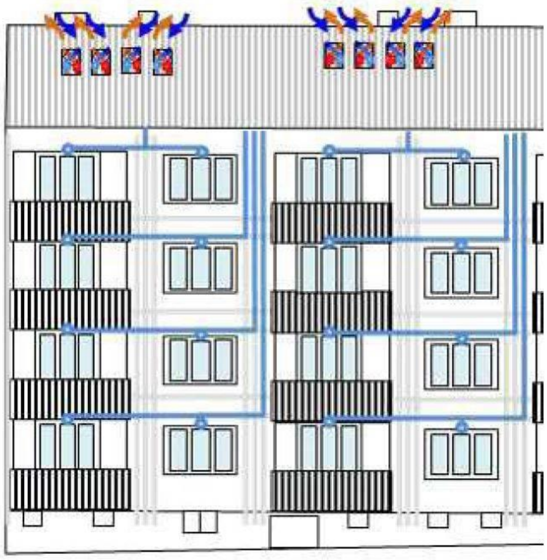


figure 50: © Fraunhofer Institut, Indicated location of the installation channels in the back of the house

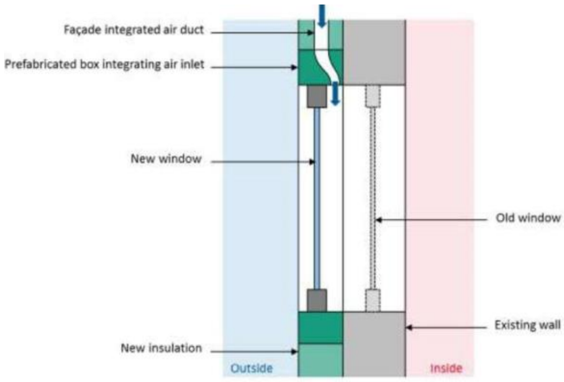


figure 51: © Fraunhofer Institut, Section of the installation frame of the windows and of the prefabricated box integrating the air inlet

figure 52: © Fraunhofer Institut, Prefabricated box integrating the air inlet before installation of the new window (left) and after (right)

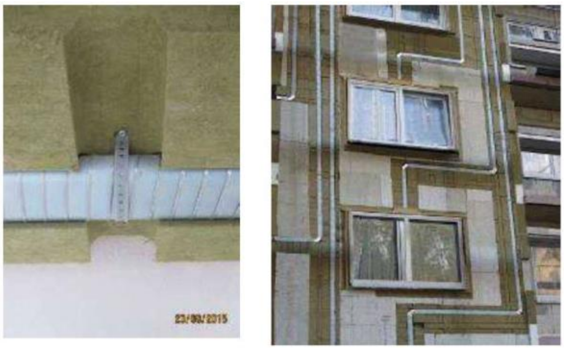


figure 53: © Fraunhofer Institut, additional fixing element and filling elements made of mineral wool to avoid remaining cavities in the insulation layer

figure 54: © Fraunhofer Institut, layer of mortar on the first insulation layer with integrated air ducts

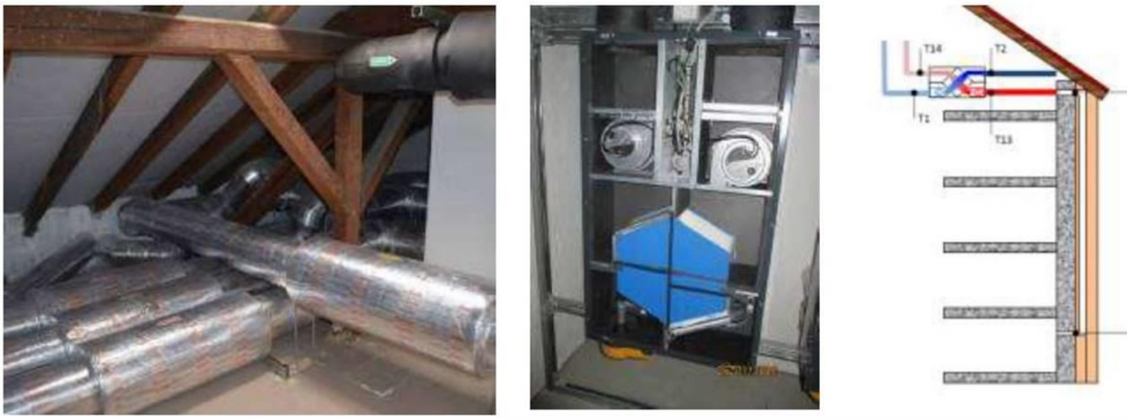


figure 55: © Fraunhofer Institut, sound attenuators and insulated air ducts in the attic (left) ventilations devices with heat recovery (centre) and position of the ventilation devices

2.1.8.3 Air supply via chimney / shaft

Author: Rainer Pfluger (UIBK)

What is the solution?

In the course of refurbishment, a change from single room stoves to modern heating systems (heat pumps etc.) or central heating systems is common. The chimney pipes of the individual stoves can be used for the vertical channel track of ventilation pipes.

Why does it work?

Because of the chimney an airtight vertical duct system is already in place. Therefore, no additional ceiling or exterior wall openings are necessary. The fire protection aspect is also fulfilled by the chimney. Since it functions like a separate fire compartment, the different floors are not connected to each other. The distribution is made from the shaft to the individual dwellings. However, the fire protection aspects must be fulfilled for the breakthroughs between the chimney and the apartments. By installing a controlled living space ventilation system, the air quality is significantly improved, and the relative humidity is regulated. In combination with a heat recovery system, the energy loss of window ventilation is minimized.

Pros and Cons:

The pros are that the vertical shaft already exists and no new ceiling- and wall openings have to be added. Another advantage is that the vertical shaft has normally a fire protection. The disadvantages are that pulling in ventilation ducts often turns out to be problematic because the bricked chimneys are neither precisely in line nor have smooth surfaces. Although the chimneys could be milled out, this work is associated with high costs. So called "Reliners" provide a remedy. These can be installed in chimney flues and placed against the chimney wall for lining. The AHRENS system consists of glass fibre reinforced thermosetting resin. On delivery it is available as a flexible, soft hose, which takes up little space when folded. Before lining the chimney has to be prepared accordingly. Other cons are the limited cross-sectional openings.

Type of Data Available:

The solution is practically tested and was implemented in the EU - project SINFONIA.

Additional Information:

Pfluger Rainer (2019) - Domestic ventilation in existing buildings. Highly efficient and cost-effective solutions for the modernisation of old buildings. Page 77

https://www.hiberatlas.com/smartedit/projects/146/AHRENS-Produktfolder-Ahrensflex.pdf

AHRENS productfolder (german)

2.1.9 Ventilation system without heat recovery

Author: Zeynep Durmus Arsan (IYTE), Gülden Gökçen (IYTE)

What is the solution?

Natural ventilation, air movement generated by air pressure difference between indoor and outdoor is controlled by openings on the building enclosure such as windows, doors and vents. Differing from air leakage, natural ventilation is the intentional passive transfer of air directed through openings of the façade and/or roof of the building. Determining the opening direction and total opening area is the subject of design for natural ventilation systems in order to obtain the best benefit from local and seasonal breezes.

Why does it work?

Natural ventilation systems have provided a traditional means of indoor climate control that has been used widely in historic buildings. The continued use of natural ventilation solutions minimizes interventions in historic building restorations and supports conservation of the heritage significance of buildings with minimum disturbance.

The manual control strategy based on long-term local experience of users is mostly enough to operate the building, yet at the same time, it hosts hygrothermal and biological risks. The manual control strategy can lead to thermal bridge occurrences in the case of unexpected climate changes and faulty control strategies by the building users. Even if natural ventilation is one of the key user-driven passive techniques, it may not always be guaranteed due to high levels of noise, concerns about security, air pollution, and adaptive reuse of buildings and changing urban density.

In colder climates, the utilization of natural ventilation systems may increase heat losses and energy costs, while in temperate climates it contributes to heat rejection, economic savings, and better thermal comfort. Therefore, the geographical location and local microclimate are the key factors influencing decision making for improving energy performance of historic buildings when considering natural ventilation.

In addition, with the aim of conservation of finite natural resources and minimizing environmental load, ventilation of historic buildings through local/seasonal winds provides the additional benefit of reducing a building's carbon footprint and pollutants to the atmosphere.

Is there any related publication?

- Gülhan, Ö., Natural ventilation design for historic libraries with CFD (Computational Fluid Dynamics) simulation, 2019.

- Coşkun, Turgay, Özcan Gülhan, Cem Doğan Şahin, Zeynep Durmuş Arsan, and Gülden Gökçen Akkurt. "The Effect of Spatial Interventions on Historic Buildings' Indoor Climate (Case Study: Tire Necip Paşa Library, Izmir-Turkey)." Energy Procedia 133 (2017): 358-66.
- Coşkun, Turgay, Cem D. Şahin, Özcan Gülhan, Zeynep D. Arsan, and Gülden G. Akkurt. "Chapter 1.11 - Ventilation Strategies for the Preventive Conservation of Manuscripts in the Necip Paşa Library, İzmir, Turkey." In Exergetic, Energetic and Environmental Dimensions, edited by Ibrahim Dincer, C. Ozgur Colpan and Onder Kizilkan, 179-92: Academic Press, 2018.
- Sahin, Cem Doğan, Turgay Coşkun, Zeynep Durmuş Arsan, and Gülden Gökçen Akkurt. "Investigation of Indoor Microclimate of Historic Libraries for Preventive Conservation of Manuscripts. Case Study: Tire Necip Paşa Library, İzmir-Turkey." Sustainable Cities and Society 30 (2017): 66-78.
- Coşkun, T., "Modelling of Indoor Climate of Historic Libraries for Preventive Conservation of Paper Based Collections", MSc. Thesis, Izmir Inst. Of Tech.-Turkey, 2016.

2.2 Heat Distribution

2.2.1 Overview of Solutions of heat distribution and production

Category	Measure	Best practice example	Author
Floor heating		Villa Castelli, Ansitz Kofler, Doragno Castle, Hof Neuhäusl	
Normal radiators		Rainhof, Kohlesilo, Magnusstraße	
Radiators with visible piping	Radiators with visible piping	General description	Jørgen Rose (SBI) Alexander Rieser (UIBK)
Air heating	Air heating	General description	Alexander Rieser (UIBK)
Infrared heating panels	Infrared heating panels	General description	Alexander Rieser (UIBK)
Wooden stoves	Wooden stoves	General description and several Best practice linked	Alexandra Troi (EURAC)
Heat pumps	Heat pump	Villa Castelli	Alexandra Troi (EURAC)
		Doragno Castel	Cristina Polo López (SUPSI)
		Necippasa Library	Gülden Gökcen (IYTE), Zeynep Durmus Arsan (IYTE)
		Glaserhaus	Cristina Polo López (SUPSI)
		Single family house Gstaad	Cristina Polo López (SUPSI)
Pellet Boiler	Pellet boiler	Ansitz Kofler	Alexandra Troi (EURAC)
		Magnusstraße	Cristina Polo López (SUPSI)
Wood chip boiler	Wood chip boiler	Platzbon	Alexandra Troi (EURAC)
Cogeneration plan	Cogeneration plant	Kindergarten Chur	Cristina Polo López (SUPSI)
		Feldbergstraße	Cristina Polo López (SUPSI)
		Single family house, Bern	Cristina Polo López (SUPSI)
		St. Franziskus Church	Cristina Polo López (SUPSI)
District heating	District heating	Solar Silo	Cristina Polo López (SUPSI)

2.2.2 Surface heating

2.2.2.1 Floor heating

See section 2.3.2.1for more examples of floor heating → Pellet boiler– Ansitz Kofler

2.2.3 Radiators

2.2.3.1 Normal Radiators

See sections 2.3.2, 2.3.5, and **Error! Reference source not found.** for more examples with normal radiators

2.2.3.2 Radiators with visible piping

Author: Jørgen Rose (SBI), Alexander Rieser (UIBK)

What is the solution?

The solution includes the visible installation of heating pipes. Especially in combination with internal insulation, a "surface-mounted installation" is often a useful solution. Internal insulation reduces the temperature in the existing wall, in some cases considerably. This increases the heat loss of the heating pipe significantly. In special cases, frost damage cannot be excluded (e.g., failure of the pump etc.). For this reason, the heating pipe is installed on the warm side of the internal insulation, the room inside.

Why does it work?

Due to the room-side installation of the heating pipe, the energy losses in the distribution are virtually zero, as the losses are directly transferred to the room. Thanks to the visible installation, a large part of the chiselling work is avoided, and reversibility is possible.

Pros and Cons:

The advantages of this solution are both high energy efficiency and reversibility. There is also a financial incentive thanks to the elimination of the need for chiselling work. However, the increased visual requirements can bring this positive effect to a standstill. A further advantage of the visible piping is, that any damage to the pipes (which will inevitably occur over the years due to corrosion etc.), will most likely be noticed straight away without water damages to constructions etc. Repairs and or replacement can be carried out relatively cheap and with no extra work included. The main disadvantage is the appearance. Especially in Austria it is not typical to install heating pipes above the plaster. For this reason, high demands must be placed on the optics and the materials used. The architectural concept must be in line with the technical solution. In Denmark, visible piping is very common, especially in older buildings, since it is thought that the advantages mentioned above outweigh the disadvantage of appearance. If there is a wish to hide the radiator and piping, a radiator cover can be custom made to fit any installation (see example below).

figure 56: Visible piping to/from radiator in apartment (from Denmark), ©Jørgen Rose (SBI)

figure 57: Radiator and visible piping from the ATLAS case Ryesgade 30, ©Jørgen Rose (SBI)

figure 58: Example showing how radiator and piping can be hidden, ©mainlifestyle.dk

figure 59: visible piping in a school in Austria, ©UIBK

figure 60: Gap between the wall and the radiators for the internal insulation, ©UIBK

figure 61: after completion of work, ©UIBK

2.2.4 Air heating

Author: Rainer Pfluger (UIBK)

What is the solution?

With air heating, a distinction is made between fresh air heating (without circulating air) and air heating with recirculation. With fresh air heating, only the outside air is used, which is fed into the building for ventilation purposes. The fresh air supply is relatively low at approx. 30 m³/h per person or an air exchange rate of approx. 0.4 1/h and should not be increased for heating purposes because otherwise the air becomes too dry. The air is heated by means of a heating register (can be supplied with any heat source), the heat is distributed via the already existing supply air duct network of the ventilation system. This eliminates the need for separate heating pipes with corresponding negative effects (slits knocking etc.) in the building. This system is usually combined with an upstream heat recovery system. Due to the limited air volume, the maximum heat load that can be supplied for fresh air heating is limited to approx. 10 W/m². However, if you increase the temperature supply, this can lead to smouldering of dust (Pyrolysis). If you increase the air supply instead, this could lead to lower humidity. Often historical buildings have higher heating loads, even in the case of ambitious thermal renovation. In this case, also recirculated air must be used. Unfortunately, this increases the necessary ventilation duct cross-section and the air velocities (noise!). This increased air circulation has a positive effect on the equalization of the room air temperatures in the building, e.g., if there is a single stove in a room.

Why does it work?
If a high-quality refurbishment is carried out in combination with comfort ventilation, it can make sense to consider heating via ventilation. The saving of radiators or panel heating systems and their distribution lines can be a decisive advantage, especially in historical buildings. Due to the low possible specific heating load with fresh air heating, it must be evaluated whether heating via air is possible. If larger thermal bridges are present in some rooms, the system will quickly reach its limits. A combination with a water-guided distribution system would be a remedy in terms of the capacity limit and the room-specific heating, but again the installations for the secondary system would be added. If a ventilation system based on the principle of extended cascade is planned, this system cannot be used either, because the high supply air temperatures would overheat the bedrooms.

Pros and Cons:
The main advantage of air heating is the absence of additional installations for heat distribution and the resulting less intervention in the building fabric. Direct heating without intermediate storage is also a benefit of the system. A disadvantage is the limited controllability of the respective rooms and the limited heating load of max. 10 W / m² net floor space. Due to the necessity of the heating power, the air exchange rate cannot be adapted to the number of people.

Is there any related publication?
Komfortlüftungsinfo Nr. 28 – Luftheizung im Passivhaus (2014) (Add link below directly to the name)

Additional Information:
https://www.hiberatlas.com/smartedit/projects/171/Luftheizung.pdf

2.2.5 Infrared heating panels

Author: Rainer Pfluger (UIBK)

What is the solution?
Infrared heaters are flat resistance elements, are easy and quick to install and require only an electrical connection. They can be installed as panels or pictures in the room. The heat is emitted to a large extent by long-wave radiation and to a smaller extent by thermal convection. The human being perceives as room temperature the average value of radiation temperature and air temperature; therefore, the comfort temperature can be reached already with slightly lower air temperatures. Basically, it should be noted that every infrared heating system is basically an electric heating system and that other heating systems also emit a similarly high proportion of radiant heat, in the end the room air is also heated indirectly by convection. These elements actually only bring energy efficiency advantages when rooms are heated only temporarily.

Why does it work?
The installation of infrared panels can be useful in historical buildings due to the low level of structural intervention and for temporary use of rooms. Especially in the case of historically valuable interiors, it can happen that major interventions in the building fabric are not possible and therefore the installation of a conventional heating system is not feasible. If the room is only used temporarily, neither the entire walls nor the room air need to be heated. If the people in the room are in direct visual contact with the panel, comfort is quickly achieved. However, if the surfaces of external walls are very cold, discomfort can be caused by the large radiation differences. As with radiators, the visual compatibility of such infrared panels with the historical interior must be reconciled.

Pros and Cons:
The Pros of the solution are Low investment costs, Quick and easy installation, low maintenance costs and a high heat radiation rate for heat emission. But this solution also has disadvantages like higher operating costs due to the use of electricity. A separate system for domestic hot water is required. In winter, the amount of electricity from oil, coal and gas power plants increases too large radiation differences (cold wall) are perceived as unpleasant.

Is there any related publication?
Ratgeber Infrarotheizung, Energieinstitut Vorarlberg (2017)

Additional Information:
https://www.hiberatlas.com/smartedit/projects/166/Ratgeber-Infrarotheizung_low_res.pdf

Infrared heating guide - Energieinstitut Vorarlberg (German)

2.2.6 Wooden stoves

Author: Alexandra Troi (EURAC)

What is the solution?

Wooden stoves – be it the tiled version, the plastered "Stubenofen" or the "open fire" – are usually placed in the living area and can either serve as an additional heat source to any other central heating system, or they can themselves be the heat generator for a centralised heating system. In the latter case a heat exchanger in the stove allows to distribute the energy with water tubes to the other rooms.

The stoves are usually fired once a day and provide the heat slowly to the room over a period of 12 to 24 hours.

Why does it work?

In many regions wooden stoves have a long tradition. Both keeping the stove itself or adapting the traditional system to an innovative whole-house-heating are interesting solutions from conservation point of view.

In order to allow for domestic hot water production in summer without firing the stove, whole-house-heating with wooden stoves is often combined with a solar thermal system dimensioned to summer needs.

Pros and Cons:

Besides the conservation aspects mentioned above, the keeping alive a heating system with long tradition, wood is a renewable energy source, which in many contexts is available locally or even from own sources and allows for CO_2 neutral heating.

Air-dried wood stored for more than 2 years has a calorific value of about 4 kWh per kg, i.e. 2.5 kg of wood replace approx. one litre of heating oil. The water content and the type of wood are decisive for the quality of the wood. Hardwood has a higher calorific has a higher calorific value per per cubic metre. 5 to 6 cubic metres hardwood (deciduous wood such as beech or oak) or 7 to 8 cubic metres of softwood (coniferous wood such as spruce or fir) replace about 1000 litres of heating oil.

Depending on the heating demand of the building the wooden stove has to be fired more or less often: in a refurbished building once a day will be fine, unrefurbished buildings need at least to be fired twice. In any case the process of firing is a manual work to be taken over by the users.

Important to take into account: When operating single-room fireplaces (wood-burning stove, tiled stove, pellet stove or similar) within the airtight shell of the house, care must be taken to ensure that no flue gas can enter the living space through negative pressure. If the stove is installed in the living/dining room or if there is a living room ventilation system, a kitchen air extractor and an airtight construction, it is advisable to operate room-air-independent stoves with their own air supply.

Additional Information:

Energie Tirol – Stückholz. Die richtige Heizung für mein Haus
https://www.energie-tirol.at/wissen/energie-bibliothek/bibliothek-detail/stueckholz/

Regular workshops are organised by Energieinstitut Vorarlsberg
https://www.energieinstitut.at/events/der-kachelofen-als-ganzhausheizung-7/

Best practice example:

Ansitz Kofler – original tiled oven in the living room repaired and equipped with room-air independent air supply
https://www.hiberatlas.com/en/ansitz-kofler--2-25.html

Platzbon – original Stubenofen repaired and still in use as additional heat source
https://www.hiberatlas.com/en/platzbon--2-118.html

Farm house Trins - https://www.hiberatlas.com/en/farm-house-trins--2-40.html

Timber-framed house in Alsace – original tiled oven in the living room repaired and equipped with room-air independent air supply https://www.hiberatlas.com/en/timber-framed-house-in-alsace-france--2-45.html

Haus Breuer Tschagguns - tiled storage stove as main heating system, which is supported by a thermal solar system https://www.hiberatlas.com/en/house-breuer-tschagguns--2-109.html

figure 62: Original tiled stove repaired at farmhouse in Trins (luft) and Alsace (right)

figure 63: Original tiled stove (left) and repaired (right) at Platzbon (Italy)

figure 64: Haus Breuer Tschagguns - tiled storage stove as main heating system, which is supported by a thermal solar system

2.3 Heating Production

2.3.1 Heat Pumps

2.3.1.1 Heat pump – Villa Castelli

Author: Alexandra Troi (EURAC)

What is the solution?

A heat pump with a geothermal source (3 probes, 80 m deep each) provides heating and cooling as well as domestic hot water. A storage tank allows for buffering demand peaks and integrating waste heat from the kitchen stove. The electricity for the heat pump is generated to a major degree by the PV modules integrated into the roof.

This is possible since the heating demand has first been reduced considerably through the insulation of the whole envelope, a ventilation system with heat recovery and the passive use of solar energy through windows (covering 30% of the demand)

Why does it work?

The heat pump itself with the geothermal system does affect neither the building materials nor aesthetics, as they are not visible from the outside.

The PV-system is integrated in the roofing and not visible from outside. Before the heritage authorities approved the PV system, several prototypes were developed for a roof-integrated and preferably invisible installation. The heritage authorities opted for the double-curled aluminum sheet covering of the roof - which is quite common for buildings of this age in a similar way - with integrated mono-crystalline PV modules, folded plates with integrated photovoltaic cells, of about 11 kWp. A sailboat outfitter supplied the extra-thin PV modules.

Description of the context:

Villa Castelli is a listed building from the 19th century located at the riverside of Lake Como (Italy). The owners set the ambitious goal of renovating the Villa, which had belonged to the family for about 140 years, to the lowest possible energy demand while maintaining the original use of the rooms and the external appearance. The renovation achieved a 90% energy demand reduction and a significant increase in comfort, demonstrating that also a listed building can become nZEB.

Pros and Cons:

Heat pump with a geothermal plant: A ground source heat pump (GSHP) as here in Villa Castelli can be used as source of low CO_2, low enthalpy energy to provide both cooling and heating to buildings. The geothermal probes supply fairly constant temperature also during winter and suffer thus less from the COP (coefficient of performance) getting worse on cold winter days than air source heat pumps. The effort to place the probes is however a considerable one, and should always be preceded by geological assessment and examination of in-situ the thermal properties of the ground.

Radiating floor: The radiant floor heating system can use low temperature heat – therefore the heat pump can work with a low temperature difference and respectively higher COP. Furthermore radiant floor heating systems provide uniform heating and thus greater comfort. The original floor, however, needs to be demolished for the installation of this technology. In the specific case of Villa Castelli this was not a drawback, since most of the ceilings had anyway to reinforced for seismic security reasons.

Is there any related publication?

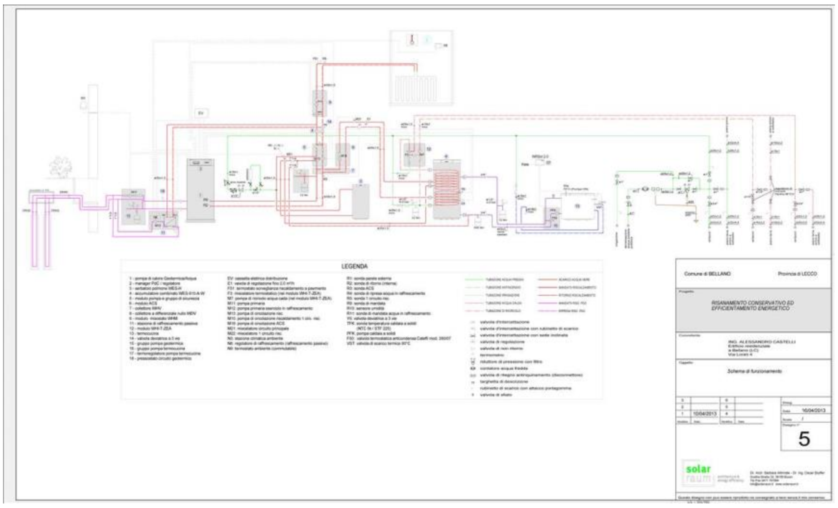
P. Penna, O. Stuffer, A. Troi, V. Carì (2019) “Villa Castelli - Transformation of Historical Building into Nearly Zero Energy Building”, *Applied Mechanics and Materials*, vol. 887, pp 148-155.

Troi, O. Stuffer, V. Carì (2018) "Villa Castelli: Sanierung mit Innendämmung auf nZEBStandard. Nutzerüber-legungen zur Nachhaltigkeit", *Denkmal und Energie*, pp 161-175.

V. Carì, O. Stuffer, E. Lucchi (2014) “Risanamento conservativo sulle sponde del lago”, *Casa&Clima* n°51, pp 44-52.

Best practice example:

Villa Castelli – https://www.hiberatlas.com/de/villa-castelli--2-23.html


LEGENDA
Comune di BELLANO
Provincia di LECCO
RISANAMENTO CONSERVATIVO ED EFFICIENTAMENTO ENERGETICO
Schema di funzionamento
5
solar

2.3.1.2 Heat pump – Doragno Castle

Author: Cristina Polo (SUPSI)

What is the solution?

The new heating system consists of a reversible air-water heat pump powered by the photovoltaic system on the roof. Distribution is made both from radiating floors and fans. The system consists in a Daikin air-water heat pump, Altherma (emrq16) with low consumption and reduced CO2 emissions as an outdoor unit with an integrated heat recovery system and the indoor unit is the Daikin Altherma Split high temperature (EKRBRD-AV1). The raised floor (Floortech patent, deltaZERO concept), dry laid and demountable, thus giving a high future flexibility, is composed of two functional layers, one load bearing and the other thermally active: the lower layer, thermo-active, consists of radiant panels of the reversible heating and cooling system. High efficiency heat recovery units for homes with double flow, HR WALL Series by S&P, were also used.

Why does it work?

Being a new system, which integrates into the newly constructed building, it does not compromise the existing castle building, there are no compatibility and conservation problems. This private residence building, a historic not-listed building in Ticino, achieved a NZEB target using also solar renewables energy. In this project the architects have re-created the shape of the castle using modern materials considering todays comfort standards and it was chosen to preserve only the medieval walls of the ancient building. New living spaces and with a new internal structure to preserve only the shell of the building joining old and new have allowed to use new and innovative technical solutions.

Description of the context:

The project aims to restore the soul of the castle, by demolishing the works made in the 20th century and using new glazed surfaces. The restoration project completes what remained of the walls and tower of the Castle to return the original shape using internal insulation, so that in the surrounding landscape the building of the past once again became legible

Pros and Cons:

The thermal energy produced that is used to heat, cool, and produce domestic hot water becoming completely free and renewable. The electric reversible air-water heat pump powered by the solar BIPV system on the roof is used for thermal and air conditioning. Heat pumps represent the most efficient alternative to fuel, oil, and electric systems in regard to both heating and cooling. Pumping the heat uses less electricity as compared to when electricity is solely used as a means to convert it. During the summers, the cycle can be reversed and the unit acts like an air conditioner. Heat pumps prices are usually high, taking into account the installation of the entire system. These running costs are prone to be lower especially if powered by solar renewable sources. The distribution of heat and cold is carried out both from underfloor heating and fans under a raised floor laid dry and removable, this factor gives a lot of interior flexibility in the arrangement of partitions and walls. Radiant floors allow major design freedom, uniform heating temperatures conditioning only the living space (important in double height spaces or with high heights) improving user comfort and do not require maintenance.

Type of Data Available:

Several information is published regarding this project and is available in the in the architect's web page and projects documentation, DeltaZero SA: https://www.deltazero.net/en/what-2/6-icon-projects/doragno-castle/

Maria Mazza & Stefano De Angelis Effrem, deltaZERO Architettura, Il Castello di Doragno, Restauro e sostenibilità energetica, Archi magazine, Rivista svizzera di architettura, ingegneria e urbanistica. August 004, 2020. Pages: 26-29. Publisher: espazium. ISSN 1422-5417, https://www.espazium.ch/it/archi4-20_castello

Solar web platform www.solarchitecture.ch: https://solarchitecture.ch/in-a-nutshell-doragno-castle/

Is there any related publication?

https://www.deltazero.net/wp-content/uploads/2018/09/20-Intervenire-sugli-edifici-storici.pdf

Best practice example:

Doragno Castle – https://www.hiberatlas.com/de/doragno-castle-rovio-ticino-switzerland--2-28.html

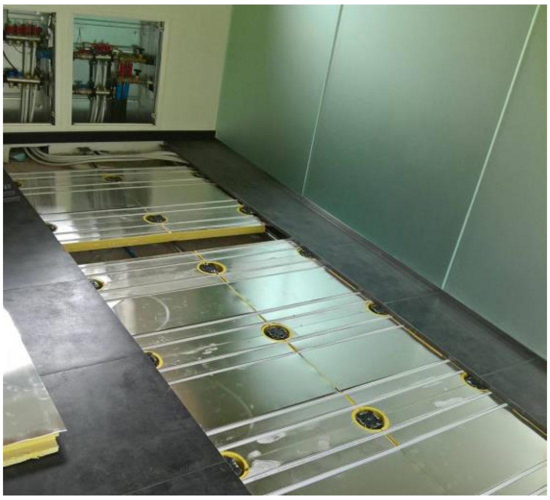
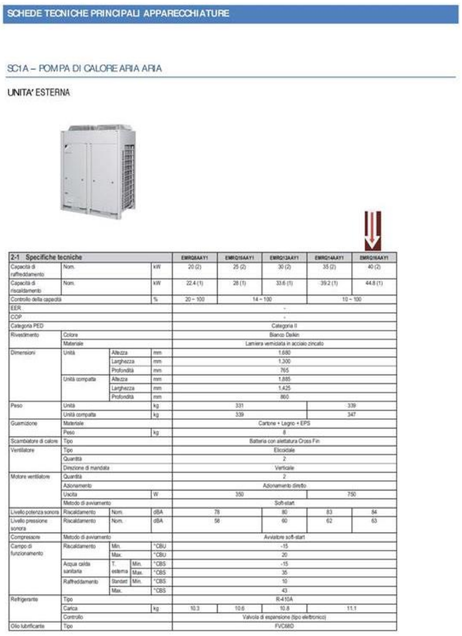


figure 65: Radiating floors © DeltaZero

figure 66: Fans in the roof © L. Carugo



SCHEDE TECNICHE PRINCIPALI APPARECCHIATURE

SC1A – POMPA DI CALORE ARIA ARIA

UNITA' ESTERNA

figure 67: Data sheet of the reversible heat pump, Daikin Altherma outdoor unit. Source: © Daikin

CAISSONS DOUBLE FLUX CONTRE-COURANT HAUT RENDEMENT

Série HR MURAL

figure 68: Heat recovery unit, HR WALL Series data sheet. Source: © S&P

2.3.1.3 Heat pump – Necippasa Library

Author: Gülden Gökçen (IYTE)

What is the solution?

Production: Ductless split type air-to-air heat pump system. The ductless split type heat pump system is made up of two main parts: the indoor air handling unit and the outdoor compressor/condenser unit. The two units are connected via a refrigerant line rather than a complicated duct system.

Distribution. The indoor unit of the heat pump houses a coil and a fan. The fan circulates indoor air over the coil. Depending on the heating or cooling mode, the air is heated or cooled while passing through the coil. The indoor unit sends the conditioned air directly into the space. The system does not need any ducts to condition and distribute the air.

Why does it work?

Compatibility with conservation – Heat Pump:

Heat pump consists of an indoor and an outdoor unit which both are visible. The outdoor unit is not attached to the building and is located in the backyard surrounded by fences

figure 69: Heat pump outdoor unit © IYTE

figure 70: Refrigerant line (covered) between indoor and outdoor units of heat pump © IYTE

The only wall penetration is the refrigerant line that connects indoor and outdoor units as shown in fig. 48. The piping is not visible from inside since it is at the back of the indoor unit (fig. 49) while a cover is used to hide it on the exterior wall of the library.

Compatibility with conservation - distribution:

The split type air-to-air heat pump system does not require installation of an air/water distribution system and ductwork. The indoor unit distributes the conditioned air directly into the space by the fan.

figure 71: Heat pump – indoor unit © IYTE

Energy efficiency – The library originally did not have any HVAC system. During restoration work in 2015-2017, a split type air-to-air heat pump system with a precise temperature and humidity control, was installed. Therefore, energy consumption of the library is increased while microclimatic conditions for manuscripts kept under control. On the other hand, R410A was chosen as working fluid of the heat pump that allows for higher SEER ratings by reducing energy consumption. Furthermore, the overall impact on global warming is low due to reduced greenhouse gas emissions and R410A does not contribute to ozone depletion.

Pros and Cons:

PROS: The heat pump system can control indoor temperature and humidity precisely. Its indoor unit does not need a large space while noise sourced by outdoor unit is decreased by not attaching it to the building. Since the system does not need any ducts for producing and distributing the air, the intervention to the building is minimum.

CONS: The performance of air-to-air heat pumps is affected by outdoor climatic conditions. Energy loss can possibly occur during transportation of working fluid between indoor and outdoor units. Since indoor unit is a singular unit with no other distribution elements, uniform indoor microclimatic conditions could not be obtained.

Type of Data Available:

Three HOBO U12 dataloggers are installed at the different locations in the library to monitor temperature and relative humidity values with 10-minute intervals. The microclimate data prior to restoration is also available.

Is there any related publication?

Gülhan, Ö., Natural ventilation design for historic libraries with CFD (Computational Fluid Dynamics) simulation, 2019.

Coşkun, Turgay, Özcan Gülhan, Cem Doğan Şahin, Zeynep Durmuş Arsan, and Gülden Gökçen Akkurt. "The Effect of Spatial Interventions on Historic Buildings' Indoor Climate (Case Study: Tire Necip Paşa Library, Izmir-Turkey)." *Energy Procedia* 133 (2017): 358-66.

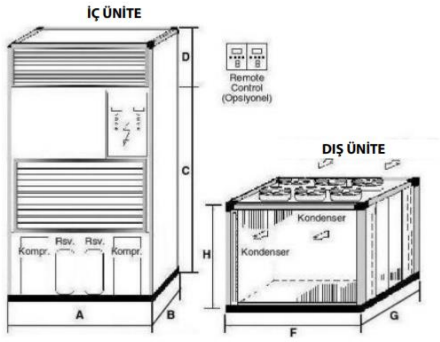
Coşkun, Turgay, Cem D. Şahin, Özcan Gülhan, Zeynep D. Arsan, and Gülden G. Akkurt. "Chapter 1.11 - Ventilation Strategies for the Preventive Conservation of Manuscripts in the Necip Paşa Library, İzmir, Turkey." In *Exergetic, Energetic and Environmental Dimensions*, edited by Ibrahim Dincer, C. Ozgur Colpan and Onder Kizilkan, 179-92: Academic Press, 2018.

Sahin, Cem Doğan, Turgay Coşkun, Zeynep Durmuş Arsan, and Gülden Gökçen Akkurt. "Investigation of Indoor Microclimate of Historic Libraries for Preventive Conservation of Manuscripts. Case Study: Tire Necip Paşa Library, İzmir-Turkey." *Sustainable Cities and Society* 30 (2017): 66-78.

Coşkun, T., "Modelling of Indoor Climate of Historic Libraries for Preventive Conservation of Paper Based Collections", MSc. Thesis, Izmir Inst. Of Tech.-Turkey, 2016.

Best practice example:

Necippasa Library - https://www.hiberatlas.com/de/necip-pasa-library--2-269.html



Teknik Özellikler

Model	Soğutma Kapasitesi (kW)	Hava Debisi (m³/h)	Buharlı Tip Nemlen-dirici (kg/h)	Elektrik Isıtıcı (kW)	Ölçüler								
					A (mm)	B (mm)	C (mm)	D (mm)	G (mm)	F (mm)	H (mm)	P. input (Yaz-kW)	P. input (Kış-kW)
HS- 6.1 LS	6	1230	4	3	800	650	1300	300	350	750	830	6,38	7,61
HS- 8.1 LS	8	1580	4	3	800	650	1300	300	350	750	930	6,92	7,61
HS- 9.1 LS	9	1920	4	3	800	650	1400	3300	400	800	930	7,23	7,61
HS- 11.1 LS	11	2200	4	5	900	700	1500	300	400	900	1030	7,77	9,81
HS- 13.1 LS	14	2800	4	5	900	750	1600	300	400	1000	1030	9,02	10,27
HS- 15.1 LS	16	3200	8	8	1000	800	1700	300	400	1200	1030	12,91	16,62
HS- 18.1 LS	18	3700	8	8	1000	850	1800	300	450	1280	1080	14,12	17,02
HS- 21.1 LS	21	4300	8	10	1000	850	1800	400	450	1280	1080	15,12	19,33
HS- 23.1 LS	23	4700	8	10	1100	900	1900	400	500	1400	1080	15,80	19,53
HS- 26.1 LS	26	5400	8	15	1400	950	2000	400	500	1480	1080	17,30	25,23
HS- 31.1 LS	31	6300	15	15	1500	950	2100	450	1650	1100	1050	25,53	32,34
HS- 34.1 LS	34	7000	15	15	1500	1000	2100	450	1750	1240	1100	26,55	32,34
HS- 39.1 LS	39	8000	15	15	1600	1000	2100	500	1750	1240	1100	29,26	33,76
HS- 46.1 LS	46	9400	15	20	1700	1100	2200	500	1900	1460	1100	31,46	39,16
HS- 60.1 LS	60	12250	15	25	1900	1100	2300	500	1700	1600	1500	36,53	45,58

fig. 50. Specifications of air-to-air heat pump © IMAS Klima

2.3.1.4 Heat pump – Glaserhaus residential building, Affoltern im Emmental (Switzerland)

Author: Cristina Polo (SUPSI)

What is the solution?

The heat is generated using two geothermal boreholes made of polyethylene pipes which are laid in the ground with a deep bore hole. The heat for the heating system is generated with a water heat pump. The hot water preparation is carried out by a 1'000l combi storage system. The heat pump, the heating group, the free-cooling function and the DHW preparation are regulated or controlled by the projected regulation. The heat load occurring in summer is extracted from the building with the floor heating pipes and released into the ground via the geothermal probe. For room heating in winter and cooling in summer, a separately controllable and shut-off underfloor heating group is provided on the ground floor, 1st floor and second floor. The heat is emitted or extracted with a conventional underfloor heating system, inserted in the underlay floor. The individual room regulation is ensured by electric room sensors. Rooms with minimum room heights are heated with radiators, the wet areas are additionally heated with a towel radiator. The heat distribution takes place via a radiator heating group which can be separately regulated and switched off from the heat generator or storage tank. A Step oven under preservation order, with built-in heating register is also operated via the radiator heating group. The individual room regulation is ensured by thermostatic valves.

Why does it work?

The only element of the heating system that touches on the protection of historical monuments is the step oven on the ground floor, whose model was chosen according to the requirements of historical monuments.

Description of the context:

This 251-year-old wooden traditional house was largely uninhabited for years. The aim of the refurbishment project in 2015 of a rural building Glaserhaus from the 1700s in Affoltern im Emmental were to repair the existing unused traditional building and back to live the original condition. This restoration is connected with the aim of preserving the overall appearance of the building, repairing the roof, facades, and surroundings, and carefully restoring the prestigious south façade. From a technical point of view, the building is solidly stabilised and energetically brought up to the latest standards. The only element of the heating system that touches on the protection of historical monuments is the step oven on the ground floor, whose model was chosen according to the requirements of historical monuments.

Pros and Cons:

It is a modern plant with high-performance machinery but with a proven principle, so the construction did not pose any particular problems. The use of geothermal energy allows reduced operating costs thanks to ideal working temperatures, but its realization has a greater impact due to the execution of geothermal probes. Geothermal power can be generated throughout the year on twenty-four-hour basis as it is not much dependent on ambient temperature and weather conditions exploitation low enthalpy geothermal resources for heating and cooling with lower environmental impacts. The energy refurbishment concept considers full renewable energies (RES) implementation: groundwater heat pump (GWHP), geothermal boreholes and DHW system is integrated in the heating system together with an integrated solar BIPV system.

Type of data available:

The energy need for the HP is an average of 6500 kWh/a, which are entirely covered by the PV production (90’493 kWh/a) a BIPV (building integrated photovoltaic) solar plant carefully integrated in the pitched roof. The building after energy retrofit reach the Minergie P standard for plus energy buildings. Minergie-P Swiss standard designates buildings with very low energy consumption and meets the highest demands in terms of quality, comfort and energy. Minergie is a voluntary building standard used in Switzerland which allows for a rational energy use and the use of renewable energy while at the same time also allows for improved living quality and low environmental pollution. After the retrofit the energy demand of the building decreased by 87% after the intervention to 26,200 kWh / a and the 89 kWp photovoltaic BIPV system generates 90,500 kWh / a. with covering of total energy requirements of about 345% as Plus Energy Building (PlusEnergieBau, PEB) for the energy transition.

The project PlusEnergieBau renovation Anliker, Affoltern iE was awarded with the Swiss Solar and the European Solar Prize in 2016.

Swiss solar prize data link:

https://www.solaragentur.ch/sites/default/files/g-16-09-21_peb_sanierung_anliker_affoltern_def.pdf

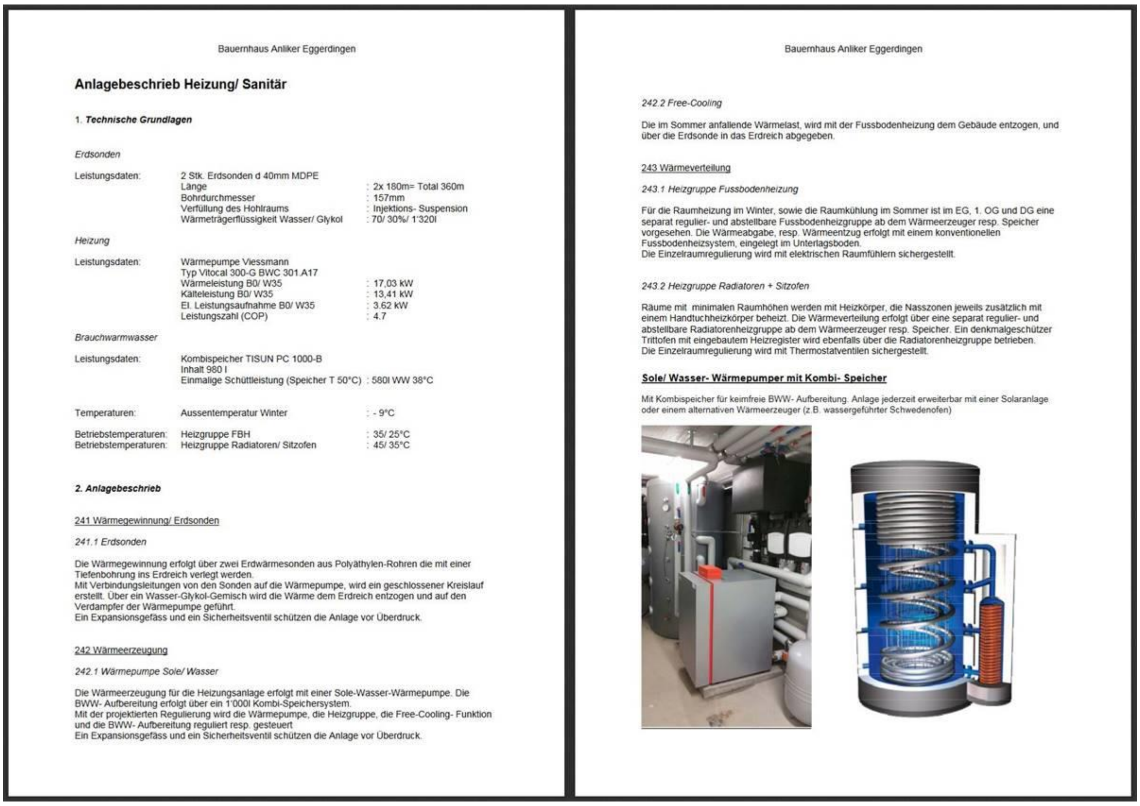
Monitoring data: https://www.energie-cluster.ch/de/deklariert-ch/plusenergiegebaeude/efh-anliker-sanierung-eggerdingen-7-3416-affoltern-im-emmental-9-3495.html

Best practice example:

Glaserhaus – https://www.hiberatlas.com/de/glaserhaus-affoltern-im-emmental-switzerland--2-234.html

figure 72: Old tiled stove © C. Anliker

figure 73: Building second floor during refurbishment works. © C. Anliker



Bauernhaus Anliker Eggerdingen

Anlagebeschrieb Heizung/ Sanitär

1. ***Technische Grundlagen***

Erdsonden

Leistungsdaten:	2 Stk. Erdsonden d 40mm MDPE	
	Länge	: 2x 180m= Total 360m
	Bohrdurchmesser	: 157mm
	Verfüllung des Hohlraums	: Injektions- Suspension
	Wärmeträgerflüssigkeit Wasser/ Glykol	: 70/ 30%/ 1'320l

Heizung

Leistungsdaten:	Wärmepumpe Viessmann	
	Typ Vitocal 300-G BWC 301.A17	
	Wärmeleistung B0/ W35	: 17,03 kW
	Kälteleistung B0/ W35	: 13,41 kW
	El. Leistungsaufnahme B0/ W35	: 3.62 kW
	Leistungszahl (COP)	: 4.7

Brauchwarmwasser

Leistungsdaten:	Kombispeicher TISUN PC 1000-B	
	Inhalt 980 l	
	Einmalige Schüttleistung (Speicher T 50°C)	: 580l WW 38°C
Temperaturen:	Aussentemperatur Winter	: - 9°C
Betriebstemperaturen:	Heizgruppe FBH	: 35/ 25°C
Betriebstemperaturen:	Heizgruppe Radiatoren/ Sitzofen	: 45/ 35°C

2. *Anlagebeschrieb*

241 Wärmegewinnung/ Erdsonden

241.1 Erdsonden

Die Wärmegewinnung erfolgt über zwei Erdwärmesonden aus Polyäthylen-Rohren die mit einer Tiefenbohrung ins Erdreich verlegt werden.
Mit Verbindungsleitungen von den Sonden auf die Wärmepumpe, wird ein geschlossener Kreislauf erstellt. Über ein Wasser-Glykol-Gemisch wird die Wärme dem Erdreich entzogen und auf den Verdampfer der Wärmepumpe geführt.
Ein Expansionsgefäss und ein Sicherheitsventil schützen die Anlage vor Überdruck.

242 Wärmeerzeugung

242.1 Wärmepumpe Sole/ Wasser

Die Wärmeerzeugung für die Heizungsanlage erfolgt mit einer Sole-Wasser-Wärmepumpe. Die BWW- Aufbereitung erfolgt über ein 1'000l Kombi-Speichersystem.
Mit der projektierten Regulierung wird die Wärmepumpe, die Heizgruppe, die Free-Cooling- Funktion und die BWW- Aufbereitung reguliert resp. gesteuert
Ein Expansionsgefäss und ein Sicherheitsventil schützen die Anlage vor Überdruck.

Bauernhaus Anliker Eggerdingen

242.2 Free-Cooling

Die im Sommer anfallende Wärmelast, wird mit der Fussbodenheizung dem Gebäude entzogen, und über die Erdsonde in das Erdreich abgegeben.

243 Wärmeverteilung

243.1 Heizgruppe Fussbodenheizung

Für die Raumheizung im Winter, sowie die Raumkühlung im Sommer ist im EG, 1. OG und DG eine separat regulier- und abstellbare Fussbodenheizgruppe ab dem Wärmeerzeuger resp. Speicher vorgesehen. Die Wärmeabgabe, resp. Wärmeentzug erfolgt mit einem konventionellen Fussbodenheizsystem, eingelegt im Unterlagsboden.
Die Einzelraumregulierung wird mit elektrischen Raumfühlern sichergestellt.

243.2 Heizgruppe Radiatoren + Sitzofen

Räume mit minimalen Raumhöhen werden mit Heizkörper, die Nasszonen jeweils zusätzlich mit einem Handtuchheizkörper beheizt. Die Wärmeverteilung erfolgt über eine separat regulier- und abstellbare Radiatorenheizgruppe ab dem Wärmeerzeuger resp. Speicher. Ein denkmalgeschützer Trittofen mit eingebautem Heizregister wird ebenfalls über die Radiatorenheizgruppe betrieben.
Die Einzelraumregulierung wird mit Thermostatventilen sichergestellt.

Sole/ Wasser- Wärmepumper mit Kombi- Speicher

Mit Kombispeicher für keimfreie BWW- Aufbereitung. Anlage jederzeit erweiterbar mit einer Solaranlage oder einem alternativen Wärmeerzeuger (z.B. wassergeführter Schwedenofen)

figure 74: Description of heating/cooling and DHW system. © Anliker Christian, Arch/Innenarchitekt SWB

2.3.1.5 Heat pump – Single family house Gstaad

Author: Cristina Polo (SUPSI)

What is the solution?

The building was not heated. With the renovation an air/water heat pump was installed. This system provides heating and DHW. The air-to-water low temperature heat pumps are the optimal choice when combined with underfloor heating or low temperature to meet current and future regulations for energy efficiency.

Why does it work?

The intervention inside the building was massive due to the absence of comforts in the original construction and the state of the building. The interior appearance was therefore touched more than the exterior, partly due to the change in function from a rural agricultural building to a residential building. This traditional building was originally used for agricultural purposes, but later abandoned. It was completely renovated in 2018 to become a single-family house. The building did not have heating system or domestic hot water previously. Ground floor and first floor slabs have also been replaced, as the original ones were not in a state of preservation (static and comfort requirements), and this allow to integrate new heating and heat distribution system.

Description of the context:

Every year in Switzerland more than 2,000 agricultural holdings are abandoned. The buildings often remain unused (CVP-Mo 11.3285). A redevelopment or conversion of older buildings into a residential building is, due to the federal legal restrictions on the preservation of cultural landscapes, not always possible. Gabriela Matti tried, with the conversion of the unused Mayensäss in Gstaad, to demonstrate that traditional buildings can be well integrated with the latest technology. A comprehensive renovation transformed the unused and unheated wooden house into a modern PlusEnergyBuilding, that hasn't lost its "old charm.

Pros and Cons:

The installation of the system involved a massive intervention, but the benefits brought to the indoor climate are high. In fact, fan coils allow a better thermal comfort as the heat is evenly distributed inside the spaces Heat pumps represent the most efficient alternative to fuel, oil and electric systems in regard to both heating and cooling. Heat pumps prices are usually high, taking into account the installation of the entire system These running costs are prone to be lower especially if powered by solar renewable sources.

Type of data available:

The energy need for the HP is an average of 6500 kWh/a, which are entirely covered by the PV production (90'493 kWh/a). The well-integrated 32 kW BIPV system generates around 27,000 kWh of CO_2 -free solar power every year. This covers the total energy requirement of the single-family house (SFH) of 17,600 kWh / a at 154% as Plus Energy House.

The building was awarded with the Swiss Solar Prize 2019. Link: https://www.solaragentur.ch/sites/default/files/g-19-10-02_solarpreispub19_fueradag_v2.p081.pdf

Best practice example:

Single family house in Gstaad – https://www.hiberatlas.com/de/single-family-house-gstaad-switzerland--2-220.html

figure 75: New indoor space. © Michi Gehret, Gehret Design architect

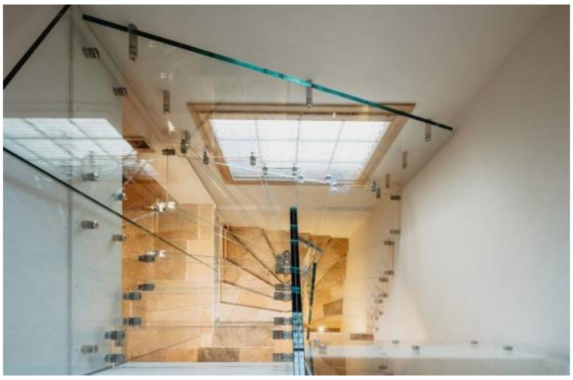


figure 76: New living spaces © Michi Gehret, Gehret Design architect.

figure 77: Building after renovation. © Solaragentur Swiss Solar Prize 2019.

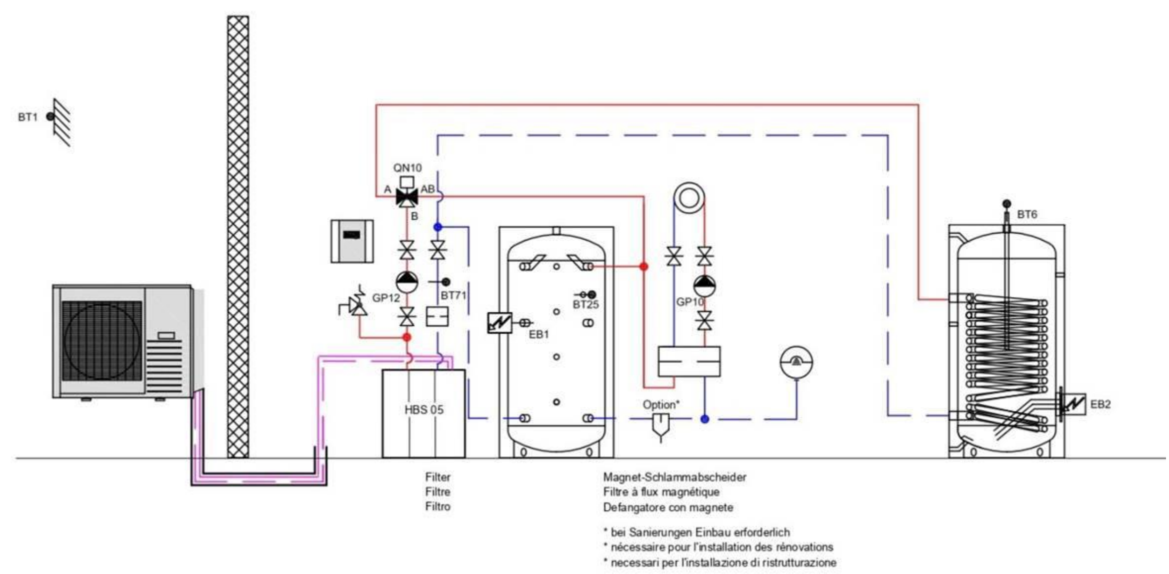


figure 78: Heat pump system. © Liebi

2.3.1.6 Heat pump – Hof "Neuhäusl"

Author: Alexander Rieser & Rainer Pfluger (UIBK)

What is the solution?

The solution is to use an air/water heat pump for the heat supply of heating and hot water. For this purpose, a compact device from Drexel und Weiss was installed. The heat pump delivers a thermal output of 7.0 kW at a power consumption of 2.28 kW at an outside temperature of -7° C and a hot water temperature of 34° C according EN 14825. This results in a COP of approx. 3.1 The COP indicates the ratio of the heating power to the electrical power input. This means that thanks to the heat pump, the electrical output is more than tripled under the above-mentioned boundary conditions. Hot water production and heating supply alternate in phases. The hot water is heated via an integrated heat exchanger. Due to the higher temperatures for hot water, the COP is significantly lower than the COP for heating. Thanks to underfloor heating and a very low heating demand, in the case of the "Hof Neuhäusl" it is possible to work with very low supply temperatures.

Why does it work?

Heat pumps generally have the advantage of only obtaining a small proportion of heating energy from electrical energy. Most of it, is extracted from water, air or soil by environmental energy. Especially in the alpine regions it is not always possible to install a groundwater heat pump or a borehole heat exchanger, which would have a higher COP, since many buildings are not located in the valley. Therefore, in this case the exhaust air after a counter-current heat exchanger is used. This airflow still has a higher temperature than the outside air and still contains a lot of water vapour. By further cooling and condensation of this water vapour, the energy for the heat pump can be provided without great development effort. However, in combination with low-temperature heating systems such as panel heating systems, air/water heat pumps can also achieve acceptable and energy-efficient values. Due to the small space requirement of the compact unit, this solution can be integrated very well, especially in historical buildings. Compared to some other heating systems, it does not require any storage space for the raw material. Classical compact units provide the energy via the ventilation system. However, since the required heating demand in refurbished historical buildings usually has to be much higher than in passive houses, the maximum heating demand of 10 W/m² for air heating is exceeded. In this case, there are device variants which provide the energy via another distribution system, e.g., underfloor heating. Due to the large heat supply surfaces of underfloor heating systems, the required temperatures in the supply pipe are much lower than with conventional radiators.

Pros and Cons:

The main advantage of air / water heat pumps is the large amount of environmental heat which is basically unlimited and does not cause CO2 emissions. Due to the smaller proportion of electrical power, CO2 emissions at a COP above 3 are lower than with oil and gas heating systems. Basically, you have to keep in mind that a part of the energy consists of electricity. The environmental sustainability of the system depends mainly on the way the electricity is generated. For example, in Austria a considerable amount of energy is generated in summer using water energy, but in winter electricity is often purchased which is generated using oil and gas. Therefore, the higher the COP, the lower the CO2 emissions. With a value of 3 it remains approximately the same. Heat pumps can be used not only for heating, but also for cooling in the summer months. The low space requirement must also be mentioned as an advantage. Especially with air / water heat pumps the investment costs are in a good relation to the output. Costs for chimneys and chimney sweeps are completely eliminated. Especially in the winter months, when outside temperatures are very cold, the efficiency of the heat pump suffers. Due to the resulting higher electricity demand, the CO2 balance is no longer as good as before. Noise pollution from heat pumps must also be taken into account in the planning stage, although modern heat pumps are often already sound-optimised. Underfloor heating has several advantages. The main advantage is the previously mentioned supply temperature. Especially in combination with heat pumps, it is essential to keep the temperature rise as low as possible. Underfloor heating systems are perceived as very pleasant due to the large area heat emission from below. With underfloor heating systems, the warm air rises evenly across the room. The major disadvantage of underfloor heating is thermal inertia. Due to the large thermal mass of the heating screed, quick heating is not possible.

Is there any related publication?

Passivhaus-Versorgungstechnik, Protokollband Nr. 20 des Arbeitskreises kostengünstige Passivhäuser Phase II; Passivhaus Institut, Darmstadt 2000. Neue Passivhaus-Gebäudetechnik mit Wärmepumpen, Protokollband Nr. 26 des Arbeitskreises kostengünstige Passivhäuser Phase II; Passivhaus Institut, Darmstadt 2004.

Best practice example:

Hof "Neuhäusl" – https://www.hiberatlas.com/de/hof-neuhaeusl--2-130.html

figure 79: © UIBK, hot water boiler

figure 80: © Drexel & Weiss, compact device

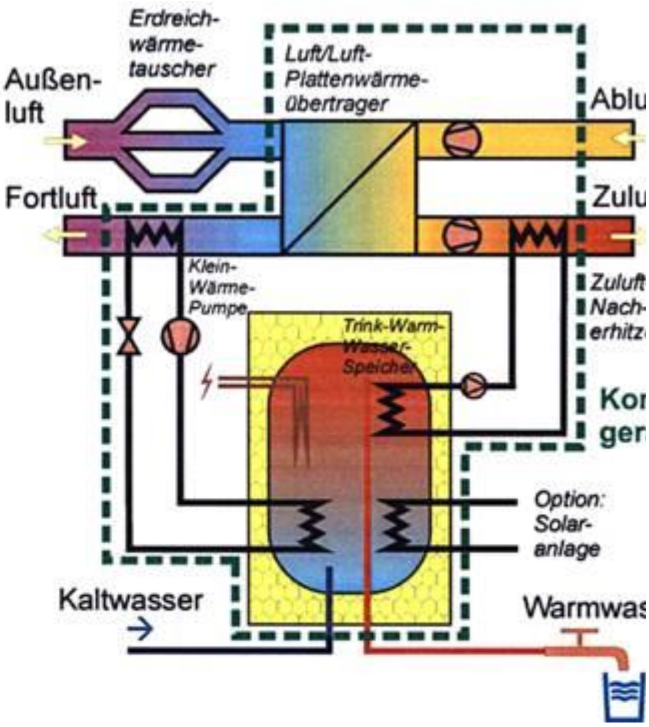


figure 81: © Passipedia, scheme of a compact device

2.3.2 Pellet Boiler

2.3.2.1 Pellet Boiler - Ansitz Kofler

Author: Alexandra Troi (EURAC)

What is the solution?

Production: Pellet boiler

Distribution: Radiating floor.

The old gas boiler was replaced by a pellet boiler, which supplies all 5 apartments in the building complex with warm water for heating and DHW. While the other four apartments use classical high temperature radiant systems, the retrofitted Orangery presented in the HiBERatlas has a floor heating system.

Why does it work?

Compatibility with conservation – Pellet boiler: When a biomass boiler is projected, fuel storage must be specifically thought about. At Ansitz Kofler there was no space available in the house or basement, but the pellets could be stored in a tank buried in the garden and are brought to the reservoir in the heating room with a suction turbine. Burying the tank could be combined with the earth works anyway done for the tubes allowing to pre-heat the ventilation air in winter and pre-cool it in summer.

Compatibility with conservation – Radiating floor: Integrating the distribution ducts in the floor allows to hide them, nevertheless this measure can be adopted only if modifications to the existing floors are not restricted.
In the case of Ansitz Kofler the existing floor were tiles on some cm of screed on earth ground – dating anyway from 1925 and not from the Orangerie, it was not worthy of preservation, but it contributed considerably to the heat losses. The floor was removed until the foundation and rebuild with a thermal insulation avoiding ascending moisture infiltration from the ground and from the walls. The multilayer floor was compounded on a gravel aggregate layer on whom a lean concrete sub-base (50 mm) was poured. This layer is used as blinding layer on which bituminous sheeting was applied. The sheeting was brought on the border of the walls and welded, in order to avoid lateral infiltration from the stone masonry. The following rigid insulation boards XPS (2 x 100 mm) were covered with a protective concrete layer (50 mm) on which all conduits and electric cables were installed. Once all crafts had applied the conduits, a 16 cm thick layer of lean concrete was poured. On the impact sound insulation, the floor heating system was installed.

Description of the contexts:

At Ansitz Kofler the focus was on the retrieval of lost Orangerie character and energy retrofit. The surrounding park was not only an important character defining element for the building, but brought also the opportunity to include the pre-heating and cooling tubes and bury the pellets tank (as well as a rain water reservoir).

The owner showed that factor 10 reduction in energy demand is possible also in a listed building. With the provision of the heat from the pellets boiler, not only the Orangerie but also the remaining building could turn CO_2-neutral.

Pros and Cons:

Pellet Boiler: With a pellet boiler providing the heat for space heating and DHW, the anyway reduced remaining heating demand after refurbishment is provided by a renewable and CO_2 neutral source.
There is no visual impact on the ensemble, since the pellets tank could be buried, and there was also no material impact, as the pellets boiler itself was installed in the original heating room.
More generally speaking, biomass boiler technology has progressed extraordinarily in the last decade, achieving high efficiency and reliability while lowering solid and gaseous pollutant emissions. This usually balances out the potential disadvantages in terms of required space, emissions and maintenance, that biomass heating technology could have compared to conventional heating systems, such as oil or gas boilers.

Radiating floor: Radiant floor heating systems work at lower temperature and allow thus for better efficiencies and the use of a greater variety of (rebewable) heat sources. They do provide uniform heating, this brings greater comfort. They furthermore do not require maintenance. On the other hand side, the floor needs to be demolished for the installation of this technology – which was however a work which had anyway to be done in the specific case.

Type of Data Available:

Ansitz Kofler has been equipped with a monitoring system, which includes both the hygrothermal monitoring of the different wall build-ups (interior and exterior insulation) and the energy system – the ventilation system with all four temperatures (supply, exhaust, fresh and exit air) as well as the energy for heating and for domestic hot water.

The thermal energy for heating is measured using a heat meter installed on the return pipe of the heating circuit. This sensor measures volume, flow and water-temperature. A second temperature sensor installed in the supply water duct furnishes supply temperatures. By means of these measurements thermal energy is calculated.

Is there any related publication?

A. Troi, H. Mahlknecht, M. Rametta, R. Lollini, M. Benedikter (2011) "Ansitz Kofler in Bolzano/Italy: Energy retrofit to near passive house standard and towards zero emission for heating and cooling". *International Conference on Energy Management in Cultural Heritage*, 6-8 April 2011, Dubrovnik, Croatia: Programme Summary.

H. Mahlknecht (2009) “Refurbishment and monitoring of an historical building. A case study”. Master thesis, *Free University of Bozen-Bolzano*.

Best practice example:

Ansitz Kofler – https://www.hiberatlas.com/de/ansitz-kofler--2-25.html

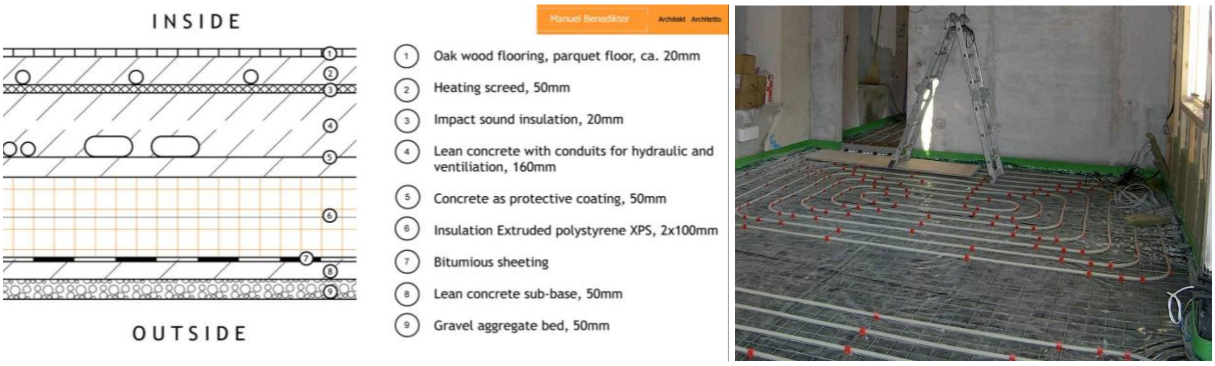


figure 82: Schematic drawing of floor buildup (left) and laying of radiating floor (right) © Manuel Benedikter Architekt

figure 83 Opening of buried pellets tank (left), pellets boiler and distribution (middle) and earth works for pre-heating and cooling ventilation air (right) © Manuel Benedikter Architekt

2.3.2.2 Pellet Boiler - Magnusstraße residential MFH, Zürich (Switzerland)

Author: Cristina Polo (SUPSI)

What is the solution?

Production: Pellet boiler

Distribution: radiator

The heat energy required to heat the building and provide the domestic hot water is generated by a wood pellet firing system. The combustion gases from the wood pellet boiler are led through a newly created chrome steel chimney over the roof. The fuel storage room is located right next to the heating center. The heat for the rooms is visibly conducted via new risers and distributed using new radiators. These were placed on the inner walls in the area of the current old oil stoves. Horizontal heating walls were installed in the bathrooms.

Why does it work?

The decentralized production of heat has been replaced with a centralized system. The system works because a new central pellet boiler has been installed instead of decentralized oil-fired stoves, improving energy efficiency. The intervention for heating was done entirely internally without repercussions on the façade that is under heritage protection. The new two main pipes pass through technical compartments. Flat tube solar collectors were installed on the roof terrace of the northern part of the house. The solar energy thus obtained can be used both for heating the domestic hot water and for supporting the heating.

Description of the context:

The two street-side facades are subject to preservation requirements and therefore could not be changed. Otherwise, the attic and the court side. Here the roof with eaves could be broken off and put back in the form of prefabricated wooden elements. In this context, the roof could be raised on the courtyard side.

Pros and Cons:

The goal was to create thermally comfortable rooms while being careful with renewable energy sources. Biomass pellet boilers cost less than most boiler types on the market and wood fuel is cost effective, making for both an energy and cost-efficient means of heating. Biomass pellet boilers are a sustainable fuel and renewable energy source as low carbon heating system than other heating systems. On the contrary, wood pellets boilers require frequent maintenance and large wood storage spaces.

Type of Data Available:

This building is a best-practice case study in HiBERatlas database platform

https://www.hiberatlas.com/smartedit/projects/88/Baubeschrieb Magnusstrasse_7.pdf

The Magnusstraße residential building in Zurich, Switzerland, is a cooperative housing at fair prices. The apartment building in Zurich needed a complete modernization. After renovation, the building meets the Minergie standard was awarded with the Swiss Solar Prize 2007 and Watt d'Or 2008.

Is there any related publication?

http://www.viriden-partner.ch/mehrfamilienhaeuser?lightbox=dataItem-is07up5j (Building documentation)

Swiss solar award 2007 documentation: https://www.solaragentur.ch/dokumente//M-07-09-21Magnusstrasse.pdf

Several information is available in the architect's web page and projects documentation: Viridén + Partner AG, https://www.viriden-partner.ch/mehrfamilienhaeuser

Best practice example:

Magnusstraße - https://www.hiberatlas.com/de/apartment-building-magnusstrasse-zuerich--2-88.html

figure 84: Roof view with solar panels ©V+P, Viridén + Partner AG

figure 86: Roof view with solar panels ©V+P, Viridén + Partner AG

figure 85: Indoor spaces after renovation ©V+P, Viridén + Partner AG

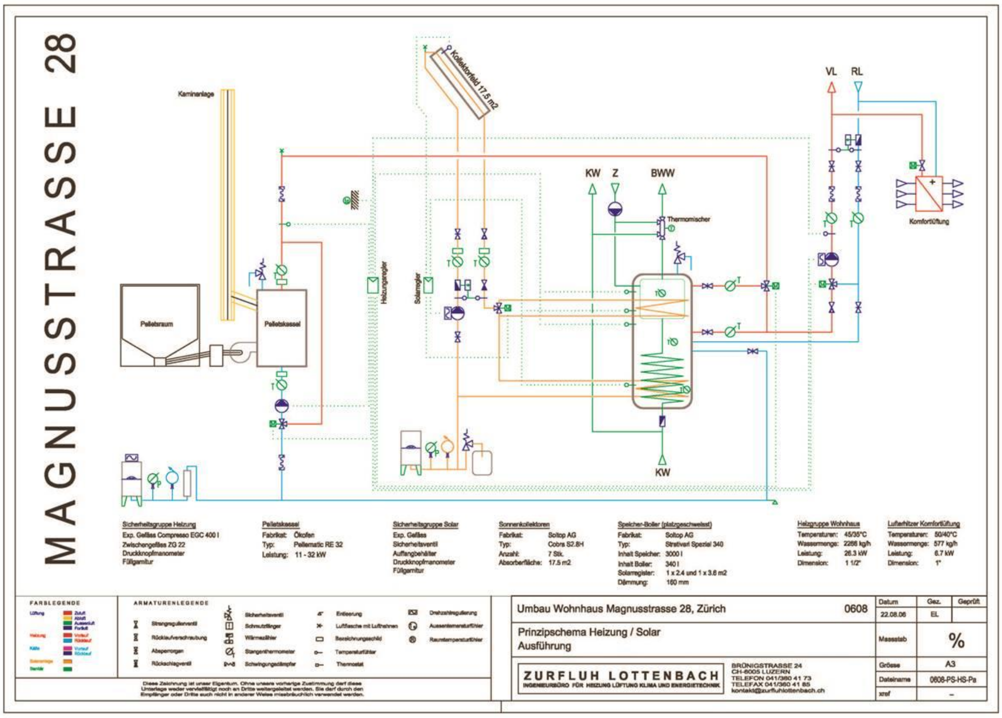


figure 87: Schematic diagram of HVAC and DWH system. © Energy Consultant Zurfluh Lottenbach

2.3.3 Wood chip boiler

2.3.3.1 Platzbon

Author: Alexandra Troi (EURAC)

What is the solution?

The wood chip boiler installed in the stable provides the basic heating to the building – mainly via radiators and partially via underfloor heating. The historic oven in the parlour is still in operation, alongside the modern heating systems.

Why does it work?

The heating system is fired with wood chips. It consumes 120m³ per year - for hot water and heating for the house, but also hot water for the barn (milking machine cleaning and cattle watering). The wood from the adjacent forests can be used, thus keeping the ecological footprint low.

Both the boiler and wood chip silo found a place under the entrance of the hayrick - additional soil had to be excavated for this purpose. The 2000-liter buffer storage is located in the cellar of the house and accessible via an external staircase.

Description of the context:

The mountain farm is located above St. Andrä, with a wide view over the Eisack valley. There are only meadows and woods all around, no traffic noise disturbs the peace and quiet. Before the renovation there were only cold water supplies in the kitchen and in the bathrooms. No heating system except the tiled stove in the parlour.

The old farmhouse is not formally protected and has nevertheless been renovated with loving attention to detail, while at the same time paying attention to a biological construction method and the use of regional materials.

Pros and Cons

The use of wood chip boilers allows farmers to use wood from their own forests, they just need to cut it with a chipper (a machine which they either own together with neighbours or can also rent) once a year or every two years depending on the storage space available. The chips are brought automatically by a screw from the storage to the burner, which results in considerable less effort than wood be needed for log wood boilers or single stoves.

Type of data available

Platzbon has been awarded the ITAS prize “Bauern(h)auszeichnung” and a respective statement of the Jury as well as a video (in German) on the energy retrofit of the farm house are available.

Energy certificate Klimahaus B – Gesamtenergieeffizienz/Efficienzy Energetica Complessiva GOLD

Best practice example

Platzbon https://www.hiberatlas.com/en/platzbon--2-118.html

figure 88 Wood from the own forests – for the wood chip boiler but also the old “Stubenofen” which was preserved

Gesamtenergieeffizienz – Efficienza energetica complessiva

Primärenergiebedarf Heizung – Fabbisogno di energia primaria per riscaldamento	11620	kWh/a
Primärenergiebedarf Warmwasser – Fabbisogno di energia primaria per acqua calda	2553	kWh/a
Primärenergiebedarf Kühlung – Fabbisogno di energia primaria per raffrescamento		kWh/a
Primärenergiebedarf Beleuchtung – Fabbisogno di energia primaria per illuminazione		kWh/a
Primärenergiebedarf Hilfsenergie – Fabbisogno di energia primaria per energia ausiliaria		kWh/a
Gesamtprimärenergiebedarf – Fabbisogno di energia primaria globale	14173	kWh/a
Gesamtenergieeffizienz – Efficienza complessiva	39	kWh/m²a
Spezifische CO_2 Emissionen – Emissioni specifiche di CO_2	4	kg/m²a
Spezifischer Primärenergiebedarf Heizung – Fabbisogno specifico di energia primaria per il riscaldamento	31	kWh/m²a
Gesamtenergieeffizienzklasse des Gebäudes Classe di efficienza complessiva dell'edificio	**Gold**	

Regenerative Energien – Fonti rinnovabili

Abdeckung Warmwasserbedarf aus erneuerbaren Energiequellen – Quota da fonti rinnovabili per acqua calda sanitaria	70 %
Abdeckung Gesamtprimärenergiebedarf aus erneuerbaren Energiequellen – Quota da fonti rinnovabili per il fabbisogno globale	74 %

figure 89 Klimahaus certification

figure 90 Construction of the room for storage and heating system

2.3.4 Cogeneration Plant

2.3.4.1 Cogeneration plant – Kindergarten Chur

Author: Cristina Polo (SUPSI)

What is the solution?

With the energetic renovation and an innovative heat network concept with the adjoining apartment building (MFH) with three families, the city of Chur is paving the way for the energy transition. There is a combined PV and thermal system on the roof. It covers its own energy requirements with 28,300 kWh/a to 95%. The solar excess heat of around 9,100 kWh / a, which cannot be used in the transition period and in summer, is delivered to the neighbouring MFH. In the winter half-year, the pellet heating of the neighbouring MFH supplies the kindergartens and penthouses with 8,800 kWh of heat. In the basement of the neighbour house there was a gas central heating which was replaced in 2014 by a pellet heating with a 1000 l accumulator. Additionally, 35m^2 of thermal collectors for hot water and heating support were installed on the roof of the conversion, with a 4500 l accumulator. Pellet heating delivers the missing energy during the winter months.

Why does it work?

Combined Heat and Power (CHP) is a great system to achieve energy efficiency, reduce emissions, and promote resiliency because is an efficient process to recover energy that would have otherwise been lost. CHP uses a heat engine or power station to generate electricity and useful heat at the same time. The system provides at least a portion of a facility's electrical load by capturing heat from hot exhaust gases; then that heat, or thermal energy, is used for things such as space heating, cooling, domestic hot water, dehumidification and/or process heating. The cogeneration plant is combined with renewable solar systems. The thermal solar collectors generate 19'200 kWh/y, of which 9'100 kWh are supplied to the property at Calandastrasse 48. In the cold winter months with little sunshine, the solar heat deficit is balanced out with the neighbour's pellet heating system. It delivers at least 8'800 kWh/a back to the kindergartens and the attic apartments. This results in an almost annual balance and an own energy supply of 95%. The solar power of the PV system as well as the solar thermal energy are used for the kindergarten operation. In this way, even the youngest grow with the application of the Solar energy. For this, the building received the Swiss Solar Prize Award 2016.

Description of the context:

The complex is divided into two structures. The residential building is characterized by the building height and the facade design as the main volume of the ensemble. The previous commercial building is deeper and due to its L-shaped geometry, forms an inner courtyard which, with its round arches and the widely projecting roof, has a high spatial quality. The specifications of the city of Chur as client were clear. The artistically valuable ensemble was to be preserved in its original expression. The earlier interventions should be dismantled, the change of use of the annex should be visible from the outside as a renewal but should be connected with the original design. And in addition: "Since Chur has been an energy town since 2011, it was necessary to incorporate the latest findings in energy and building physics into the renovation."

Pros and Cons

An on-site cogeneration system can provide reliable and high-quality electricity and thermal energy and can save cost on energy bills due to its high efficiency. CHP positively impacts the environment by reducing air pollution and greenhouse gas emissions. Unluckily, cogeneration is also suitable only where both hot water and electricity are needed at consistently high and continuously levels. Systems development can be expensive and cannot be considered truly sustainable in the long term when used to extract efficiencies from fossil fuels.

Type of data available

The project manager of the architectural office did his master thesis (sustainable building) on the property.

Is there any related publication?

Master thesis - available the complete presentation tables as annex. Additionally, a presentation at one "exchange of experience". Magazine TEC21 (Januar 2016 Nr. 1-2) Magazine Kultchur (November 2016)

https://www.hiberatlas.com/smartedit/projects/148/Leitsystem KG Calanda.pdf

Additional Information:

This building is a best-practice case study in HiBERatlas database platform and was awarded with the Swiss Solar Prize in 2016.

Link to energy-cluster.ch data: https://www.energie-cluster.ch/de/deklariert-ch/plusenergiegebaeude/schule-doppelkindergarten-chur-sanierung-(solarpreis-2016)-calandastrasse-50-7000-chur-9-3583.html

Solar scheme

https://www.hiberatlas.com/smartedit/projects/148/KIGA_150916_A3_4.pdf

Complete presentation tables of master work (German)

https://www.hiberatlas.com/smartedit/projects/148/Kindi Calanda ERFA.pdf

Presentation at an "Exchange of experience" (German)

Additional Link / URL

Link to Swiss solar prize data:
https://www.solaragentur.ch/sites/default/files/g-16-09-22_dwhg_und_doppelkindergarten_chur_def.pdf#

Best practice example

Kindergarten and apartments Chur – https://www.hiberatlas.com/de/kindergarten-and-apartments-chur-switzerland--2-148.html

figure 91: Solar panels and PV integrated on the south front (C) Ralf Feiner, Malans

figure 92: Picture of the roof © Ralf Feiner, Malans

figure 93: 1000 l accumulator © City Chur

Leitsystembild Kindergarten Calanda; 25.03.2020

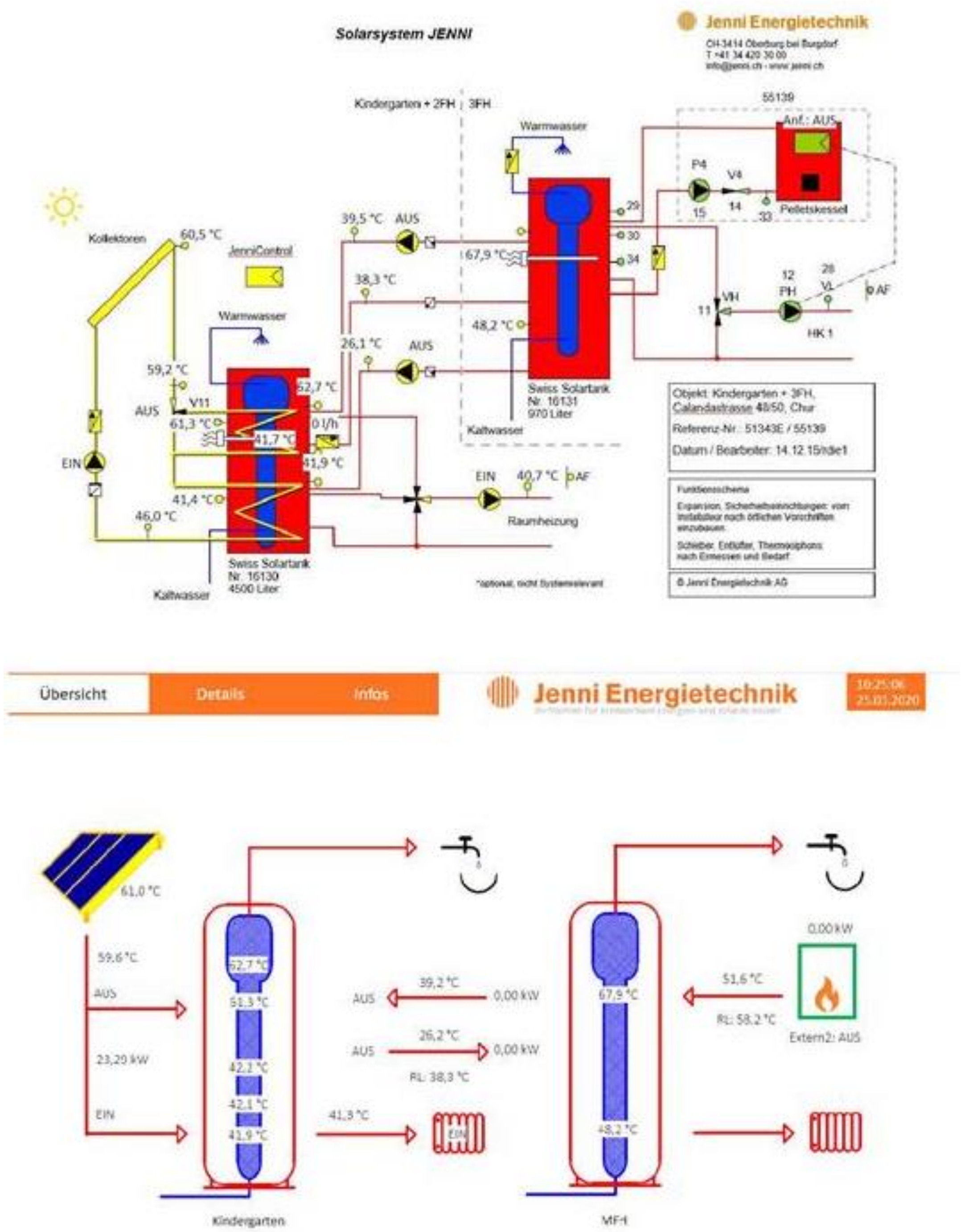


figure 94: Solar, HVAC and DHW scheme.© Jenni Energietechnik AG.

2.3.4.2 Cogeneration plant – Feldbergstraße Residential building Basel, Switzerland

Author: Cristina Polo (SUPSI)

What is the solution?

Combination of solar thermal and photovoltaic energy for HVAC and DWH with a 40 m3 larger thermal energy storage for solar thermal heating storage. The heat distribution system considered the existing piping and mostly radiators that were already in place. The entire energy requirement for heating, domestic ventilation, hot water and auxiliary energy is covered on the roof of the building. On the one hand, this is achieved through state-of-the-art thermal insulation techniques, on the other hand through passive and active use of solar energy (thermal and photovoltaic). Around 10 kW of PV will be installed. The solar thermal energy is farmed in 40'000 litres of storage. Thermal collectors from Ernst Schweizer AG Type: AV 23 light flat collector Total 34.5 m2 integrated in the roof area.

Why does it work?

Several requirements of the cityscape commission for façade and roof design had to be met. In this case panels have been integrated in the south pitch which has not any requirements of protection and on the dormers on the north pitch. This solution has been discussed and accepted by the Commission.

Description of the context:

Two more than 100-year-old apartment buildings on Feldbergstrasse are being renovated to produce more energy than they use for heating/hot water, ventilation and auxiliary energy. The 12 apartments did not meet today's comfort requirements. Accordingly, the apartments were poorly rented or stood empty. The need for maintenance were high. The refurbishment project provided for the merging of the two buildings, as the floor plans (more or less identical) and the inner courtyard were also merged and revitalized. The modernization was planned very carefully weighted to the architectural and ecological concerns. In addition, comfort is increased, and energy costs are massively reduced.

Pros and Cons

Scalability of the solution: if the 1.5 million buildings in Switzerland were renovated on this basis, corresponding to the current technical progress, the total energy needs of our housing stock would decrease from 125 TWh/a to around 9 TWh/a. The resulting energy substitution of nearly 115 TWh/a corresponds to the annual production of 15 large-scale fossil fuel or nuclear power plants, such as Gösgen with 7.5 TWh/a. This exemplary architectural and energy achievement should be brought to the attention of every parliamentarian.

Type of data available

Several data are available in the architect's web page and projects documentation: Viridén + Partner AG, https://www.viriden-partner.ch/mehrfamilienhaeuser

The project was awarded with the Swiss solar prize in 2009. Link: https://www.solaragentur.ch/dokumente//G-09-08-20%20Viriden.pdf

Is there any related publication?

https://www.hiberatlas.com/smartedit/projects/67/Systemkompente Solaranlagen Feldbergstrasse_1.pdf

Factsheet solar

Additional Link:

http://www.viriden-partner.ch/plus-nullenergiehaeuser?lightbox=dataItem-is05dqmd

Best practice example:

Feldbergstraße – https://www.hiberatlas.com/de/residential-and-commercial-building-feldbergstrasse-basel--2-67.html

figure 95: Roof with solar thermal and PV ©Nina Mann

figure 96: Tank 40'000l ©V+P, Viridén + Partner AG

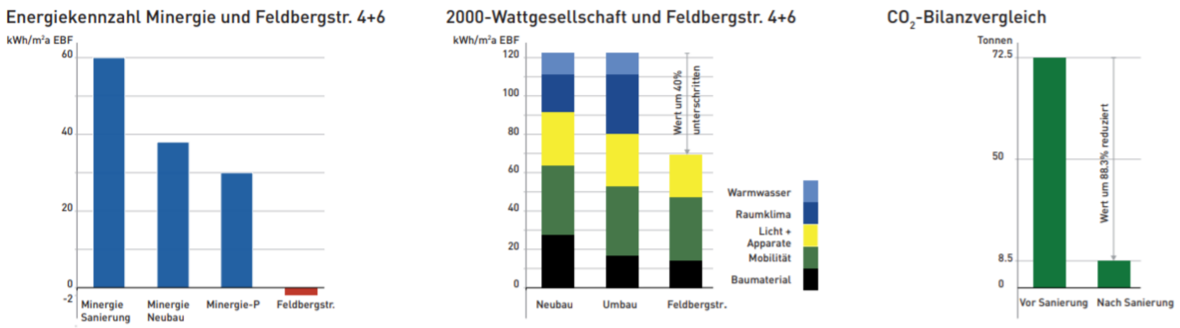


figure 97: Energy data and CO2 emissions savings after renovation ©V+P, Viridén + Partner AG

2.3.4.3 Cogeneration plant – Single family house, Bern

Author: Cristina Polo (SUPSI)

What is the solution?

The new heating system includes several interventions. The main source is the water heat pump (Optiheat water / water all-in-one OH 1-8es by CTA AG), which is supplied partly by geothermal probes and partly by the PVT system. The water is stored in a 2840 litters tank (Jenni solar storage tank). It also works thanks to the stove. The stove Tolima Aqua Compact by Olsberg can be easily integrated into new or existing heating and hot water systems. Combined with a thermal solar system, the entire heating system can be designed. This not only reduces heating costs, but also the environmental impact, because is CO2-neutrally. In addition, a 'Frischwasserstation' which contains a small heat exchanger to provide our warm water (Brauchwasser) on demand which prevents the formation of legionella were installed. The hot water of the solar tank is used to heat up the 'Brauchwasser' in the Frischwasserstation when required. From the tank the water is then distributed to the historical radiators and wall radiators. Since originally no conventional solar system was possible due to monument preservation regulations, a thermal collector that is not visible from the outside has been developed, with which the heat can be efficiently extracted from the natural slate roofing. The collector consists of copper lamellas, which are clamped between the slate plates. The heat is conducted via the fins into a soldered copper tube, through which it is dissipated via a glycol solution, as in conventional collectors. Due to possible condensation moisture and to increase efficiency, a 1 cm aerogel insulation, covered by a sub-roof foil, was placed between the roof battens and the slate. The total thermal generation is around 10,000 kWh of heat per year.

Why does it work?

A combination of several energy renewable sources has been implemented to achieve the best energy efficiency balance for the building considering the high level of protection. The energy renovation concept considers balancing energy consumption needs and energy production through RES. efficiency while minimizing consumption. The goals for the renovation of this building are manifold: minimize energy demand (reach a Minergie level, the Swiss standard of quality, comfort and energy efficiency), use environmentally friendly building materials, maintaining the character of the house (preservation of historical monuments), consider urban environment, adhere to the cost framework (subsidies as Minergie and Bern renovated) and, where necessary, seek and implement new solutions. The whole system has been designed to perfectly integrate with the construction. The heat is distributed through radiators and through a stove. Historical radiators were not changed during the renovation (except newly painted) and wall radiators have been fitted to the wall with a minimal intervention in terms of space. The water heat pump is supplied partly by geothermal probes and partly by the PVT and the natural slate collector systems. Both systems are used to support the heat pump by increasing the water temperature into the heat pump whenever possible and thus to improving the COP. The PV and solar thermal ST system (as well as the hybrid PVT) has been built to adapt perfectly to the shape, colour and materials of the roof.

Description of the context:

The building is a detached single-family house, a two-floors neo-baroque construction with a mansard rooftop and is dated 1898. The general situation of degradation and the need to minimize energy demand collide with the important aspect of historic buildings preservation. The challenge is to achieve maximum results in both fields, opting for several high efficiency interventions, but at the same time with minimum aesthetic impact. As usual at road forks and corner houses in the Kirchenfeld district, according to the Kirchenfeld-Brunnadern building inventory, the house was designed with special care: the south-east corner of the house is characterized by a corner covered with the mansard roof. The house is listed in the cantonal building inventory and classified as worthy of protection (highest protection level). For this reason, any changes must obtain the approval of the Department of Historic Monuments.

Pros and Cons:

The new thermal system consists in the replacement of the gas heating system with a heat pump, geothermal probes and a stove. The whole thermal system act in combination with solar thermal panels, PVT hybrid modules under the natural slate roof and the BIPV modules integrated in the South pitched roof. The challenge is to achieve maximum results to preserve the original historical value of the building opting for several high efficiency interventions combined together, but at the same time with minimum impact. The intervention maintains the original aesthetics and character of this neo-baroque building, due to the high protection level. This way, the interior space of the building remains practically unchanged and thanks to the renovation, the total energy requirement fell from 46,900 kWh per year by 76% to 11,100 kWh / a. The energetic renovation of the building, which is over 100 years old, reduced the annual CO2 emissions by 10.6 tons. The project shows which energy and emission reductions are possible even in listed buildings. Investment cost are higher than conventional solutions as includes the roof intervention cost with innovative and customized BIPV, PVT and STh under natural slate collectors. PVT and natural slate collector systems are also used to regenerate the geothermal probes/ground temperatures with excess heat available from the PVT and the slate collectors on multi-day to seasonal time scale (on diurnal time scale the solar tank is the heat storage). This regeneration is a win-win situation: By cooling the PVT panels and transferring the excess heat (up to 12 kW) into the ground e.g., in summer, the PVT panels produce significantly more electricity (up to 500 W) than the pump required to transfer the heat into the ground (~50W). The regeneration thus increases the net solar electricity production and at the same time prevents the ground to cool down over time, assuring a constantly high COP over the lifetime of the geothermal probes. In addition, the cooled roof helps the rooms of the top floor to remain cooler in summer.

Type of data available

The purchase of electricity was reduced by a factor of 2.2 despite the switch from gas heating to a heat pump. The external energy supply for heating, hot water, ventilation, and control (i.e., without household electricity) could be reduced by a factor of 10, the CO2 emissions by a factor of 14.

Article and video published in Hausinfo, a neutral online information platform on all topics relating to the house, published in German and French (Ed. GVB Services AG and the Homeowners Association Switzerland, HEV): "Architecture report: Energy-producing roof despite monument protection". The article contains information on the products and the technical plans used in the building refurbishment.

Link: https://hausinfo.ch/de/bauen-renovieren/unterhalt-renovation-sanierung/ausbau-umbau/architektur-umbauten/bern-denkmalschutz.html

Additional Link

Winner of the Swiss Solar Prize 2014, "B" category for building's retrofit. Link:
https://www.solaragentur.ch/sites/default/files/g-14-10-03_hutterli_roethlisberger_solpreiskatsan.pdf

https://www.hausinfo.ch/de/home/gebaeude/architekturreportagen/hutterli-bern.html

Type of monitoring: Continuous
Description: The strategy of monitoring is to follow the temperature of the solar systems (sloping, PV, PVT) according to the external air temperature. This is the link:

https://grovestreams.com/singleDash.html?org=2776f02c-f718-3407-83e0-78bc4c61ecda&itemUid=10f024e4-0cf4-37df-a184-79853932b9d6&api_key=f66a4104-ad33-3159-90e6-10bd46a26c29

Documents: Monitoring

Best practice example

Single family house, Bern – https://www.hiberatlas.com/de/single-family-house-bern-switzerland--2-174.html

figure 98: Installation hybrid system © M. Hutterli

figure 99: Installation slate system © M. Hutterli

figure 100: Installation hybrid system © M. Hutterli

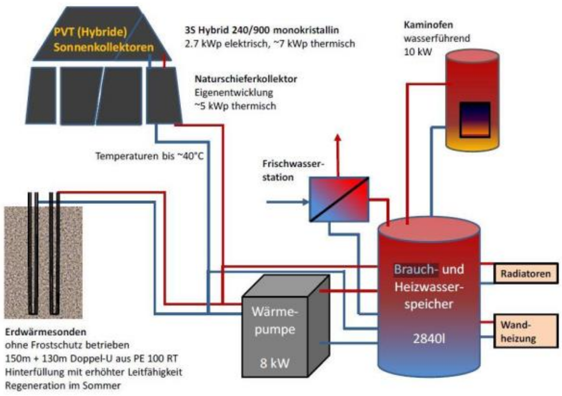


figure 101: New heating system © M. Hutterli

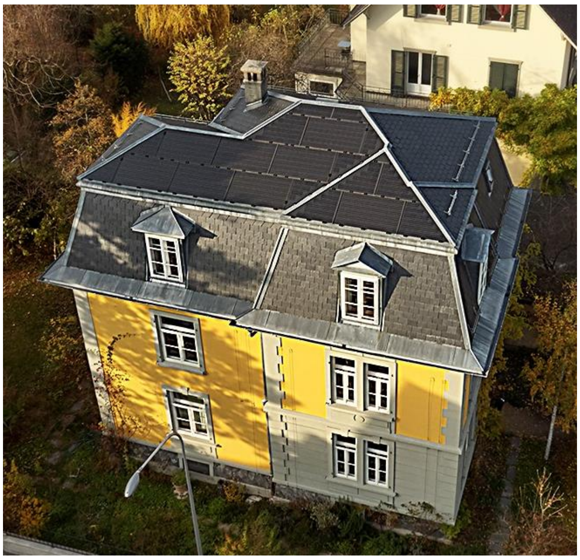


figure 102*: South slope with integrated solar thermal collectors under natural slate roof and BIPV and PVT hybrid modules © C. Martig.*

figure 104*: Solartank © M. Hutterli*

figure 103*: Assembly of during construction works of solar thermal collectors under the natural slate roof. © M. Hutterli*

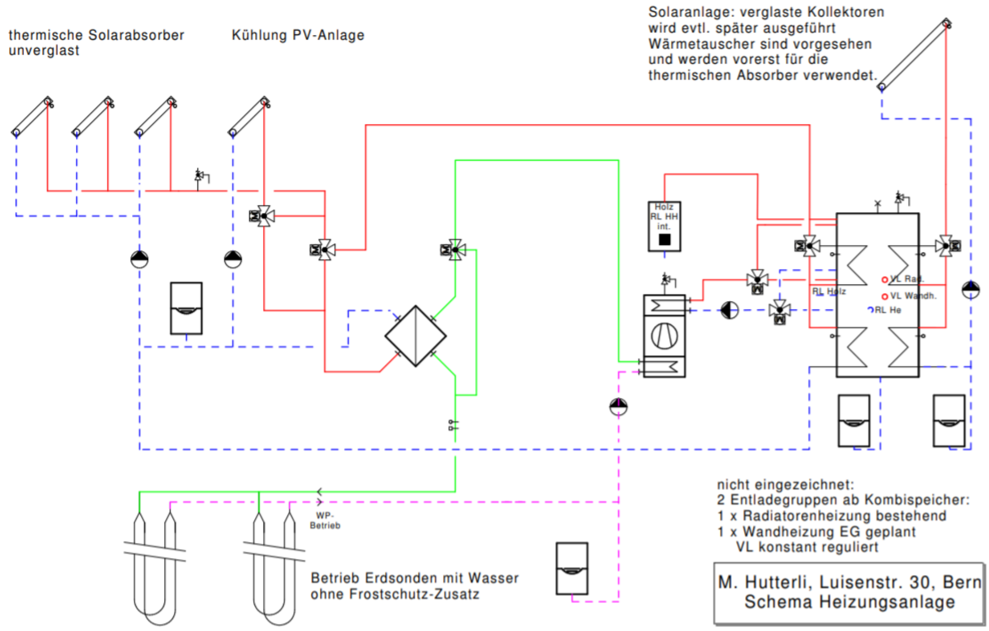


figure 105: Heating system scheme. © M. Hutterli

2.3.4.4 Cogeneration plant – St. Franziskus Church

Author: Cristina Polo (SUPSI)

What is the solution?

Most of the technical installations come from the first construction stage, especially the oil heating system from 1989. The average heating oil consumption was around 7,000 litters per year. The heating system needed to be replaced and had to be replaced by an environmentally friendly new heating system. For this reason, a geothermal heat pump system was introduced for the building heating instead the old oil boiler and the heat pump system works in combination with the solar thermo-photovoltaic (PVT) modules installed. The roof areas are completely covered with the solar modules. The same modules with only slightly varied connection details could be used both for the roof with the conventional in-roof photovoltaic system and for the roof with the PVT system (photovoltaic and thermal). The technically and functionally different roof surfaces have an almost identical appearance. The roof edges at the site and at the eaves are also identical, so that a very uniform architectural design result.

Why does it work?

The heat for the heating system is generated with a water heat pump. The heat load occurring in summer is extracted from the building with the floor heating pipes and released into the ground via the geothermal probe. The solar BIPV and the solar thermo-photovoltaic (PVT) systems are well integrated in the whole heating system and in turn are well-integrated in the complex surface of the existing roof. The solar PVT system complies with the geometric and spatial and construction compatibility criteria required by current regulations for the integration of solar systems in historic buildings (grouping, in-plane with the roof slope, respect for the eaves lines and roof edge, joint precision, etc.). The aesthetic, material and colour compatibility with the existing roof is optimal because respect the original colour of the roof. The reflection rate is slightly higher with respect to the original roof tile that has been replaced. The final result is very good and well-integrated. PVT-system on the pitched roof (south-side). Module type: Eternit Integral II_190Wp_GG-L_BS2 special. 135 standard + 9 custom-made.

Description of the context:

The Roman Catholic Church of St. Francis Ebmatingen, built in 1989, urgently needed renovation. An old oil heater, an outdated insulation and a partially damage roof ensured a disproportionately high energy requirement of 84,400 kWh / a. In winter 2018/19, the structural and energetic renovation followed with new insulation, geothermal heat pumps, photovoltaics with thermal energy (PVT) and LED lighting. As a result of these measures, the total energy consumption to date has decreased by 35% from 84,400 kWh / a to 54,700 kWh / a. The character of the church was still preserved. The renovation costs amount to CHF 1.2 million. Of the 543 m2 PV system that is optimally integrated into the roof, 161 m2 are equipped with PVT modules. In addition to electricity, they also produce 41,800 kWh / a of heat, which is conducted 300 m deep into the ground in summer which a part is recovered in winter. The installed power of the PV / PVT system is 90 kW. This means that 78,900 kWh / a of CO2-free electricity is generated annually, and 41,800 kWh / a of thermal energy is generated with the 161 m2 thermal solar collectors. Both plants generate a total of 120,700 kWh / a. This means that the PEB church has an energy supply of 221% (Plus Energy Building, PlusEnergieBau)

Pros and Cons:

The solar photovoltaic integrated system and solar thermal PVT are well-integrated in the complex surface of the existing roof. It complies with the geometric and spatial and construction compatibility criteria required by current regulations for the integration of solar systems in historic buildings (grouping, in the same plane with the roof slope, respect for the eaves lines and roof edge, joint precision, etc.). The aesthetic, material and colour compatibility with the existing roof is optimal because respect the original colour of the roof. The reflection rate is slightly higher with respect to the original roof tile that has been replaced. The final result is very good and well integrated.

Type of data available

This church renovation serves as a role model both in terms of energy and ecology. The St. Franziskus Ebmatingen church renovation project was awarded by the Swiss Solar Prize in 2019 and have won a European Solar Prize the same year, 2019.

Link: https://solaragentur.ch/sites/default/files/g-19-10-02_solarpreispub19_fueradag_v2.p042_43.pdf

European solar prize brochure:

https://www.eurosolar.de/en/images/EVENTS/ESP/ESP_2019/Brochure_ESP2019.pdf

Is there any related publication?

Römisch-katholische Kirchgemeinde Egg ZH Pfarrvikariat Maur ZH: ENERGETISCHE SANIERUNG KIRCHE ST. FRANZISKUS EBMATINGEN (Festgottesdienst 24.3.2019)

Service of the Swiss Radio and Television RSI, in Italian language news on Friday 15.11.2019, Published on: 15 November 2019, 21:24, Link: https://www.rsi.ch/news/svizzera/Una-chiesa-a-zero-emissioni-12421722.html

Best practice example

St.Franziskus Church – https://www.hiberatlas.com/de/st-franziskus-church-ebmatingen-switzerland--2-128.html

figure 106*: From left to right: new geothermal heat pump heating system; execution of the bore holes and oil boiler pre-intervention. © D. Studer*

figure 107: PVT panels during works ©Studer

figure 108: PVT panels during works ©Studer

2.3.5 District heating

2.3.5.1 District heating – Solar Silo, Basel (Switzerland)

Author: Cristina Polo (SUPSI)

What is the solution?

Production: district heating

Distribution: radiator with visible piping

The Basel Energy Act only allows new oil and gas heating systems to be installed in exceptional cases. The Basel-Stadt cantonal energy plan shows which energy sources will be available for heat supply in the future. IWB (Industrielle Werke Basel) to the Basel district heating network, which for the first-time supplied customers with heat from the waste disposal plant in Basel (KVA) in 1942, has so far connected around 5,300 house systems. With a pipeline network of over 222 kilometres, around 45,000 households are now supplied with district heating.

Why does it work?

In order to reduce primary energy demand and CO2 emissions, District Heat generation is to a great extent based on recycled heat from power generation (called Combined Heat and Power CHP), from industrial processes and from waste incineration. The rest is based on the direct use of renewable energy sources, mainly for peak demand. The entire area is heated by district heating, which Sulzer-Burckhardt AG installed in the 1980s and replaced the old coal boilers. The cheapest and most efficient measure to reduce energy consumption is to lower the room temperature, whereby a temperature reduction of 1 ° Celsius brings 5% savings. A room temperature of 18 ° is recommended in the offices and 16 ° in workshops and halls. Thermostats are hung in all rooms so that residents can control the temperature themselves. In the large high halls, the air heaters were replaced by gas radiant heaters, which radiate the heat exactly where it is needed instead of heating the entire volume.

Description of the context

The former building of the heating centre and the coal silo of Maschinenfabrik Sulzer and Burckhardt in Basel over the past 15 years, has been completely converted into a multipurpose building making way for a cultural district. The Solar Silo is the result of the refurbishment of an old coal silo tower, where coal was stored to produce heat for an ex-industrial field “Gundeldinger Field”, established in 1844. In the last 15 years, the foundation Kantensprung AG has bought the industrial area to return this site to the local population. The main criteria for site transformation are: neighbourhood, ecology and integration. Therefore, this transformation has been carried out adopting a holistic sustainable approach: re-use of existing materials, rainwater collection, green roofs, photovoltaic systems and space reconversion for social/work/commercial activities. With regard to the photovoltaics, it has been integrated into the building envelope to provide a visible sign of the shift from the use of fossil fuels for an old manufacturing site to the use of renewable energies for a new cultural and commercial site. The project is part of the "2000 watt society - pilot region Basel".

Pros and Cons

Main advantages of the intervention are zero purchase and overhaul costs for the boiler and more safety. The centralized warming allows major energy efficiency and reuse of heat from the waste disposal plant plus benefits in pollution reduction thanks to use renewable sources. Heat production by district heating is more efficient than individual production is incomparably easy to run and maintain for customers. Another major benefit of District Heating systems is that they can use a wide variety of local energy sources (including biofuels, geothermal, solar and wind that can be more effectively utilised when integrated into District Heating networks). DH entails moderate investment costs and very low maintenance costs as work automatically. As a centralized system, the space occupied by the heating system in each building unit is negligible with minimal technical intervention of the plants, an important aspect when intervening in historical buildings that can be quite a complicated issue and requires careful planning in certain cases. Although there is the advantage of steady pricing due to public tariffs and predictable prices local pricing differences can be given.

Type of data available

The refurbishment project of Solar Silo building was awarded with the Swiss Solar Prize in 2010. Link: https://www.solaragentur.ch/sites/default/files/g-15-09-02_mehrzweckgebaude_kohlesilo_basel.pdf

Article in Haustech 12/2015. Link: https://www.hiberatlas.com/smartedit/projects/51/1_Beleg_2nd-life-Batteriespeicher_Haustech.pdf

Article in TEC21 24/2015: https://www.hiberatlas.com/smartedit/projects/51/tec%2021%2024_2015.pdf

Book: Gundeldinger Feld - A machine factory in transition, Kantensprung AG (ed.), editions denkstatt Basel, ISBN 978-3-9524556-0-9. [Internet]. 2020; Available from: https://www.denkstatt-sarl.ch/app/download/10804542174/Buch_GundeldingerFeld_SCREEN.pdf?t=1586173367

figure 109: Radiator with visible piping © Martin Zeller

figure 110: Urban context close Solar Silo building, "Gundeldinger Feld" area in Basel. © P. Bonomo SUPSI

figure 111: Visible piping © Martin Zeller

2.4 Assessment of solutions according EN 16883:2017

2.4.1 Methodology of Assessment

The European standard EN 16883:2017 acts as a guideline for building owners, authorities and professionals to apply the existing standards in the field of energy efficiency to the specific requirements of historic buildings. It proposes and describes a systematic procedure for improving energy performance of historic buildings and, in particular, the assessment and selection of the appropriate measures that match the requirements of the building in question.

The standard provides a number of assessment criteria in the following categories:

- Technical compatibility
- Heritage significance of the building and its settings
- Economic viability
- Energy
- Indoor environmental quality
- Impact on the outdoor environment
- Aspect of use

In the course of IEA-SHC Task 59, the criteria of the standard have been specified in detail in order to conduct a detailed assessment of the individual topics. The aim is to show how the assessment criteria should be applied and to convey the scope of such a detailed assessment. The following chapter contains the adapted and detailed assessment catalogue for the renovation of historical external walls. Further on, the criteria catalogue is presented and exemplified in chapter 2.4.2.2 with the help of some practical examples.

2.4.2 Detailed Assessment of ventilation systems

2.4.2.1 Detailed Assessment criteria catalogue for ventilation systems

2.4.2.1.1 Technical compatibility

Description of the technical compatibility of the solution in the historic building. Are there some problems when installing this solution?

Hygrothermal risks

In principle, the hygrothermal risks are reduced by the integration of a ventilation system and the associated permanent dehumidification through exchange with dry external air during the cold winter months.

Nevertheless, when installing ventilation systems, care must be taken to ensure that no excess pressure is created in the room (Balance adjustment). This would lead to the possibility of warm humid air being squeezed into the construction and causing condensate. For this reason, the selected system should be examined for possible problems in this context.

Biological risks

As described in the criterion above, the building's dehumidification must be checked. If the moisture loads in the construction or in the interior are too high, mould may occur. In this context, the use of membrane heat exchangers (enthalpy heat exchangers) must also be assessed. In case of unfavorable outside air conditions, excessive humidification of the supply air can occur, especially in the transitional periods.

Robustness/Buildability/design/Application

Is the solution robust and buildable? Are there special requirements in design or application? How susceptible to errors is the solution during the installation.

Thermal bridges/Connection

Is there a risk of thermal bridges when installing this solution? Are critical wall penetrations planned or are there wall-integrated systems? Thermal bridges must be checked in this context.

Reversibility

Is the solution completely reversible or can the intervention be considered as highly sustainable and compatible? All necessary openings are irreversible. The solution must be checked for its number and size of breakthroughs and its compatibility with the historical building fabric. Are existing chimneys or shafts usable? The possible use of already existing shafts and openings has a positive effect on the reversibility of the solution. In this context, ventilation concepts should be compared when choosing between different solutions.

2.4.2.1.2 Heritage significance of the building and its settings

Description of the Heritage significance of the building and its settings. Are there some problems when installing this solution?

Material, constructional, structural impact

Is there an impact in the material, the construction or the structure when installing this solution?

The fact that a ventilation system is made of new materials and is installed in addition to the existing system, there is always a certain impact. In this context, however, the materials used should be coordinated with the overall concept of the renovation and evaluated.

Architectural, aesthetic, visual impact

Is there an architectural, aesthetic, visual impact when installing this solution? In this context, the nature of the optical influences must be examined. Can the solution be shown openly as part of a renovation, or can it be integrated into the new architectural concept by using certain materials? E.g., conscious presentation of the new ventilation (spiral ducts in loft etc.). Does the solution have to be installed invisibly and is integration possible in this context (use of hollow spaces in ceilings etc.)? How invasive is the solution (number of necessary ducts, size of the ventilation unit)? All changes to the inventory must be considered. How can supply and exhaust air be integrated into the external appearance. Are overflow openings between the rooms necessary (e.g., cascade ventilation, active overflow, etc.) How to design or integrate the supply and exhaust air grilles? Are suspended ceilings necessary and compatible with historical values.

Spatial impact

Spatial influence can occur during integrating a ventilation system under the following circumstances: 1) is a suspended ceiling necessary? 2) Are rooms used for the installation of the ventilation unit or is there enough space for it?

2.4.2.1.3 Economic viability

Capital costs

How high are the expected capital costs? The costs for planning and installation have to be considered. The costs can vary in the areas of material (pipes, equipment, etc.), installation costs and constructional necessities (breakthroughs, suspended ceilings, overcurrent openings, etc.). The direct cost of installing the solution and the economic savings will be evaluated (prior to installation). The capital cost could also be expressed using a monthly credit payment considering the cost of the credit at the moment as most of the building's owners will need such arrangement. This will also permit to compare the monthly economic saving with the credit payment.

Operating costs, including maintenance costs

How high are the operating costs and the maintenance costs (required electricity for fans, maintenance costs for filters and on the unit, possible cleaning by qualified personnel)?

Economical return

Consideration of heat recovery, possible costs for dehumidification devices in case of increased requirements. Also, the increased living comfort must be considered in this connection. The calculation of the economical return should be based on the overall levelized cost. It begins with the capital cost as defined in the capital cost section plus the cost of the credit if needed. Then the discounted cost of the expected operating and maintenance cost on a fixed period (usually 30 years) are added. The economy on the energy bill has to be calculated considering a scenario of an increase in the purchase price. This scenario has to be stated. The economical return has to be compared with the expected service life.

Two kinds of calculations could be performed: with or without public subsidies. **Reference (norm ISO 15686-5)**

Economic savings

Is there an economic saving over the live cycle? To assess the economic savings, one most perform thermal simulations of the buildings before and after the retrofitting. The main savings with ventilation is in the recovery of heat, although this never justifies the investment costs from an economic point of view.

With the topic ventilation must be considered other points of evaluation however which cannot be seized in costs. By ventilating the living comfort is increased and the damage potential at the building reduced.

2.4.2.1.4 Energy

Description of the energetic performance of the solution in the historic building. Are there some special effects to considerate?

Energy performance and operational energy demand in terms of primary energy rating (total), primary energy rating (non-renewable), primary energy rating (renewable)

Mainly the required power for the fans is considered in this context. Can the electricity be covered by renewable energies (e.g., photovoltaic) in the course of the refurbishment concept?

Life cycle energy demand in terms of use of renewable primary energy and non-renewable primary energy

The LCA analysis' result (if available) is evaluated. In the LCA calculation all the stages of the life of the product are considered: from the raw material extraction, through the material manufacture, to the disposal or recycling of the product.

2.4.2.1.5 Indoor environmental quality

Maintaining the desired level of indoor environmental quality and user comfort is the prime objective of most buildings. The indoor environment shall be suited for the intended future use of the building. A poor indoor environment may be a reason to improve the energy performance of a building.

Indoor environmental conditions suitable for building content preservation

Especially museums often have special requirements for the control of temperature and relative humidity. In this context, the requirements for the content of the building must be defined and checked. Is the ventilation system suitable for possible control according to the requirements for temperature and RH?

Indoor environmental conditions suitable for building fabric preservation

Especially in cold climates, the ventilation removes moisture from the interior. In connection with other renovation measures such as interior insulation, increasing air tightness by replacing windows etc., the room conditions achieved must be checked.

Indoor environmental conditions suitable for achieving good occupant comfort levels

As mentioned in the previous point, in cold climates the air is dehumidified by ventilation. Depending on the number of occupants or persons staying in the building, the ventilation concept has to be designed (e.g., air exchange rate of approx. 30 m^3/h and person). If the air is too dry, moisture recovery should be checked. Ventilation also removes other pollutants such as VOC or radon. Increased loads or requirements must be checked in this context.

2.4.2.1.6 Impact on the outdoor environment

Emission of other harmful substances

Ventilation also removes other pollutants such as VOC or radon. Increased loads or requirements must be checked in this context.

2.4.2.1.7 Aspects of use

Influence on the use and the users of the building

How does the integration of a ventilation system affect the user? Especially the ventilation behavior must be considered in this context. If the thermal envelope is renovated, the air tightness of the building is also increased. If the system is integrated into an already renovated or airtight building, it is no longer necessary to ventilate the building several times a day. The behaviour during the warm months should also be checked. Is a post-ventilation possible if the system is operated in summer? Furthermore, the system should be checked for possible problems with drafts or noise. Especially drafts can be caused by faulty planning or faulty installation.

Consequences of the change of use

Is the ventilation and in particular the air exchange adjusted to the type of use? The moisture balance depends on the type of use and the number of people. In an office, for example, far greater moisture loads occur due to the larger number of people in the room than in a living room.

Ability of building users to manage and operate control systems

How is the system controlled? Is it easy to understand or is extensive training necessary? Is there an automatic control by sensors, if so, how is it maintained?

2.4.2.2 Detailed Assessment example of ventilation system

In this section the assessment of an active overflow system is demonstrated and examined in detail using a fictitious refurbishment case as an example. Due to the wealth of information that is requested in the course of a detailed assessment, it is necessary to relate the information to a specific case. The aim is to show how the assessment criteria should be applied and to convey the scope of such a detailed assessment.

figure 112: similar farmhouse in Tyrol as described in the fictional example. Source: Alexander Rieser

The fictitious refurbishment case is represented by a farm building in Tyrol from the 18th century. Shortly after the end of the Second World War, a cellar was built. The entire farm was built with timber block construction (log walls) and has an average room height of 2.40 m in the living rooms. The attic is not a finished living space and contains roof trusses within an unconditioned space. The building is not a listed building but is subject to local heritage protection of the village. In order to enable contemporary use, the building will be thermally upgraded. Due to the protection of the historic appearance of the village, the external appearance of the building is not allowed to be changed. In order to guarantee at least a room height of 2.40 m and thus maintain the parapet heights of the windows and the external appearance, the wooden ceilings are only structurally strengthened and not extended by any additional depth in the floor construction.

2.4.2.2.1 Technical compatibility

The category "technical compatibility" assesses the solution for various risks in connection with the building structure and feasibility.

Hygrothermal risks: Ventilation generally has a positive influence on the structure and materials of a historical building. Excess moisture loads are removed through the exchange of air. Like any other classical ventilation system, the active overflow system also has to ensure the required air exchange in order to achieve the desired relative humidity. With an active overflow system, the exchange of air between rooms must be implemented. This can be achieved by leaving the interior doors open or by increasing the air flow rate through active transfer. However, the system must be designed to ensure that no significant overpressure is created in ventilated rooms by the overflow fans. As a result, moist warm air could penetrate the construction via leaks, condense and cause damage. To avoid this, the flow direction of the active overflow should be chosen from the room to the mixed air room.

Biological risks: Depending on the design and construction, biological risks can arise from the above-mentioned overpressure. In the case of the wooden construction, presented in this example, special attention must be paid in this regard. Through the thermal refurbishment of the external walls, a higher airtightness level is achieved which must be verified by a blower door test.

Robustness/buildability/design/application: Due to the typical arrangement of the rooms of agricultural buildings in Tyrol, the corridor is well suited to be used as a distribution zone, the so-called "mixed air room" (Figure 8). The main access for fresh air is from the attic via the existing chimney of the smokehouse. The installation of the active overflow units must be coordinated with the appearance and structure but can be integrated into the interior doors and in the internal log walls. For this reason, no special structural knowledge or conservation skills are required, but a certified system should be selected for the overflow units.

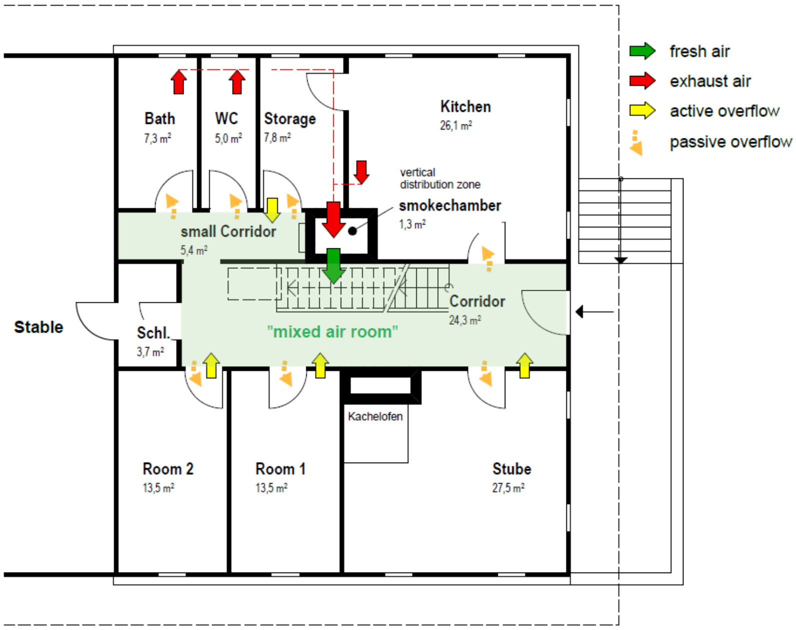


figure 113: Example of an active overflow system based on a typical floor plan in Tyrolean farms. The vertical distribution of the air takes place via the continuous former smoke chamber.

Thermal bridges/connection: Due to the installation of the ventilation unit in the unconditioned attic no thermal bridges are created by the penetration of the insulated ceiling.

Reversibility: The system is not completely reversible due to the penetrations made for piping of the supply and exhaust air channels and the openings for the active overflow units.

2.4.2.2.2 Heritage significance of the building and its settings

Different impacts of the building's materiality, appearance, and proportions regarding aspects of historic preservation are investigated.

Material, tectonic, structural impact: The active overflow system has a minimal impact on the structure of the existing building. Penetrations for supply and exhaust air must be taken into account. The fans of the overflow system require a power connection which must be hidden within the wooden walls. Possibilities for this are the placement of cables in the skirting boards as well as a hidden routing of the cables in the door frames.

Architectural, aesthetic, visual impact: This solution is particularly beneficial from an architectural point of view. Only one air supply opening for the ventilation unit is required on the facade. This opening can be integrated into the façade in different ways such as hidden by wooden grilles in the ridge region. In the northern hemisphere care must be taken to install the air intake opening on the north facade to avoid the intake of very warm air in the summer months. Due to the limited number of supply and exhaust air openings, with proper design attention there are hardly any visual impairments (Figure 9). Thus, these openings must be included in the refurbishment concept in order to be installed such that they are as hidden as possible. The primary challenge is the integration of the active overflow units. However, there are a number of solutions to integrate them into the design concept while maintaining the historic fabric. Various solutions to integrate the units in walls and doors are available on the market. In the example of a historic farmhouse the fans can be integrated quite well into wooden log walls. Old wood covers can be integrated into the architectural concept. Noise protection should also be considered.

figure 114: Integration of an exhaust air opening in a typical suspended wooden ceiling as commonly found in Tyrolian farms. Source: Michael Flach

Spatial impact: Starting with the vertical hidden piping in the existing chimney, a solution for the air supply openings must be considered. Flat ducts can be integrated between the beams of the wooden ceiling and hidden by a second wooden cover at the bottom to match the look of the existing wooden soffit. An air intake opening coming directly from the unused chimney of the smoking chamber would also be a possibility if it is concealed by a suitable wooden grille.

2.4.2.2.3 Economic viability

Capital costs: Due to reduced supply air ductwork, less silencers and supply air inlets, the capital costs are low for a mechanical ventilation system.

Operating costs, including maintenance costs: The total electricity costs of the active overflow system are approx. 20-30% higher, depending on the floor plan configuration, compared to a standard heat recovery system. The reason is the higher flowrate for the mixed air zone (only partly compensated by the lower pressure drop of the supply air duct system) [6573] (p.77).

Economical return and savings: Economically, there is almost no significant savings when compared to the existing building before refurbishment, the advantage is the reduced visual impact on the historic building while increasing comfort and IEQ. The main savings with mechanical ventilation is in the recovery of heat, although this by itself would not justify the investment costs from an economic point of view. The topic of mechanical ventilation must be considered within the context of other points of evaluation such as heritage value, which cannot be easily quantified in terms of economic costs. By integrating active ventilation, the indoor comfort is increased and the damage potential due to moisture accumulation in the building is reduced.

2.4.2.2.4 Energy

The higher the air exchange rate through active transfer, the lower the global air exchange rate (air exchange rate of outdoor air and indoor air) of the system can be. This should be taken into account especially in the winter months as too high of a global air exchange rate can result in air that is too dry. Due to the higher air exchange rates used in active transfer, a higher energy demand results from the fans. By installing a heat recovery system, the ventilation system provides a considerable contribution to improving the energy efficiency of the building.

2.4.2.2.5 Indoor environmental quality

Indoor environmental conditions suitable for building content preservation: In the example case there are no special objects, paintings or other furnishings that require very controlled climate conditions.

Indoor environmental conditions suitable for building fabric preservation: Thanks to the new ventilation system, high moisture loads in the building can be controlled and avoided. Especially in combination with internal insulation, this ventilation solution represents a decisive advantage and is recommended due to the increased air tightness resulting from the refurbishment measures.

Indoor environmental conditions suitable for achieving good occupant comfort levels: This point can be answered in general terms. The controlled air exchange not only removes excess moisture from the rooms but also other indoor air pollutants such as particle matter, VOCs (Volatile Organic Compounds) and radon.

Emission of other harmful substances: There are no risks to be expected with regular maintenance of the filters and the system. Harmful substances from indoor air are diluted by the mixing of fresh air controlled by the air exchange rate.

2.4.2.2.6 Impact on the outdoor environment

The heat recovery system saves energy which has a direct positive effect on the CO2 balance of the building. The installation of a ventilation system also makes sense in order to improve the function and durability of the building.

2.4.2.2.7 Aspect of use

Influence on the use and the users of the building: As the general name of a comfort ventilation system suggests, ventilation increases the living comfort for the user. It is no longer necessary for the user to manually ventilate several times a day and hygienic air quality is also maintained at night.

Consequences of the change of use: The fans can cause noise pollution at high air exchange rates. For this reason, the maximum airflow rates through active transfer of 70 m3/h per room must be observed. Up to this airflow limit a sound level of below or equal to 23 dB(A) can be guaranteed.

Ability of building users to manage and operate control systems: The ventilation system must be correctly adjusted according to the number of occupants. The more people there are in the building, the higher the air exchange rate must be (at least 30 m3/h/person). Maintenance work such as filter exchange of the ambient air supply or extract air filters must be carried out by the occupant.