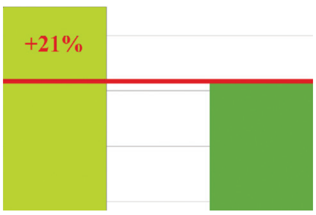
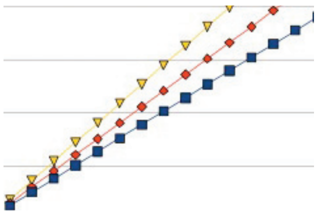
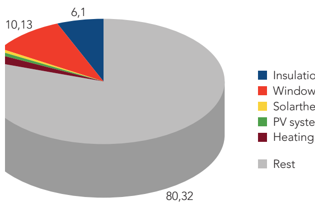
ENERBUILD Result 5.3

# Killer arguments and opportunities

March 2011

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EUROPEAN TERRITORIAL COOPERATION
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# Killer arguments and opportunities

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## Introduction

The project ENERBUILD stands for Energy Efficiency and Renewable Energies in the Building Sector in the Alpine Space. It deals with critical points in the dissemination of know-how on energy-efficient and energy-producing buildings. Key factors identified by the transnational consortium relate to vocational training, to additional research on user behavior, to role models in public construction, to financing of energy-producing plants on buildings and to the placement of sample planning processes around energy-efficient building.

This brochure deals with the critical attitude of builders towards the passive house. The aim is to address the arguments to analyze them and to comprehend them technical. The scientifically designed brochure provides detailed information on the arguments and is suitable for civil engineering education, as well as for general knowledge. This project part was substantially prepared by five institutes and coordinated by TIS-Techno Innovation South Tyrol. In the conviction that prejudice to the future-oriented building standards can be degraded with this base material we from the coordination office thank all involved project partners for the sound processing.

Regional Development Vorarlberg
Franz Rüf

The NENA network is an association of organizations involved in the project. The network provides experts in connection with the demand for talks, lectures and individual consultations. For more information: http://www.nena-network.eu

**Note on further results of ENERBUILD**

**Education**

- Overview of education programs and vocational trainings for energy saving and producing buildings in the Alpine Space

**Examination**

- Summarizing survey on existing buildings on healthy living with new and advanced construction technology
- Killer arguments and opportunities for energy-efficient construction and the passive house
- User habits, impact on energy consumption in passive houses - results of a comprehensive long-term measurement

**Efficiency**

- Certification of energy-efficient public buildings Summary of instruments in the Alpine Space
- Transnational comparison of instruments according to ecological evaluation of public buildings
- ENERBUILD Tool: Transnational Pilot Testing on 46 Buildings and Experiences on Advisory Services

**E-Producing**

- Synthesis on producing energy on buildings in the Alpine Space
- Green Electricity? - Yes, please! 100% local Green Electricity in combination with private funding for the development of power plants on buildings using the example of Vorarlberg
- Eco Power Stock Exchange – In-depth information for monitoring offices

**Innovation**

- The Alpine World of Innovation - A collection of innovative examples in planning processes, pilot initiatives and stimulation of innovation


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Published:
March 2011
Project ENERBUILD
Result 5.3

Alpine Space Programme
www.alpine-space.eu

# Killer arguments and opportunities

## Editorial

Even today in 2011 citizens living in passive houses are is still only a minority in relation to the total population. Although the awareness level of the passive house technology has increased enormously in recent years, there is a certain scepticism fuelled by rumours. As in many other areas of life, man treats the unknown with reserve. Criticism on new things has often many backgrounds. In the case of the passive house it somehow serves as a justification for those who have just built a house the usual way, for others it is the suspicion of new developments and, for a third group, the criticism of the passive house is meant to paper over their own ignorance.

Currently this can be experienced especially in discussions with architects and building professionals. Every criticism basically has its justification. The effort of information on further developments and improvements has caused it, at least it has secured knowledge.

Scientists have teamed up in the area of energy-efficient building and healthy living and systematically worked up the points of criticism. These scientific findings have been collected and analyzed in depth. The cross-border cooperation between the scientists of the ENERBUILD project showed some amazing results. By an in-depth analysis the problem area was more clearly defined and possible causes for criticism were pointed out. These are important statements for producers, engineers and construction managers.

Additionally, it is plausibly explained to the reader how the point of criticism might probably have come up and why it has become irrelevant in connection with the passive house and the state-of-art . The present study addresses both producers and raisers of passive houses as well as citizens who are involved in the issue, because they may intend to build a new home. So to everybody involved in constructing buildings we recommend dealing with the points of criticism and to let the arguments sink in. As the coordinator of the project ENERBUILD I would like to thank all active scientists who were committed to clarifying the points of criticism and to undercut the killer arguments. I would also especially like to mention the project partner TIS that supervised the coordination of scientific work, as well as EURAC, which summarized the content work and structural processing of the scientific contributions and finally all project partners that joined the elaboration. All in all, I am convinced that this study contributes to a high confidence in decision-making and so supports the dissemination of energy-efficient building.

## Summary

The report analyze some presumed problems of passive house concept finding killer arguments (in other word final arguments, facts, solutions proving the actual possibility to realize effective building) and/or opportunities (for enterprises and research centre) will be provided for each problem considered.

The above problems were faced considering both technical-scientific literature and case studies, in order to deepen both theoretical and practical aspects. The opportunities (of business for SME) are mainly based on promising technologies and questions still open.

The following issues were treated: ventilation &airtightness, heating&cooling, economics, architecture, daylighting and the name unattractiveness.

High performance buildings are airtight buildings, not only for purely performance reasons but also in order to satisfy other building physics requirements: air infiltration inside structures must be avoided to prevent condensation. The (questionable) trend toward smaller housings (and, hence more concentrated vapor releases) together with air-tightness is making ventilation a critical issues. Ventilation issue can be handled through a careful design that uses an integrated approach. The design process must continue through a good commissioning and an accurate maintenance (both ordinary and extraordinary). Many opportunities still remains for SMEs that would like to optimize the present systems, also dealing with control and overall house managing.

Passive Houses are buildings which assure a comfortable indoor climate in summer and in winter without needing a conventional heat distribution system. To permit this, it is essential that the building's heating load does not exceed 10 $W/m^2$. The small space heat requirement can be met by heating the supply air in the ventilation system. The standard has been named „Passive House" because the 'passive' use of incidental heat gains – delivered externally by solar irradiation through the windows and provided internally by the heat emissions of appliances and occupants – is essentially enough to keep the building at comfortable indoor temperatures throughout the heating period. Finally, to keep the desired indoor comfort conditions, when a good architecture was developed it is enough a good control of the heating (and/or cooling) system through appropriate measurements giving

the needed input to be elaborate to launch actions that allow to adjust the systems setting to face internal and external loads.

Although currently, energy saving in the building sector is the most diffuse sustainability issue, this subject is not well known and accompanied by a skeptical approach. Often the interest and sensibility for these arguments is rejected due to the economic aspects, where an investment appears too high and payback period too long. The carried out analysis process the measure of the economic life of this investment in terms of its payback period is 11 years. It means that the capital return per year from the start of the project until the 11 years of accumulated cash flow is equal to the cost of the investment. After that in 19 years it will be possible to have a profit equal to an initial capital.

Is it more attractive to buy the apartment in energy performance A or B? Considering that the lifetime of a building is equal to 50 years and reasonable payback time for this type of investment is 25 years, the choice of a real estate in ClimateHouse standard A rather than Climate House standard B is profitable.

In discussions about Passive Houses, often an image of a high-tech house, with no heating and very little freedom to design, comes into mind. Since a Passive House is meant to achieve certain goals by following certain rules, this seems to also become the main direction for the design, its architecture and aesthetics. The aesthetics of a passive house depends a lot from the technological solutions used to save energy, such as iper-insulation, size and position of windows, composition, kind of roof, etc., but, as many publications show, the variety of Passive Houses designs is great. It is up to planners, architects and advisors to find the best balance among architectural solutions (building aesthetics, functionality, composition) and energy efficiency. There is the big opportunity to promote Integrated Design Process with two main needed professional skills: IDP facilitation (managing the process, from concept to continuous commissioning), dynamic energy simulation (quantitatively supporting the process).

As Passive Houses often rely on passive solar gains through their windows to reduce the heating demand, in general, they should be equipped with accordant glazing that also provides good day lighting. If the window surfaces are large, they can collect solar gains well, but the same instance could also result in seasonal overheating. Therefore, a thoughtfully designed shading system in connection with precise application of matching glazing qualities could provide adequate heat protection, while keeping energy inside. Designers can use architectural (building shape, windows size, interior wall, etc.) and building (plaster painting) choices to better transport the light inside the building. Right balance among window surfaces, reveal finishing, Ug, g-value and Tv allow to achieve good illumination level while keeping very high insulation level. SMEs can find business opportunities developing cost-effective solar tube: collector, funnel, emission point that reduce space need on the roof and for light distribution.

## Objective

Main goal of this report is to scientifically analyze some presumed problems of passive house concept, in terms of its „Not effectiveness". Killer arguments (in other word final arguments, facts, solutions proving the actual possibility to realize effective building) and/or opportunities (for enterprises and research entities) will be provided for each problem considered.

Several issues were analysed:

1. Ventilation
2. Heating and Cooling
3. Economic aspects
4. Architecture and aesthetics
5. Air tightness
6. Daylighting

For the success of this study  all the Partners involved gave a great Contribution. They are:

1. EURAC - Italy
2. VLBG - Austria
3. FH-Rosenheim - Germany
4. Lucerne University of Applied Sciences and Arts (HSLU) - Switzerland
5. Tis Techno Innovation South Tyrol - Italy

At the end a special thanks to  Helmuth Krapmeir a pioneer of Killer arguments in Passive house.

# 1. Ventilation

**Editor: Province of Trento**

## 1.1 General framework

High energy performance and high comfort buildings are today airtight and mechanical ventilated buildings.

Air tightness and mechanical ventilation are deeply linked: an airtight space needs as much as possible a controlled ventilation strategy in order to guarantee the minimum air change rate (comfort) and trying to reduce the ventilation energy losses. Mechanical ventilation systems (nowadays normally always with integrated heat recovery systems) are therefore the best technology in order to achieve this optimum conditions of the ventilation operation, thanks to:

- Air fluxes control in term of air temperatures, humidity and speed, air spatial distributions,
- Heat recovery system, that allows, in winter, the exchange between the warm air subctracted to the heated room and the incoming fresh air from the external environment.

On the contrary, in the building energy balance the electrical consumption of the mechanical ventilation machine has to be accounted. Furthermore, unexpected conditions of operation can lead to discomfort conditions and higher heating demand caused by the lack of flexible ventilation strategies.

Airtight buildings with mechanical ventilation systems are at present the reference for high standard building not only for purely energy performance reasons (reduction of the ventilation heat losses thanks to reduction of infiltration, controlled air fluxes and the heat recovery system) but also in order to satisfy other building physics requirements for better comfort and trying to avoid structures damages. For example, condensation problems are full documented and are deeply related with air change and humidity balance issue.

Therefore, the (questionable) trend toward smaller housings (and, hence more concentrated vapor releases) together with air-tightness is making ventilation a critical issues.

A class B rating can usually be obtained with natural ventilation (in practice exhaust fans in the kitchen and bathrooms and regular window opening).

Better ratings (class A and higher) require mechanical ventilation.

The correct ventilation rate is still an open question (according to Std. EN 15251 a value in the range 0,5-0,7 ach should be used for a residence with a 2,5 m high ceiling)

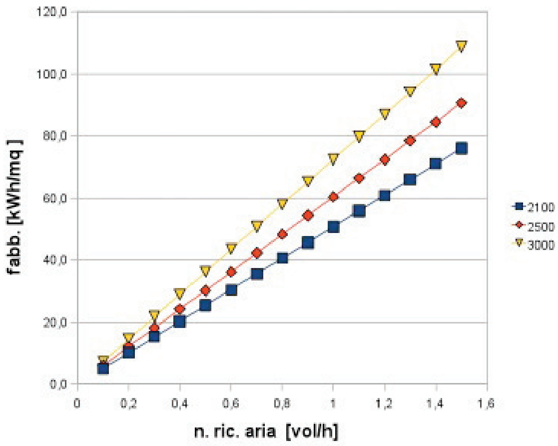


Fig. 1 Energy need vs air change rate and degree days reported in the graph legend

The „Passivhaus" concept suggests much lower values (around 0,3 ach), also in order to avoid the potential need for humidification in the German winter climate.

The effectiveness of a system, in general, can be defined as the ability of a system to have or cause a certain (desired) effect. The desired effect, or main objective, of a residential mechanical ventilation system is to remove airborne contaminants and supply clean fresh air to those parts of a room where it is needed (Sandberg, 1981; Sandberg and Sjöberg, 1983). Ventilation effectiveness can therefore be defined as the ventilation system's ability to remove airborne contaminants and supply fresh air to those parts of a room or dwelling where it is needed; i.e. in such a way that a good indoor air quality is created and maintained efficiently (Van der Pluijm, 2010).

The Passive House standard offers a cost-efficient way of minimizing the energy demand of new buildings in accordance with the global principle of sustainability, while at the same time improving the comfort experienced by building occupants (Schnieders, 2003).

If the PassivHaus core objectives are energy saving and comfort, the mechanical ventilation system (MVS) is one of the core solutions besides the high level of insulation. Ventilation should assure improved comfort conditions thanks to the controlled quantity and of incoming air and of its properties (in particular temperature and relative humidity). Therefore, stale internal air has to be exchanged with fresh outdoor air at regular intervals. This can definitely not be done by just opening windows twice a day. Ventilation principle will work accurately only if polluted air is removed constantly and in an effective way out of kitchen, bathrooms, and all other room with significant air pollution. Fresh air has to be supplied to the living room, children's room, sleeping rooms, and workrooms to substitute the removed air. The system will supply exactly as much fresh air as is needed for comfort and for good indoor air quality; only outdoor air will be supplied – no recirculated air. This will lead to a high level of indoor air quality. [www.passivhaus-tagung.de/Passive_House_E/ventilation_06.html]

Hence, a non effective ventilation system implies condition of discomfort, risk of structural damages (possibility of mould growth) and the increase of the energy demand. (Axel Bretzke, 2009)

User general common approach to mechanical ventilation systems is quite doubtful. The main issues related to the user distrust is mainly related to MVS design, usability, maintenance and flexibility. All these factors can push users in switching off the machine with - as a consequence - low quality of the incoming air (in terms of right air changes, spatial homogeneity in the internal target environments), internal discomfort conditions (low air temperatures, air dryness) and higher energy demand (higher ventilation losses).

At this concern it is interesting to refer to a Dutch research elaboration reported below.

Building engineers and public (occupational) health institutions initially were skeptical about the performance of this type of ventilation system. To address this skepticism, the municipal health office Groningen (GGD Groningen) performed a study to relation between indoor air quality and mechanical ventilation in 28 dwellings in Groningen and Zuidhoorn (Duijm and Meijer, 2002). This study showed that the system did indeed often not perform as intended. In most of the 28 dwellings the indoor air quality was poor. In 2006, after having received several health concerned complaints, the municipal health office Eemland (GGD Eemland) performed a similar study to the relation between health and ventilation in 99 dwellings in the district 'Vathorst' (Duijm et al, 2007). The publication of the results in 2007 and the 2008 broadcast of Zembla (current affairs show) concerning MVHR (Mechanical ventilation with Heat Recovery), can be considered to be a decisive moment in the previously rapid growing domestic application of MVHR systems. A study to occupants behavior regarding MVHR systems (Soldaat, 2007), a study to the relation between health complaints and mechanical ventilation (Leidelmeijer et al, 2009) and a TNO study to indoor environment in Dutch dwellings (Dongen and Vos 2007) all confirm the findings of GGD Groningen and GGD Eemland. The studies all show similar and structural causes for malfunctioning of the MVHR system. That is: a too low ventilation capacity due to the undesired use of the capacity level switch induced by noise nuisance; poor maintenance / dirty air filters; erroneous design, installation and setup of the system; and, the undesired use of the capacity level switch due to the perception of draft and the perception of a low relative humidity. In many situations these causes result in air flow rates that are too low to comply with the Dutch Building Codes or the advices of the Dutch Health Council (GR 1984) which again results in a poor indoor air quality. (Van der Pluijm, 2010)

On the other hand, several foreign studies show that the MVHR system can perform well, resulting in a healthy and pleasant indoor environment. As part of the research project CEPHEUS, a study to the indoor environment in over 100 passive houses in Germany, Switzerland, France, Austria and Sweden. was performed. There were no significant problems found with the ventilation system in relation to indoor air quality and thermal comfort (Feist, 2001) (Schnieders, 2003) it is reported that users often rate their ventilation system as good or excellent. (Van der Pluijm, 2010)

## 1.2 Analyses

**Not effective ventilation: problems and solutions summary**

| Presumed problems | Performance indicators | Causes | Killer argument (K)/ opportunities (O) |
|---|---|---|---|
| Cold Incoming air flow | Incoming air temperature | Lack of specific equipment (e.g. bypass) | **K:** Using natural ventilation the incoming air has the external temperature. Mechanical ventilation with Heat Recovery and By-Pass of the possible geothermal heat exchanger (earth duct) surely improve the situation from energy and comfort point of view.<br>**O:** a more flexible mechanic ventilation system should be planned - opportunities for designers education and MVS enterprises |
| Dry incoming air | UR in the room | Wrong ventilation design (air change rate), low internal humidity sources | **K:** Using humidifier<br>**O:** Develop compact machine integrated with Heat Recovery System to control also ai Humidity |
| High air speed | Room inlet air speed | Wrong designing of the ducts and / or of the machine | **K:** Ensuring to define a high quality design of the mech ventilation as a whole and for single components (HR, distribution ducts, vents, control system, fans, earth ducts and by-pass), also with prediction on operational matter and supported by CFD analyses for studying distribution of air flows.<br>**O:** Need of education modules on ventilation layout and components (for designers) and on their managing (users).<br>**O:** New compact machine including all the above features. |
| Not adaptable at changing loads | $CO_2$, T | Reasonable deviations from average occupancy against low flexibility in ventilation usage | **K:** Responsive systems<br>**O:** BMS with holistic approach considering loads and plants (HVAC) |
| Noisy equipment | Sound pressure level | Lack of acoustic insulation and of needed devices, bad designing of the duct flow. | **K:** Good design, commissioning and ordinary maintenance |
| Frequent maintenance | Number of maintenance activity | Machines needs specific/severe working conditions | **K:** Strict maintenance schedules for filter replacing is necessary in order to have high IAQ, but it costs less than the energy saved; for cases with operation conditions far out of the standard, a more precise designing and eventually additional components are needed<br>**O:** develop new materials and/or components to reduce maintenance needs, keeping high performances |

| | | | |
|---|---|---|---|
| Spatial homogeneity of the air change | $CO_2$, T, RH in different internal spaces | Wrong position/typology of the diffusers/vents in relation of the spatial geometry. Air plants and system designing not coupled with the internal architectural choices. | **K:** Designers must take care of this aspect following in details the related standard and using also specific tools (CFD software)<br>**O:** innovative vents configuration and distribution approach. |
| Efficiency of heat recovery system | Efficiency | Confusion caused by different calculation methods | **K:** Calculate effectiveness in actual working conditions<br>**O:** enhanced heat exchangers |
| High power consumption | Yearly energy consumption for ventilation | Ventilation machine needs electricity to work | **K:** consumption is very less than the thermal loss reduction |
| Interference with other combustion equipment | Incoming air quality | Wrong design | **K:** Interference with other combustion equipment requiring fresh air supply and exploiting „stack effect" to evacuate flue gases, especially in mountain and rural areas (gas fired kitchen ranges, fireplaces, wood burning stoves) |

## Cold incoming air flow

### Problems description and actual facts

Situations of cold incoming air flow cause normally a double negative effect. By one side there is the discomfort condition for users, by the other the increase of the energy heat demand for the need of air post heating (with a compact mechanical ventilation system or with a traditional heating system).

In general, the air regulation level achieved with a mechanical ventilation system with heat recovery should guarantee an optimal heat exchange between the exhaust air and the fresh incoming flow. In other words, the incoming air temperature should be high enough for comfort conditions. Nevertheless, if the ambient temperature is not in the comfort ranges, the heat recovered can be not sufficient in order to heat up the incoming outside air up to a comfortable temperature condition. Therefore, the need of an air post-heating or of an „active" heating device (radiators, radiant systems)is arised. In particular, in case of absence of air post-heating devices the discomfort condition could lead the users to switch the machine off, causing for example selfmade natural ventilation strategies (again discomfort and increasing of heating demand).

An example of the described conditions has been reported during a monitoring project carried out by Eurac Research in a residential retrofitted house that achieve high energy standard in Bolzano (Italy) (M. Zani, 2008) (Mahlknecht, 2010. Data show a inlet air temperature in average 2-3°C below the room temperature in winter. Also feedbacks from the users pointed out the need to switch off the ventilation device in order to keep the comfort conditions. In the analyzed air plant, a geothermal horizontal heat exchanger is used in order to pre heat (in winter) and pre cool (in summer) the outside air. The presence of this device without bypass can create unfavorable situations (middle seasons) when the mild external air is cooled down. The temperature step between incoming air and design inlet air temperature cannot be covered by the heat recovery. These behaviors create discomfort and therefore a not effectiveness of the ventilation system.

Hence, there can be critical periods during which the design conditions are not realized and the internal temperature does not allow an adequate heat exchange between the fresh air and the exhaust air.

### Killer arguments (K) and opportunities (O)

**K:** The presence of a air post-heating device avoids the discomfort condition. This device can lead to unexpected extra heating demand caused by ventilation.

**O:** The described problems and conditions create an opportunity for house and air plants designers. Detailed analyses in the transient regime can highlight critical condition leading the designers to other design choices.

O: Finally, the ventilation air plant should be planned flexible as much as possible in order to face internal and external load variations without influencing the internal comfort. For example, the use of bypass (or post heating) and controlled valves allow the use of the geothermal heat exchanger just when the conditions are favorable.

## Dry incoming air

### Problems description and actual facts

A low relative humidity (RH) is a general problem in winter for dry-cold climates in heated spaces. The problem is physically originated when cold external air with a not so high humidity content (absolute humidity) get into a warm environment. The relative humidity falls causing the perception of dry air (for persistent heavy conditions health problem can be caused)

This problem can be a persistent situation in Mechanically Ventilated (with Heat Recovery) dwellings. However, experimental tests and monitoring data shows that is not a problem directly caused by the presence of the MVS as shown in the analyses of Van der Pluijm (Van der Pluijm, 2010).

In the monitored cases, measurements in the occupied dwelling show that the RH is frequently low (< 30%). It must be mentioned that in the coldest period (mid December to mid January) the air flow rates are 15-50% lower than required by the Building Codes (n.d.r. Holland). On the other hand, in the same period the indoor temperatures are considered to be high in both the living room and the sleeping room. The feedback of the occupants showed that the perception of dry air could lead to intentionally lowering the ventilation capacity using the capacity level switch. A low RH is a persistent problem that could affect ventilation behavior and therefore the effectiveness of MVHR. The moisture balance however shows that this is not specifically caused by the MVHR system, but that it is a product of air flow rates, moist production and indoor and outdoor temperatures.

Relative humidity can get very low, but this is not a problem directly related to MVHR. The effect of a low RH however, can be the undesired use of the capacity level switch. (Van der Pluijm, 2010)

### Killer arguments (K) and opportunities (O)

K: The problem of dry air winter condition is a problem generally affecting all heated spaces in winter for cold dry external conditions. The problem can be studied in design phase for static and transient conditions and can be solved thanks to with humidity control devices.

O: The highlighted problem lead to some opportunities for the research entities and the enterprises operating in the Building Management Systems (BMS).

- Replacing the capacity level switch by an automated process could be a solution. However, research to the effect of the inability to be in control of the system on user behavior / appreciation of the system is needed.
- Allowing a lower indoor air temperature by applying radiant heating instead of high temperature radiators also has a positive effect on RH. (VanDerPluijm, 2010);
- Use of ventilation machines with humidification devices;
- Installation of plants and flowers increasing the internal humidity sources.

## High air speed

### Problems description and actual facts

One of the typical problem in a mechanical ventilated system is related with the internal air velocities that can be perceived high in the living zone and will lead to discomfort conditions. Also in this case, experimental tests and monitored data have been collected and analyzed by Van der Plijim (Van der Plijm, 2010)

### Killer arguments (K) and opportunities (O)

K: The presence of standards and best practice as well as experimental data shows that the air speed problem can be fully avoided. Even though several studies show a relation between the presence of MVHR and complaints regarding draft, the measured air velocities in the living zone did not exceed the criterion of 0,2 m/s for any of the measured variants. The perception of draft however varies from person to person and depends besides the air velocity also on air temperature and turbulence intensity.

O: Nevertheless, minimizing the possibility of perceivable air velocities in the living zones must be taken into account when designing a MVHR system. Therefore the type of supply valve (low inducing), the positioning of supply valves and air flow rates per valve must be well designed. This let a great opportunities to designers and technical education entities in order to provide the right competences and knowledge. Therefore, air velocity problems can be easily avoided thanks to a better designing.

## Not adaptability at changing loads

### Problems description and actual facts

Effectiveness of mechanical ventilation systems could be primarily related to the ability to remove airborne contaminants and supply clean fresh air to those parts of a room where it is needed. Starting from this commonsense, caused by a non-continuous variation and adaptability of the ventilation machines provided air flows, a not effective removal of the pollutants in the indoor environment can be registered especially in conditions of overcrowded apartments.

A first experience of this problem comes from the detailed studies of the TU Eindovehn (Van der Plijm, 2010). In both the test dwellings the ventilation capacity did neither comply with the ventilation design nor the Building Codes at the start of the measurement period (September 2009). Based on the measurements by N. van Erk (Erk, 2009) in September 2008, the air flow rates did also not comply with the design and the Building Codes after the initial construction/installation delivery (before the Hybalansplus distribution system was replaced - table 2.3). It must be mentioned that the distribution system (central distribution unit in the attic and fixed supply and exhaust valves at the end) is relatively new in the Netherlands. At the end of the measurement period, after several modifications / reconfigurations of the MVHR systems in both dwellings, the set capacities and resulting $CO_2$ levels are considered to be acceptable. Hence, based on the measurements in the test dwellings and the information from literature concerning the problems with MVHR in the Netherlands, the recurring problem of insufficient ventilation capacity in MVHR ventilated dwellings is not a technical shortcoming of the ventilation system itself; however, installer's expertise and solid installation qualification procedures are indispensible for MVHR to be successful. (Van der Pluijm, 2010)

Besides this, occupancy levels can affect the effectiveness of ventilation. According to the Building Codes (n.d.r.in the Netherland) design of air flow rates is based on the floor area of a room. Deviations from average occupancy levels are therefore not accounted for. (Van der Pluijm, 2010)

Another experience has been performed by the Eurac Research within the monitoring activity of the first social PassivHaus in Italy (Castagna, 2008). The monitoring campaign has shown that for the flat with inhabitants higher than the planned number, the average of the $CO_2$ concentration is higher than the other apartments. Furthermore, user behavior lead in winter to open the window causing higher energy consumption and higher discomfort for the presence of important mass of cold air coming from the outside.

### Killer arguments (K) and opportunities (O)

O: One of the biggest limit of the MVS is the lack of high flexibility in responding to unplanned conditions, e.g. users presence higher than the planned one. An opportunity for ventilation machine builders is in the direction of the creation of more flexible machines.

O: Secondly, occupancy levels based products such as an intelligent capacity distribution system (manual or $CO_2$ based) or user-friendly building control systems could be solutions in the future.

O: Finally, designers should invest planning time in the verification of the reference norm limits also in operation conditions out of the designed ones.

## Noisy equipment

### Problems description and actual facts

Noise nuisance is a persistent problem in MVHR ventilated dwellings.

The Dutch experience (Van der Plijm, 2010] states that in the occupied test dwelling high installation noise levels proved to have a negative effect on ventilation behavior. Over the period that noise nuisance was mentioned as a problem, the occupants ventilated at capacity level 1 for 93% of the time – supplying not more than 15% of the required amount of fresh air to the living room and less than 50% to the monitored sleeping room. After the latest system modifications / reconfigurations (table 2.3) the criteria $L_{I;A} \leq 27$dB in the sleeping rooms and $L_{I;A} \leq 30$dB in the living room of the unoccupied dwelling are satisfied (air flow rates conform Building Codes). After similar adjustments to the system in the occupied dwelling the complaints regarding noise nuisance disappeared. Based on the measurements in the unoccupied test dwelling, feedback of the occupants and the information from literature concerning the problems with MVHR in the Netherlands, installation noise of MVHR systems seems to be a significant and recurring problem. (Van der Pluijm, 2010)

### Solutions: killer arguments and opportunities

K: High noise levels can be caused by an erroneous configuration or design of the system; however, there is no indication that the problem is insuperable by implementing standard measures. Installation qualification procedures and installer's expertise again are considered to be indispensible to avoid high installation noise levels. (Van der Plijm, 2010) O > This can be considered as killer arguments even if it opens to further opportunities in the practitioners and designers education sectors.

# 1. Ventilation

Editor: Province of Trento

## Maintenance

### Problems description and actual facts

A MVS represents an important component in the maintenance list. The machine has to work as regularly as possible in order to guarantee the desired internal conditions. One of the most frequent maintenance action to be performed concerning MVS is the cleaning/replacement of the air filters. In case of dirty conditions the machine can perceive a pressure drop higher than the standard level until the stop of the machine.

The LED indication for filter replacement should provide to the users of the system the information regarding the status of the filters. Often the ventilation machine status is not adequately readable and the maintenance requirements clear for the users. Therefore, stand-by conditions of the machine are often registered. Furthermore, if no feedback is given by the system it is not unlikely that problems with the prompt replacement of the filters could occur.

### Killer arguments (K) and opportunities (O)

**O:** An opportunity for enterprises in the field of the MV machine exists in terms of developing of smarter alarm system and filters materials.

## Spatial homogeneity of the air change

### Problems description and actual facts

The air paths in rooms of a dwelling is not homogeneous due to variations in system-properties or to room-geometry. The air distribution within the internal environments and therefore the comfort perceived by the users in different positions can be strongly different. The problem cannot be generalized due to the infinite number of differences in systems and houses internal geometries. Nevertheless, it is important to highlight known problems and possible strategies for solutions.

Also this problem has been studied by the (Van der Plijm, 2010) thanks to the use of an experimental test-bench. The air flow pattern visualizations show that the mechanical supplied air mixes well with the present air in the sleeping room. The smoke tests in the living room of the unoccupied test dwelling confirmed this. With the efficiency measurement in the living room of the unoccupied dwelling and the variant study in laboratory a quantitative measure of ventilation efficiency is obtained. At least for small rooms it can be concluded that the ventilation efficiency is robust for changes in system properties and room-geometry. For larger and more complex rooms more research is required. The variant study in laboratory showed that neither the closet in front of the supply valve, the varied air flow rates, the different positions of the supply valve, the type of valve nor the decreased supply air temperature affected the age distribution of air in the room.

### Killer arguments (K) and opportunities (O)

**K:** Standards and tools exist and should be used during the design phase in order to deeply study the main flow paths and possible critical comfort conditions in the whole internal conditioned space. The killer argument is that best practice and research studies can show reliable methods of designing air inlets and internal use of the space.

**O:** What is missing, and therefore what can be an opportunity for designers, is on the one hand the use of software for the detailed evaluation of the airflow paths and on the other hand the interaction with internal space designers in order to develop solutions coherent with the ventilation devices (inlet and outlet).

## Efficiency of heat recovery system

### Problems description and actual facts

There are different methods of testing the efficiency of heat recovery efficiency. Dependent on the method the degree of efficiency is calculated supply-air or exhaust-air sided. Some methods consider the condensate, some don't.

The table on the right side gives an overview over three of the many different methods of testing and calculation:

Depending on the method the testing results differ. The testing of one product with all three methods explained above shows that the value differs significantly in the case of bad insulated ventilation machine boxes, but differs only slightly in the case of good ones.

As therefore there are testing procedures for mechanical ventilation systems which often produce unrealistically positive test results, the PHI recommends: If reliable measured values are not available, or a certificate is not presented, then the values should be calculated by subtracting 12% from accreditation test results.

An efficiency value of 75% can be used to calculate the efficiency of a counterflow heat exchanger in situations where accurate technical data are not available.

Crossflow heat exchangers have lower efficiencies. A value no higher than 50% can be used without more detailed measurements (PHI, 2007).

| Method | 1 | 3 | 4 |
|---|---|---|---|
| Norm | According to DIN EN 308 | According to Passivhaus-Institut PHI | According to DIPT (Deutsches Institut für Bautechnik DIBT) |
| Formula | $n_t = \frac{t_{22} - t_{21}}{t_{11} - t_{21}}$<br>$t_{22}$ = Supply air temperature<br>$t_{21}$ = Outdoor air temperature = 5°C<br>$t_{11}$ = Exhaust air temperature = 25°C<br>$tw_{11}$ = Exhaust air wet bulb temperature < 14°C<br>$\varphi_{Exh}$ ~28% r. H.; that means no condensate | $n_{HRV,eff} = \frac{\vartheta_{Exh} - \vartheta_{Outg} + \frac{P_{el}}{m * c_p}}{\vartheta_{Exh} - \vartheta_{Outd}}$<br>$\vartheta_{Outd}$ ~ 4 - 6°C<br>$\vartheta_{Exh}$ ~ 21°C<br>$\varphi_{Exh}$ ~25-28% r. H.<br>$P_{el}$ = input power blowers | $n_{HRV,eff} = \frac{\dot{H}_{Sup} - \dot{H}_{Outd}}{\dot{H}_{Sup} * - \dot{H}_{Outd}}$<br>enthalpy of exhaust air in case of humid outdoor air<br>MP = metering point<br>MP1: $t_{Outd}$ = -3°C, = 36%<br>MP1: $t_{Outd}$ = +4°C, = 46%<br>MP1: $t_{Outd}$ = +10°C, = 56%<br>at all MP: = 80%, $t_{exh}$ = 21°C |
| Efficiency calculated | Supply-air sided | Exhaust-air sided | Supply-air sided |
| Measurement | Dry – without condensate | Dry – without condensate | Humid – with condensate |
| Insulation casing | Casing at testing insulated 50 mm | - | - |
| | $n$ appears slightly better than in method 3 | $n$ describes here an effective value, which rises in case of humid exhaust air about 3 - 5% | $n$ appears significantly higher than in method 3 |
| Tightness | at 100 Pa: int. leakage ≤ 3%<br>at 250 Pa: int. leakage ≤ 3% | at 100 Pa: int. leakage ≤ 3%<br>at 100 Pa: int. leakage ≤ 3% | at 100 Pa: int. leakage ≤ 5%<br>at 100 Pa: int. leakage ≤ 5% |
| Relation released/ received heat | $P_1 = c_P * q_{m11} * \Delta t_{11-12}$<br>$P_2 = c_P * q_{m22} * \Delta t_{22-21}$<br>$0,95 \leq \frac{P_1}{P_2} \leq 1,05$ | - | - |

Source: www.paul-lueftung.net/downloads/erklaerungzuverschwirkungsgraden_091020.pdf

**Killer argument & Opportunities**

**K:** The different methods of calculation are generally well documented and each method lead to a different value of efficiency (differences are much higher for low performance machines).

**O:** The producer and tester SMEs should provide to the users methods and testing data with more clearness.

**O:** Designers and planner should consider always the differences in calculation in order to be as much as possible transparent with customers.

## High power consumption

**Problems description and actual facts**

The electric power consumption of the ventilation machine can be easily compared with the energy saving deriving from the use of the heat recovery system. In this calculation, the main role is played by the effectiveness of the heat recovery system (see discussion above).

Nowadays, high technology devices can assure very high heat recovery efficiencies. Starting from the technical data and applying a safety coefficient, an energy balance should be performed in case of sceptisim.

**Killer arguments (K) and opportunities (O)**

**K:** The condition of operation in terms of energy balance can be easily verified for each building. Nowadays the efficiency of the heat recovery (corresponding to the energy saving and to a huge reduction of the ventilation losses) can be considered around 75% (PHI, 2007).

**O:** Designers and energy performance evaluator should always consider the different methods of calculation of the heat recovery efficiency. A standard should be elaborated with the definition of a common way of calculation of the heat recovery efficiency for the building energy balance.

# 1. Ventilation

Editor: Province of Trento

## Interference with other combustion equipment

### Problems description and actual facts

Interferences with other combustion equipment requiring fresh air supply and exploiting „stack effect" to evacuate flue gases, especially in mountain and rural areas (gas fired kitchen ranges, fireplaces, wood burning stoves) can be found.

Normally these problems would affected also other ventilation strategies (natural ventilation) and therefore a deep analyses of the external environment should be performed before the building design.

Killer arguments (K) and opportunities (O)

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# 2. Heating and cooling

**Editor: PP4-FH- Rosenheim**

## 2.1 General framework

The Passive House standard offers a cost-efficient way of minimizing the energy demand of new buildings in accordance with the global principle of sustainability, while at the same time improving the comfort experienced by building occupants.

However, there are, in connection to the passive houses, always resist arguments against the operation of the heating-and cooling systems.

Heating system

The special in passive house is that they do not require an active system. Only a controlled ventilation system is necessary. Many consumers and same experts doubt that this works. On cold winterdays, it is not possible to heat only with the ventilation system. The room temperature will decrease. Especially room witch are oriented to the north direction. In this room the solar gains can not use completely.

Cooling system

With passive systems passive houses are also cooled. There are different techniques possible. Houses for private using you can use, for example, a ground heat exchanger. Some people doubt that this works. Especially on many hot days. The consequence would be that the rooms overheat. The occupants no longer feel themselves well.

The following lines will refute this arguments:

The passive house creates the basis on which it is possible to meet the remaining energy demand of new buildings completely from renewable sources. What makes the approach so cost-efficient? Following the principle of simplicity, it relies on optimizing those components of a building which are necessary in any case:

The building envelope, the windows and the automatic ventilation system (which is expedient anyway for hygienic reasons). Improving the efficiency of these components so that

a separate heat distribution system is no longer needed. This will reduce additional costs.

The term „Passive House" refers to a construction standard that can be met using a variety of technologies, designs and materials. It is basically a refinement of the low energy house standard. Passive Houses are buildings which assure a comfortable indoor climate in summer and in winter without needing a conventional heat distribution system. To permit this, it is essential that the building's heating load does not exceed 10 $W/m^2$.

The small heating load is roughly equivalent with an annual space heat requirement of 15 kWh/($m^2$a). Passive Houses thus need about 80% less space heat than new buildings designed to the various national building codes valid in 1999. The small space heat requirement can be met by heating the supply air in the ventilation system. The standard has been named „Passive House" because the 'passive' use of incidental heat gains – delivered externally by solar irradiation through the windows and provided internally by the heat emissions of appliances and occupants – essentially suffices to keep the building at comfortable indoor temperatures throughout the heating period.

It is a part of the Passive House philosophy that efficient technologies are also used to minimize the other sources of energy consumption in the building, notably electricity for household appliances(http://passiv.de/07_eng/news/CEPHEUS_ECEEE.pdf, 18.12.2010)

## 2.2 Analyses

**heating and cooling: problems and solutions summary**

| Presumed problems | Performance indicators | Causes | Killer argument (K)/ opportunities (O) |
|---|---|---|---|
| Not effective heating | Indoor temperature, living environment | Lack of expected heat gains (sun, internal gains) | K: Too cold in Winter because of inadequate heating.O: Building automation, control of ventilation systems and heating and cooling system of measurement sensors in the building |
| Not effective cooling | Indoor temperature, living environment | Overinsulation, low air change rates | K: Too hot in Summer because of excessive insulation (or other reasons…).O: Building automation, control of ventilation systems and heating and cooling system of measurement sensors in the building |

## Not effective heating/cooling

### Problems description and actual facts

Passive houses offer extended living comfort with only 15 to 20% of the space heating demand of conventional new buildings. This is achieved by improving the efficiency of building components, such as walls, windows or ventilation system, which are necessary in every building anyway.

Thus, the extra costs of passive house standard is only 100Euro/m² compared to a building that is built according to current legal regulations (http://passipedia.passiv.de/passipedia_de/grundlagen/wirtschaftlichkeit).

Some consumers are sceptical of this theory. They believe that this type of heating is not possible or not yet mature. Their arguments are:

- On cold winter days, it is not longer possible to heat the rooms on the ventilation system. The heat storage (transport) capacity of air is not large enough to cover the heat demand in each room.
- On hot summer days, passive houses in wooden construction tend to overheat. The reasons are excessive insulation or missing heat storage capacity in the exterior walls.
- A building does not work without active heating system.

Within the EU-funded demonstration project CEPHEUS (Cost Efficient Passive Houses as European Standards), 14 passive houses with 221 dwelling units have been built at different building sites, with different planners and users and of different construction types. In this paper, detailed measurements for 11 passive house projects are presented. All projects show extraordinarily low space heat consumption with an average during the first heating season of 20 kWh per square meter living area .

Compared with newly erected buildings that obey local legal standards, 80% of the space heat consumption could be saved. In addition, the total primary energy consumption (including household electricity) was less than 50% of that of conventional new buildings.

The mean room temperature in the heating period was 21.4°C. Even at very low outdoor temperatures the room temperatures did not go down significantly. The measurements show that the buildings also offer comfortable summer conditions. Indoor temperatures rarely rose above 25°C. Users were well pleased with the simple techniques used. Even with tenants in low-income housing the projected energy savings could be reached. A social research project showed a high degree of user satisfaction.

The graph shows the mean values of the measured indoor temperatures in winter. The values generally refer to the months of November to February. 07-Dornbirn was only occupied in late December 2000; here the temperature data are for January and February.

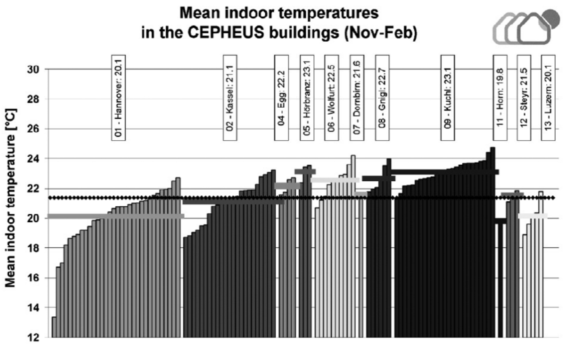



Fig. 2: Mean indoor temperatures in winter (generally from 1 November to 28 February).

The continuous lines shows the mean values of the individual building. The pointed black line shows the mean values of all buildings. The x - axis shows the time for the individual buildings.

Also the figure shows that in all CEPHEUS buildings the mean indoor temperature over all occupied zones and the whole measurement period was above 20°C. Occupants typically set temperatures between 21 and 22°C; the range of the occupied houses is, however, from 17 to 25°C (the mean temperatures below 17°C measured in 01-Hannover belong to unoccupied houses). When the insulation standard of a building is improved, a trend towards higher indoor temperatures can generally be observed: If the improved comfort is technically realizable at low cost, it is evidently also desired (http://passiv.de/07_eng/news/CEPHEUS_ECEEE.pdf).

### Killer arguments (K) and opportunities (O)

**K and O:** In essence, the arguments relating on the performance of the heating and cooling system. With the following measures these arguments should be refuted.

- Improving information flow between planer and user. The planners should receive detailed information on user behavior. So it will be easier to calculate the energy consumption.
- Creation of further training on the passive house. Integrated planning is particularly important for passive houses. All involved person groups should be trained in the basics of passive house calculating and implementing.
- Consumers will increasingly have the opportunity to test passive houses initially. To live in a passive house, is the best way to refute arguments killer. The residents can make their own option about „Living in a passive house".

# 3. Economic aspects

**Editor: TIS**

## 3.1 General framework

Currently, energy saving in the building sector is the most diffuse sustainability issue. Unfortunately, this subject is little known and accompanied by a skeptical approach. Often the interest and sensibility for these arguments is rejected by economic aspects, where an investment appears too high and payback period too long.

The possibility of an answer for the questions: ‚How much does high-performance building cost?' and ‚How long should it take for an investment to return itself?' could be very useful to convince the people choosing the buildings in high-energy performance solutions rather than another standard models.

In the first part, becoming from the analysis of various residential complex in the city of Bolzano, it has been chosen two types of apartment buildings (the volume around 20.000 m³) with different energy performance classification A and B, which are calculated according to ClimateHouse Agency's norms.

Starting from the output of previous work phase, it will be analyzed the construction cost of each buildings and the incidence of single technological components and also high-performance products on the total price.

Finally, it will be possible to compare the results of different energetic scenarios to establish a percentage difference between the construction costs of two building energy performance classification.

At the end, the payback period and break-even-point (BEP) will be calculated for an investment in high energy performance building.

The goal of the following analysis is to encounter presumed problems regarding costs and payback period and break-even-point (BEP) of an investment in high-energy performance buildings. The presumed problems are described and then compared to current facts and studies. Propositions for killer arguments, and/or opportunities are provided for each problem considered.

The following part of discussion deals with the methodology of choice and the comparison between buildings in energy performance classification A and B; construction costs of these building; incidence on the total cost of single energy performance technological components (walls, roofs, slabs) and products (insulations, high-performance windows etc.); percentage ratio derived from difference of costs between two building energy performance A and B classification, previously taken into consideration, and after that, the payback period and break-even-point (BEP) of an investment.

„Low energy buildings are known under different names across Europe. A survey carried out in 2008 by the Concerted Action supporting EPBD identified 17 different terms in use to describe such buildings used across Europe, among which the terms low energy house, high-performance house, passive house/Passivhaus, zero carbon house, zero energy house, energy savings house, energy positive house, 3-litre house etc. In the relevant literature additional terms such as ultra-low energy house can be found. Finally, concepts that take into account more parameters than energy demand again use special terms such as eco-building or green building.

Variations exist not only as regards the terms chosen, but also what energy use is included in the definition. Ideally, the minimum performance requirements should take into account all types of energy use that is demand for space heating (cooling), water heating, air conditioning as well as consumption of electricity. This is often not the case. On the contrary, the definition may cover only space heating ignoring all electricity demand that may cover most heating needs for instance in office buildings" (Thomsen/Wittchen, European national strategies to move towards very low energy buildings, SBI (Danish Building Research Institute, 2008).

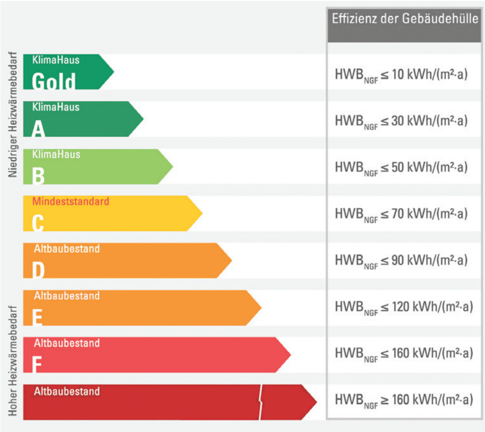
After this brief introduction that defines the concept of low-energy building, it is important to understand the interaction between the construction costs in the building energy performance classifications A and B.

The problem of a choice of ClimateHouse Standard A rather than ClimateHouse Standard B is essentially connected with the economic factor. The fact is, that the modern and sophisticated technological solutions are expensive and the possibility to achieve the well-being in own home, is to spend more money at the beginning. This statement often discourages the people to make an investment. Additionally, it creates a prejudice that the risk of an investments incurred by a customer, will not be amortized in the reasonable time. Furthermore, the presumed dilemma in a choice of a home in Standard A instead of Standard B also depends on others factors:

- desideratum thermal comfort level and well-being level;
- destination of real estate (rent or own propriety):
- difference between the energy performance A and B is not so noticeable.

„The housing sector requires specific measures, as it accounts for 40% of the overall energy used in Europe. However, there is a huge potential for decreasing this number, as it is shown by many initiatives.

In South Tyrol the KlimaHaus/CasaClima initiative motivates to build houses in an energy-efficient way. As a result, every newly built house consumes at the most 70 kWh (equivalent to 7 l of oil) per m² per year for heating. This is a 70% reduction with respect to the average consumption of the building stock.




KlimaHaus®
CasaClima

Fig. 1 Energy-efficient buildings in Tyrol obtain a certificate and a plaque.(www.klimahaus.info)

The success of the above mentioned certification is based on its implementation strategy.

This strategy stands on three pillars: the certification itself that awards energy-efficient houses, the education programme which is teaching planners and craftsmen the fundamentals of modern building and, last but not least, the marketing campaigns that have been able to communicate to the citizens the advantages of energy efficient buildings" (DietmarÜberbacher& Marcella MorandinÖkoinstitutSüdtirol).

## 3.2 Analyses

### 3.2.1 Methodology of choice and comparison

The objects of analysis are the apartment buildings in energy performance A and B classification, which are calculated according to ClimateHouse Agency's norms (UNI EN 823).

Among the various residential complex in the area of Bolzano, the number of buildings appropriated for comparison is very low.

The buildings fit for confrontation should have a similar parameters like:

- heating volume and area;
- area-to-volume ratio (A/V);
- number of apartments;
- orientation;
- similar period of construction;
- the same building energy performance classification;
- the same climatic zone.

Consequently, in Bolzano (South Tyrol, Italy), it was possible to have only one case of study, which compares two buildings from different residential zones: CasaNova (energy performance A certification) and Firmian (energy performance B certification).

In the following part will be described the principal characteristics of each buildings.

### 3.2.2 Casanova Project, Building EA8 b

| | |
|---|---|
| Gross heating area: | 6.660m² |
| Gross heating volume: | 20.866 m³ |
| Area- Volume - ratio: | 0,31 |
| Axis of orientation: | East-West |
| Number of apartments: | 55 |
| Customer | Ipes (Istituto per l'Edilizia Sociale della Provincia autonoma di Bolzano) |
| Energy Performance Certification | 30 kWh/m² per year (ClimateHouse A) |

# 3. Economic aspects

Editor: TIS

The high-energy performance of this building is achieved using the thermal insulation without the forced ventilation. The structure of this building is in reinforced concrete. The vertical components are compound of wall in poroton bricks insulated with mineral wool (thickmess18 cm, U-value 0,18 W/m²K), while the horizontal parts like slabs adjacent to not heating zone (total thickness 76 cm, U-value 0,18 W/m²K) are insulated with a calcium silicate foam (thickness: 10 cm). The building coverage is insulated with extruded polystyrene (thickens of XPS: 12 cm). The windowing system is vary performance with triple glazing, ‚Low-E' coating, low-conductivity gas and timber frame (Ug = 0,6 W/m²K, Uf= 1,8 W/m²K, g = 0,5).

The photovoltaic system is installed on the green roof with peak power of 17 KW and the evacuated tube collectors (85,96 m²) with heat exchanger for solar water heating. In apartments is used underfloor heating and cooling systems supplied by district heating (teleheating) of Bolzano.

### 3.3.3 Firmian Project, Building B 2.2


| | |
|---|---|
| Gross heating area: | 5.687 m² |
| Gross heating volume: | 18.117m³ |
| Area- Volume - ratio: | 0,37 |
| Axis of orientation: | East-West |
| Number of apartments: | 57 |
| Customer | Ipes (Istituto per l'Edilizia Sociale della Provincia autonoma di Bolzano) |
| Energy Performance Certification | 49 kWh/m² per year (ClimateHouse B) |

The high-energy performance of this building is achieved using the thermal insulation without the forced ventilation. The external wall is compound of poroton bricks and insulating in calcium silicate boards (thickness 8 cm, U-value 0,31 W/m²K). The horizontal parts like slabs adjacent to not heating zone (total thickness 47 cm, U-value 0,36 W/m²K) are insulated with an extruded polystyrene XPS (thickness: 5 cm). The green roof coverage is insulated with extruded polystyrene (thickness of XPS: 12 cm). The windowing system used in this building has double glazing, ‚Low-E' coating, low-conductivity gas and timber/aluminum frame (Ug = 1,10 W/m²K, Uf= 1,78 W/m²K, g = 0,62).

The photovoltaic system on the roof has a peak power of 7,5 KW. There is no installation of a solar thermal system provided. The building has a central heating system with gas fired condensing boiler (rated output of 500 KW) and terminal heating radiators.

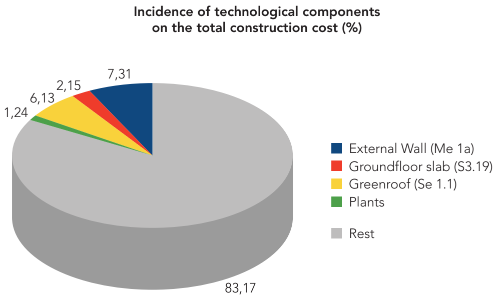
### 3.4.4 Analysis of construction cost

In this part of work, the all economic valuation has been based on the cost estimation of two buildings furnished by IPES (Istituto per l'Edilizia Sociale della Provincia autonoma di Bolzano).

The following presentation demonstrates the analysis of construction cost of building EA8 b (CasaNova) in energy performance A.

The examples of the reported costs in the table, show only the parts of the building which influence the energy performance.

| Casanova Project, Building EA8 b | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total construction cost: □ 7.516.233,77 | | | | | | | |
| External Wall | | Ground floor slab | | Green roof | | Plants (Thermal solar system, PV system, Heatinf system) | |
| Cost (€/m²) | Gross heating area (m²) | Cost (€/m²) | Gross heating area (m²) | Cost (€/m²) | Gross heating area (m²) | Cost (€/m²) | Gross heating area (m²) |
| € 129,81 | 4.233 | € 193 | 841 | € 119 | 801 | - | - |
| Total cost | € 549.485,73 | Total cost | € 161.893,00 | Total cost | € 95.255 | Total cost | € 93.045,00 |
| Incidence | 7,31% | Incidence | 2,15% | Incidence | 1,27% | Incidence | 1,24% |

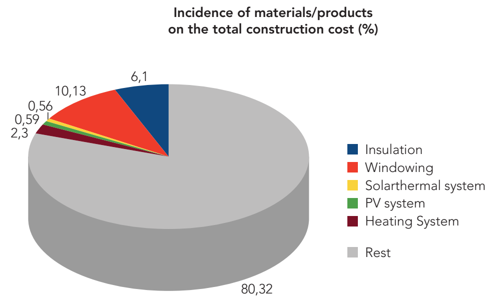



In the table below the costs of single technological materials/products are presented which influence the additional costs to achieve the energy performance in standard A.

* The cost of materials marked with a star derived from the List of Building Cost and Estimates (Chamber of Commerce, Industry, Crafts and Agticulture of Bolzano, 2010)

| Technological components | Type of insulation | Thickness (cm) | Gross heating area (m²) | Cost of material (€/m²) | Total cost (€) | Cost (€/m²) |
|---|---|---|---|---|---|---|
| External wall | MW | 18 | 4233 | € 75,03 | € 317.601,99 | - |
| Wall (Me 4.1) | MW | 12 | 294 | € 59,70* | € 17.551,80 | |
| Wall (Me 2) | MW | 18 | 56 | € 75,03 | € 4.201,68 | |
| Slab (Si 3.1) | WF | 5 | 841 | € 17,42 | € 14.650,22 | |
| Slab (Si 3.1) | Calcium Silicate Foam | 10 | 841 | € 65,26 | € 54.883,66 | |
| Technological components | Type of insulation | Thickness (cm) | Gross heating area (m²) | Cost of material (€/m²) | Total cost (€) | |
| Slab (Se 5.3) | EPS | 5 | 110 | € 8,55* | € 940,50 | |
| Slab (Se 5.1) | EPS | 5 | 24 | € 8,55* | € 205,20 | |
| Slab (Si 4.1) | WF | 16 | 13 | € 30,00* | € 390,00 | |
| Flat roof (Se 1.3) | XPS | 5 | 124 | € 10,86* | € 1.346,64 | |
| Slope roof (Se 1.3) | WF | 2,2 | 801 | € 9,84 | € 7.881,84 | |
| Slope roof (Se 1.3) | WF | 18 | 801 | € 48,69 | € 39.000,69 | |

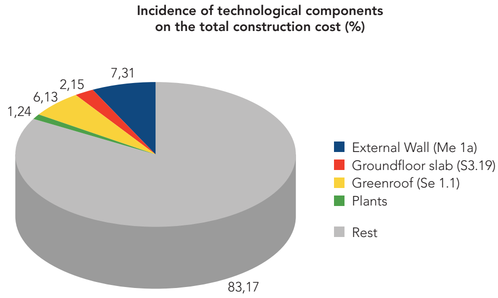
| Cost of products | | Incidence of materials/products on the total construction cost | |
|---|---|---|---|
| Insulation | € 458.654,22 | Insulation | 6,10% |
| Windowing | € 761.656,82 | Windowing | 10,13% |
| Solar thermal system | € 42.122,17 | Solar thermal system | 0,56% |
| PV system | € 44.223,30 | PV system | 0,59% |
| Heating system | € 172.533,92 | Heating system | 2,30% |



# 3. Economic aspects

Editor: TIS

| Firmian Project, Building B 2.2 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Total construction cost: □ 6.164.732,46 | | | | | | | |
| External Wall | | Ground floor slab | | Green roof | | Plants (Thermal solar system, PV system, Heatinf system) | |
| Cost (€/m²) | Gross heating area (m²) | Cost (€/m²) | Gross heating area (m²) | Cost (€/m²) | Gross heating area (m²) | Cost (€/m²) | Gross heating area (m²) |
| € 117,80 | 4.091 | € 59 | 993 | € 80 | 1.064 | - | - |
| Total cost | € 481.919,8 | Total cost | € 58.736,- | Total cost | € 85.120,- | Total cost | € 45.400,- |
| Incidence | 6,41% | Incidence | 0,78% | Incidence | 1,13% | Incidence | 0,60% |



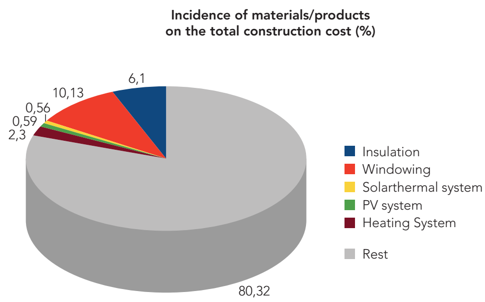

The construction costs of the second building - Firmian B 2.2 represented by the energy performance standard B, are described by the following tables and graphs.

In the table below the costs of single technological materials/products are presented which influence the additional costs to achieve the energy performance in standard A.

* The cost of materials marked with a star derived from the List of Building Cost and Estimates (Chamber of Commerce, Industry, Crafts and Agticulture of Bolzano, 2010)

| Technological components | Type of insulation | Thickness (cm) | Gross heating area (m²) | Cost of material (€/m²) | Total cost (€) | Cost (€/m²) |
|---|---|---|---|---|---|---|
| External wall | Calcium Silicate Foam | 8 | 4091 | € 67,50 | € 276.142,50 | - |
| Green roof | XPS | 12 | 1064 | € 23,08* | € 24.557,12 | |
| Slab | XPS | 5 | 622 | € 7,00 | € 4.354,00 | |
| Technological components | Type of insulation | Thickness (cm) | Gross heating area (m²) | Cost of material (€/m²) | Total cost (€) | |
| Slabs adjacent to not heating zone | XPS | 5 | 371 | € 7,00 | € 2.597,00 | |
| Loggia (up) | Calcium Silicate Foam | 8 | 336 | € 67,50 | € 22.680,00 | |
| Loggia (down) | XPS | 5 | 255 | € 7,00 | € 1.785,00 | |

| Cost of products | | Incidence of materials/ products on the total construction cost | |
|---|---|---|---|
| Insulation | € 332.115,62 | Insulation | 4,42% |
| Windowing | € 398.013,00 | Windowing | 5,30% |
| PV system | € 32.400,00 | PV system | 0,42% |
| Heating system | € 13.000,00 | Heating system | 0,17% |



### 3.4.5 Analysis of cost for payback period

The calculation of the payback period for an investment reported on this specific case of study considers costs like heating bills, maintenance and repair cost of plants.

The first table confronts the heating and warm water demands for buildings in energy performance A and B. After that, the energy consumption will be reported for a building unit of area 100 m² with annual utilization costs expected.

| Building in ClimateHouse A Standard | | Building in ClimateHouse B Standard | |
|---|---|---|---|
| Heating system | | Heating system | |
| Construction cost | € 7.516.233,77 | Construction cost | € 6.164.732,46 |
| Gross heating area (m²) | 6.660 | Gross heating area (m²) | 5.687 |
| Construction cost/m² | € 1.128,56 | Construction cost/m² | € 1.084,- |
| Hating demand (kWh/m² a) | 30 | Hating demand (kWh/m² a) | 49,42 |
| Annual heating demand (kWh) | 199.800 | Annual heating demand (kWh) | 281.051,54 |
| Energy cost of district heating (€/kWh) | € 0,085 | Energy cost of central heating (€/kWh) | € 0,08 |
| Annual heating cost | € 16.983 | Annual heating cost | € 22.484,12 |
| Annual heating cost/m² | € 2,55 | Annual heating cost/m² | € 3,95 |
| Warm water demand (kWh) (50 l. for 1 person per day) | 1,47 | Warm water demand (kWh) (50 l. for 1 person per day) | 1,47 |
| Annual warm water demand (kWh) (50L for 1 person per day) | 322 | Annual warm water demand (kWh) (50L for 1 person per day) | 536,55 |
| Annual warm water cost per 1 person | € 27,40 (free energy from solar system 40% of total demand) | Annual warm water cost per 1 person | € 42,92 |

| Plant maintenance cost in ClimateHouse A Standard | | Plant maintenance cost in ClimateHouse B Standard | |
|---|---|---|---|
| Solar thermal system | | Warm water system (gas fired condensing boiler ) | |
| Area (m²) | 85,96 | Rated output (kW) | 500 |
| Maintenance costs 2,5 €/m² | € 214,90 | Maintenance costs (€) | € 510,- |
| Annual reparation costs (amortization 50 years) | € 240,- | Annual reparation costs (amortization 50 years) | € 240,- |
| Annual plant replacement cost (amortization 50 years) | € 1.124,10 | Annual boiler replacement costs (amortization 50 years) | € 260,- |
| | | Annual plant regulation | € 500,- |
| Annual total cost | € 1.579,- | Annual total cost | € 1.510,- |
| Annual total cost/m² | € 0,237 | Annual total cost/m² | € 0,265 |

| Annual total utilization cost in ClimateHouse A Standard for 100 m² | | Annual total utilization cost in ClimateHouse B Standard for 100 m² | |
|---|---|---|---|
| Annual heating cost (€) | 255 | Annual heating cost (€) | 395,36 |
| Annual hot water cost (€) | 109,6 | Annual hot water cost (€) | 171,7 |
| Annual reparation and replacement (plant) cost (€) | 23,71 | Annual reparation and replacement (plant) cost (€) | 26,55 |
| TOTAL (€) | 388,31 | TOTAL (€) | 593,61 |

The difference of construction costs between the above compared building units per 100m² is equal to € 4.455,93 and the difference of annual total utilization costs is € 205,30

# 3. Economic aspects

Editor: TIS

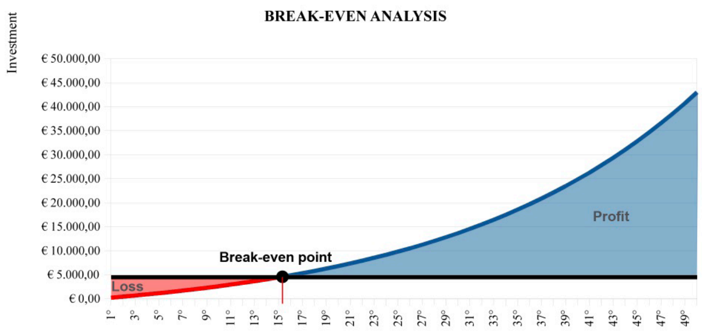
## 3.6. Killer arguments (K) and opportunities (O)

**K:** Starting from the output of cost analysis, in this specific case of study, it is possible to define the percentage ratio derived from difference of construction costs between these buildings in energy performance A and B classification. The following graph shows that considered building in energy performance A costs 21% more than the similar building in energy-efficient standard B.

Construction costs in energy performance A and B


**K:** „The payback period for a project is the length of time it takes to get your money back. It is the period from the initial cash outflow to the time when the project's cash inflows add up the initial cash out-flow. The payback period is also referred to as the payoff period or the capital recovery period" (P.P.Peterson, F.J.Fabozzi,2002).

The conclusions of payback period and break-even point for this specific case of study are presented by following table and graph.




| Year End | Exp. Cash Flow (5% increase/ year) | Accumulated Cash Flow | Investment of € 4.455,93 |
|---|---|---|---|
| 1° | € 205,30 | € 205,35 | |
| 2° | € 215,56 | € 420,91 | |
| 3° | € 226,34 | € 647,26 | |
| | | | |
| 15° | € 406,48 | € 4.430,11 | |
| 16° | € 426,80 | € 4.856,91 | the investment is paid back (BEP) |
| 17° | € 448,14 | € 5.305,05 | |
| | | | |
| 23° | € 600,55 | € 8.505,69 | |
| 24° | € 630,58 | € 9.136,27 | the profit has exceeded the initial capital |
| 25° | € 662,11 | € 9.798,38 | |
| | | | |
| 48° | € 2.033,69 | € 38.601,49 | |
| 49° | € 2.135,37 | € 40.736,86 | |
| 50° | € 2.242,14 | € 42.979,00 | |

The economic analysis of an investment show the cash flow in next 50 years. The expected cash flow derives from the difference of utilization cost (heating cost, maintenance and repair costs) per year between two units of 100 m² in energy performance A and B. It is considered that the energy rates will continue to increase given that fuels which is most used such as natural gas is non-renewable. The question is by what amount will the energy cost increase? In this example is used a fairly safe estimate index of a 5% increase (including also the rate of inflation) per year for the next 50 years.

In the analysis process the measure of the economic life of this investment in terms of its payback period is 15/16 years. It means that the capital return per year from the start of the project until the 15/16 years of accumulated cash flow is equal to the cost of the investment. After that, in 23/24 years it will be possible to have a profit equal to an initial capital.

**K:** From the previous results, limited to one specific case of study (only two building suitable for comparison) stand out that the difference of construction cost between ClimateHouse Standard A and B is equal to 21%.

Is it more attractive to buy the apartment in energy performance A or B? Considering that the lifetime of a building is equal to 50 years and reasonable payback time for this type of investment is 25 years, the choice of a real estate in ClimateHouse standard A rather than Climate House standard B is profitable.

**O:** The economic valuation of high-energy performance buildings could be exploited also in other cases with different: energy-efficiency classification; construction typology, building typology.

**O:** The statistic data (based on this case of study) demonstrating the short payback period and the widen period of profit, could be an encouraging input to put on the market high-energy performance apartments.

**O:** The building in Climate House A is characterized by a very low heating demand, therefore would save on heating costs, improve the thermal comfort and in the future increase the value of real estate.

# 4. Architecture and aesthetics

**Editor: Lucerne University of Applied Sciences and Arts – Engineering & Architecture on behalf of ZVDK**

## 4.1 General framework

In discussions about Passive Houses, often an image of a high-tech house, with no heating and very little freedom to design, comes into mind. Since a Passive House is meant to achieve certain goals by following certain rules, this seems to also become the main direction for the design, its architecture and aesthetics. The following paragraphs discuss the following questions: the boring or dull architectural design of Passive Houses and the sad or unattractive name of a „Passive" House.

### 4.1.2 Boring/ dull architectural design

**Objective**

The goal of the report's following part is to encounter presumed problems regarding the ‚Boring architectural design' of Passive Houses. The presumed problems are described and then compared to current facts and studies. Propositions for solutions, killer arguments, and/ or opportunities are provided for each part of the discussion.

The next chapters cover the compact design of Passive Houses, including their flat roofs and thick walls. Also, the Passive House approach to window openings is given below, as are technical installations that have an impact on the external appearance of the building. The last section will provide information about the variety of Passive Houses and their blending in with the context.

**Presumed problems**

Constructing an energy efficient Passive House means to be limited to certain principles to achieve the demanded performance, particularly a good surface-to-volume ratio that is manifested in a compact building. These rules restrict the architectural design and variety of newly built Passive Houses. Passive Houses consist of flat roofs, thick walls, and thus deep reveals (cf. killer argument ‚Bad Illumination'). Light enters the building via large window openings on the south façade, but no or only small window openings are facing north. Often, photovoltaic elements and/ or solar collectors are found on the roof or the façade, and ventilation channels or shafts are visible, thus a Passive House can be easily identified. With the mentioned parameters, Passive Houses do look very alike, and often they don't fit their urban context (e.g. conventional homes).

## 4.2 Analyses

**Compact design, flat roof, and thick walls**

In addition to direct external solar gain to cover the main part of the space heating demand, Passive House buildings also conserve the energy that is produced inside (by electrical equipment, household appliances, and people). Once energy has entered the space or has been emitted there, it has to be kept as efficiently as possible. Using a compact design first of all minimizes the surface area through which heat could transmit and get lost. The compact design also reduces the volume that has to be heated, so less energy is needed. Adjusting the 'thermal surface-to-energy reference area-ratio' (basically the surface-to-volume ratio ‚S/V') therefore affects the heating demand. Thus, often the chosen, more simple and compact form reduces the overall energy demand. Adjusting the S-/V ratio, proportionally changes the heat demand at a rate of about 1:1 (cf. Brunner, 2010, p.32ff). While the energy used for space heating and warm water is reduced by minimizing the volume that has to be heated, the usable floor area should also be maximised. The compact design usually leads to simplified construction, i.e. to less cost spent on complex construction (cf. Brunner, 2010, p.32ff). It simplifies the detailing of connections, corners, edges, ridges, etc. In this way, junctions can be sealed more easily and reliably, and the goal of an air-tight building according to the Passive House standard can be achieved also more easily. Thermal bridges are reduced, and particular planning of the structure avoids shading those windows, which are meant for solar gain.

As the Passive House is relying on passive methods to provide heating (e.g. solar energy, MVHR), a heating fuel tank or gas tank is no longer needed. In turn, the space that would be needed for this type of conventional heating can be used otherwise. (cf. Graf, 2003, p.8)

The flat roof is often part of the compact design approach and also imparts the modern spirit. It reduces the roof area, through which heat could be lost. Instead of the low-ceilinged and inclined attic of a pitched roof, the rectangular section of the space under a flat roof provides fully usable space. In winter, the snow stays on the roof and even provides additional insulation (cf. BFE, 2001).

As the flat roof is well-insulated, so are the walls. The wall thickness is the outcome of the constructional part and an additional insulation thickness of 25-40cm. Thus, the total width of a Passive House wall becomes easily about 40-55cm. In this way, Passive House walls achieve the recommended U-values of less than 0,16 $W/m^2K$ to fulfil the principle of extremely low energy losses (cf. Graf, 2003, p.12ff). The ‚EnergyBase' office building in Vienna, Austria, makes use of an only 31cm thick lightweight wood construction (cf. Brandstätter, 2009, p.60-64) to achieve its overall efficiency.

As the thoroughly insulated shell of a Passive House building keeps thermal energy within its envelope (the thermal losses are minimised), internal heat sources (people, electric equipment and appliances, i.a.) are more influential than in conventional buildings, where in general more heat is lost. (cf. Graf, 2003, p.9)

As the standard of a Passive House does not require certain materials, constructions or designs (cf. Graf, 2003, p.12), but energy efficiency values, it is up to architects and planners to achieve the required energy efficiency performance. However, it might be desirable, to keep the construction as thin as possible, so use the maximum net area of the space given by regulations or zoning. To reduce the wall thickness, the application of vacuum insulation panels is a good option. In the IEA/ECBCS Annex 39 – ‚High performance Thermal Insulation' several institutions and authors researched vacuum insulation in the building sector. „For buildings most of the vacuum insulation panels (VIP) activity is still in the R&D phase with some demonstration projects. Germany and Switzerland are the only countries where a market in its early stage has been established. Almost exclusively fumed silica boards are being used. Fumed silica with a thermal conductivity of about 0,004 W/(m·K), meaning 4cm of VIP achieve a U-value of 0.1 W/($m^2$K) [for comparison, e.g. rockwool with a thermal conductivity of about 0.04 W/(m·K) would have to be ten times as thick (40cm)] is the best core material due to the small size of the pores and the low heat conductivity of the powder. There are only three producers of fumed silica in the world, and two of them are large EU companies: Wacker (Germany), Cabot (USA) and Degussa (Germany)" (IEA, 2005, p.7f). Today's interest in VIP technology rises, but a wide use of vacuum insulation is still hindered by the high price and the lacking confidence in VIP technology and its use in building applications (cf. IEA, 2005, p.107). The panels have to be handled with extensive care, so the highly sensitive envelope is protected, and the vacuum can be maintained. Also the panels must be planned and executed precisely, since once produced, the panels cannot be altered in shape or size (cf. IEA, 2005, p.62). Furthermore, it must be possible to exchange a single panel in case of failure (cf. IEA, 2005, p.4/9/81f). If a panel fails, the thermal conductivity is reduced, and so the U-value of the whole structural element is reduced to about 50% (cf. IEA, 2005, p.27-79). Monitoring the panels and providing 'backup' insulation to avoid temperatures below the dew point in certain places would help out in case of failure. Other obstacles are missing quality assurances or product approvals for VIP and VIP based systems for buildings (cf. IEA, 2005, p.108).

**Window openings**

In general, windows provide the interior with natural daylight, the determine views and connect the outside with the inside, thus extending the percept space beyond the boundaries of the building itself. In a Passive House, even as windows are highly insulated, they are still the most crucial part of the building's envelope as they achieve significantly higher (= poorer) U-values than opaque surfaces. Hence, there is generally more energy lost passing through the windows than through walls.

If the design foresees large window openings, the energy loss also becomes larger. In the case of orienting large glazing areas towards the equator, however, the heat loss is compensated by greater heat influx (which is accordingly higher on large than on small windows). Orienting windows to the south takes advantage of the free and passive solar energy that also contributes to the heating. Facing windows east or west, however, can more easily lead to overheating in summer while providing less solar gains during the heating period. „Windows need careful planning and, where necessary, appropriate sun protection. The window specifications needed to achieve the Passive House standard depend on the local climate conditions" (iPHA, 2010a, p.9). Since there are many different types of glazing units available, the right one for each occurring situation can be chosen, e.g. double glazing on the south façade for more solar influx, and high performing triple glazing on the other sides of the building to minimize thermal energy loss (for further aspects of windows, their elements, and installation, refer to killer argument ‚Bad illumination'). Built examples as the Passive-Energy-Standard Housing in Salzburg, Austria show, that the Passive House standard can also be achieved by treating the windows equally on both sides of the building - the southern side and the northern side. (cf. Detail 6/2007, p.652ff)

**Technical installations (e.g. ventilation channels/ shafts, thermal solar collectors, or photovoltaic panels)**

A Passive House makes no use of a conventional heating system (e.g. burning fuel to produce heat), but receives its heating by passive solar influx and the heat recovery unit of its mechanical ventilation. Basically, one technical system is traded for another more efficient one. Therefore, chimneys and fuel storage tanks (and the space which is needed to install them) are not needed any more. Sometimes ventilation channels or shafts can be noticed. They provide the mechanical ventilation with heat recovery (MVHR) system with geothermic preheated incoming air.

Additionally - often to provide warm water – thermal solar collectors can be installed at the roof or the façade. As the direct solar influx for space heating, they also make use of the free solar energy to heat water that is used in the building.

Since almost every building is in need of electricity, some builders or investors install photovoltaic elements, to cover some or even all of the electric power they consume. Often the investment is taken to qualify for subsidies or in case the building is located remotely and not connected to the power grid. One example for the latter is a refuge on the mountain Hochschwab, Austria, at 2.154m. Due to its high alpine surroundings it has to be self-sufficient and also take ecological care in regard to its sewage. According to the Passive House concept, e.g. it is optimised to efficiently use solar energy. (cf. Treberspurg/ Hofbauer, 2006, p.22ff) (cf. Detail 6/2007, p.624-627).

In an optimal planning process, the requirements of a Passive House can be met with conventional elements (cf. Menti, 2009, p.26-32).

**Variety and context**

The concept and standard of a Passive House is restricted to specific energy efficiency. These limits place all Passive House buildings in the same process, to meet the required standards. Even if the goal is the same, the ways to get there are manifold. Passive House technology is not restricted to specified shapes or materials. Every architectural style and every idea of dwelling can be put into practice, no matter if it is a mansion, a residential home, a high-pitched roof, or a cube. The question of ‚how to live?' is not limited either. Modern open floor plans with flowing transitions of spaces are as possible as a rather closed floor plan with strictly divided rooms. Construction material can be used as diversely (cf. Graf, 2003, p.7). While, often, residential Passive Houses are being built in the Passive House standard, other types of use and public buildings are also possible and even refurbishment projects can meet the Passive House standards (e.g. the former Post Office building in Bolzano, Italy). As designing a Passive House building leaves freedom to layout, size, placing the windows etc., it is possible to blend into the urban context while achieving the energy values with rather subtle measures. It is also possible, and that is maybe where the boring image of a Passive House came from, to focus solely on the energy efficiency of the structure, the orientation etc., and thus the architectural design was rather neglected.

Not to forget, there might also exist building codes and restrictions which dictate very specifically, where, and how to place a building on the site. Again, these still leave many possibilities to planners, investors, and architects for how to react and design.

As mentioned earlier, sometimes, remote locations even predetermine the use of an autarkic concept as the Passive House.

## 4.3 Killer arguments (K) and opportunities (O)

The standard of a Passive House is restricted to specific energy efficiency (a limited heating load of 10W/m$^2$ of living area, in Central Europe that equals a maximum space heat demand of 15 kWh/m$^2$a. Also, total primary energy is limited to 120 kWh/m$^2$a, and excessive temperature frequency must be less than 10% - over 25°C; air tightness must be less than 0.6 times the house volume per hour with the building pressurised to 50Pa by a blower door.) (cf. IEA, 2008, p.67). How to achieve these ‚hard factors', is up to planners, engineers, and architects. It has mainly been implemented on the residential building sector, but the numbers in other uses and public buildings are also growing (cf. Menti, 2009, p.26-32). Nonetheless, having emerged in the beginning of the 1990s - at about 20'000 Passive Houses built until today (cf. iPHA, 2010b) - the Passive House seems to still be an innovative concept.

**Compact design, flat roof, and thick walls**

**K:** A compact design minimizes the surface area through which energy could transmit. Thus, it reduces the volume within the complete thermal envelope. Less volume has to be heated while the maximum usable net area is provided. Through simpler construction, fewer costs are spent. A less compact design can be compensated for by other means (e.g. better insulation, more efficient use of passive solar energy, building service engineering, etc.) (cf. Menti, 2009, p.26-32).

**K:** The flat roof is part of the compact design approach. It also minimizes the roof area while providing a fully usable space underneath. It imparts the modern spirit, i.e. innovation.

**K:** The wall thickness is due to energy efficiency which can be achieved by the application of 25-40cm of insulation. An alternative are vacuum insulation panels (VIP), which provide the same

U-value at about a tenth of the thickness. VIPs are very innovative and mostly still in the R&D phase. Using VIPs, it must be considered to take precautions measures as monitoring the panels, and replace them in case of failure. They must be handled with care and need correct planning since the cannot be altered on-site. Very good protection is given, if VIPs are part of a pre-fabricated element, e.g. wood modules (cf. FIZ, 2007) (cf. FIZ, 2004). Used in prefabricated manner, they are a slim alternative, especially for refurbishment projects (cf. FIZ, 2008). Further development is expected.

O: To compensate for thick walls, zoning parameters could be adjusted, to enable builders to not loose net area due to the thicker perimeter of the building. E.g. the site coverage index could be adapted.

O: It is up to planners, architects and advisors to find the best balance among architectural solutions (building aesthetics, functionality, composition) and energy efficiency. There is the big opportunity to promote Integrated Design Process with two main needed professional skills: IDP facilitation (managing the process, from concept to continuous commissioning), dynamic energy simulation (quantitatively supporting the process).

#### Window openings

K: Window openings of a Passive House provide daylight and view. They are not needed for ventilation any more, but they have to complete the thermal envelope of the building. Triple, quadruple or vacuum glazing can achieve low Uw-values. Large windows should be facing south, since the solar influx in one year more than compensates for the heat loss via the glass. Also, overheat protection must be considered through particular balancing solutions (e.g. ventilation, sun protection, heat storage medium) (cf. Menti, 2009, p.26-32). New products are being developed, that reduce the dimensions of the window frame. Overlapping the frame with insulation provides less thermal loss while showing less of the frame from the outside.

#### Technical installations (e.g. ventilation channels/ shafts, thermal solar collectors, or photovoltaic panels)

K: In many cases, a Passive House is heated by passive solar influx and an MVHR unit. A ventilation channel/ shaft through the ground would pre-heat the incoming air (or pre-cool it in summer). This system guarantees hygienic air renewal, while minimising energy losses via ventilation. However, air heating is not mandatory. (cf. Menti, 2009, p.26-32)

K: Thermal solar collectors are an option to passively use the sun to heat water for different uses (or another liquid as transfer medium). Their use has advantages since renewable energies are put into calculation with lower impact; thus, they improve the overall performance (cf. Menti, 2009, p.26-32). BIPV (building Integrated Photo-Voltaics) components can reduce the impact on architectural language [http://www.iea-shc.org/task41/]

K: Photovoltaic elements can provide electric power to the building or put the produced power into the public grid (e.g. for receiving subsidies or as the energy strategy of an Energy Saving And Producing (ESAP) building).

BIST (building Integrated Solar thermal collector) components can reduce the impact on architectural language [http://www.iea-shc.org/task41/]

#### Variety and context

O: As many publications show, the variety of Passive Houses designs is great. Passive House components do not have to look like they were applied isolated from the overall design of the building they are given to. Early on in the planning process, many architects and planners commit to the Passive House standard. Thus, with an early integrated approach, the advantages of Passive House components and philosophy can be combined with ambitious architectural design. As different as are situation and planners, so are Passive Houses (e.g. refer to www.passive-housedatabase.eu, www.passivhausprojekte.de, current publications).

O: As some sites are quite remote, the autarkic system of a Passive House is an excellent option to construct a self-sufficient building 'off the grid' within such a context. (cf. Sulzer, 2009, p.46-50)

#### Further opportunities

O: All parties involved (builder, planners, architects) need to commit to the Passive House standard from the very beginning of the design, since upgrading a low-energy house to a Passive House often leads to disproportional higher expenses. (cf. Menti, 2009, p.26-32)

O: If architects and engineers are new to the energy efficient building sector, they might need assisting professional expertise. They need to consciously integrate energy (= cost) matters from the very start of the designing and developing process. For example, the quality and form of the envelope (air-tight, well-insulated, triple glazed windows, reduced/ no thermal bridges) is a crucial element concerning energy saving and conservation. (cf. Ragonesi et al., 2009, p.6,8). To catch up on new developments and implementation strategies, advanced training for architects and planners is available (in Switzerland, e.g. for the Minergie-P standard. As planners improve their knowledge, also owners or users of Passive House buildings need to be informed on how to run a Passive House in an energy efficient manner. (cf. Menti, 2009, p.26-32)

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# 5. Sad/ unattractive name

**Editor: Lucerne University of Applied Sciences and Arts – Engineering & Architecture on behalf of ZVDK**

## 5.1 General framework

### Objective

The following paragraphs engage the 'Unattractive/ poor name' that is given the ‚Passive' House. The presumed problem of negative connotations to the term 'Passive House' is discussed, several facts are reviewed, and suggestions, killer arguments and/ or opportunities are indicated.

The discussion takes on the Passive House concept, the Passive House standard (certifications, label and trademark), the promotion of the label, and subsidies. Also the reference to the concept of Energy Saving And Producing (ESAP) buildings is given.

### Presumed problems

The word 'passive' brings several negative connotations. A web search on synonyms lists expressions as resigned, non-resistant, motionless, influenced, apathetic, dull etc.(http://synonyme.woxikon.de/synonyme-englisch/passive.php). If the term 'Passive House' is promoted – especially to people without professional knowledge about the philosophy and the context of Passive Houses, on the first sound, these connotations might come into mind.

## 5.2 Analyses

### Concept and standard

The concept of a Passive House refers to its ability, to maintain comfort by means of passively 'receiving' energy (another meaning of the expression 'passive' – instead of 'active = giving') and very efficiently using the energy.

On the question ‚What is passive about a Passive House?', the International Passive House Association answers: „The heating system. A Passive House doesn't need to be heated actively, because it essentially uses passive heat gains to heat itself. This way, only a minimal amount of additional heat needs to be supplied. This concept is based on excellent thermal insulation and a highly efficient heat recovery system. The heat stays inside and doesn't need to be provided by an active system. The 'passive' principle is well known in engineering, it is an effective strategy to securely, reliably, and efficiently achieve a goal. 'Passive security', 'passive filters', 'passive cooling', and 'Passive Houses' are examples of the successful implementation of this principle.

Of course, all these technical applications are not exclusively ‚passive' in the proper sense of the term; minor intervention is inevitable for directing the respective process towards the desired course. It's not about ‚letting it happen', but rather about controlling processes in such a way that a certain goal is achieved with minimum effort, as if it were happening all by itself."(iPHA, 2010, p.8)

Furthermore, the term Passive House is referred to as certain energy efficiency standard. The energy demand and efficiency has to be calculated with the Passive House Planning Package (PHPP) tool. For a residential building the numbers are as follows:

- Specific space heat demand max. 15 kWh/m$^2$a
- or heating load max. 10 W/m$^2$
- Pressurization test result n50 max. 0.6 h/1
- Entire specific primary energy demand incl. domestic electricity max. 120 kWh/m$^2$a

Is the required performance achieved, the certification as 'Quality Approved Passive House' can be awarded. (cf. PHI, 2009, p.1) Therefore it is guaranteed, that the construction is very energy efficient and the energy consumption is very low.

### Promotions and subsidies

From 2005-2008, the ‚Promotion of European Passive House' (PEP) introduced the term and concept Passive House to several European countries. The „project aimed at the development of easy accessible web based documentation for stakeholders in the building process to solve national market introduction barriers. The project also aimed at the distribution of this information via international and national workshops, seminars and conferences. It can be concluded that the PEP-project has been successful. All participating countries made significant progress in the societal embedding process of Passive Houses and in most countries the Passive House concept is on the brink of breaking through nationally. Further, the PEP-project contributed successfully in the internationalisation of the Internal Passive House Conference and fixed the definition of a Passive House for three geographical European regions. Finally, the PEP website with its wealth of information was a powerful tool for promotion of Passive Houses in Europe." (Elswijk, et al, 2008, p.4)

Also agencies are rising, which disseminate the knowledge of low-energy buildings, Passive Houses, and other aspects of the emerging mega trend sustainability.

Since the low energy consumption and the ecological aspects of Passive Houses are quite attractive, some cities already released regulations, to meet the Passive House requirements for newly built public buildings. Thus the image of innovation, responsibility, sustainability, and future orientation of the city and its administration are also promoted as the Passive House (name, concept, label, energy standard, quality certification, etc.). E.g. Frankfurt am Main, the ‚Passive House Capital of Germany', decided to carry out new public buildings according to the Passive House standard.(cf. Schulze, 2010)

Since there are additional costs for a Passive House that might hinder (private) builders, e.g. the German KfWBankengruppe offers Passive House loans with lower interest rates. (cf. KfW, 2002)

Some cities even offer loans without interests, or direct financial funding (e.g. the German cities Walldorf and Oldenburg) (cf. Walldorf, 2010) (cf. Oldenburg, 2010).

### ESAP concept

Taking the Passive House concepts and standards to the next level, ESAP buildings rely on the approved methods and low energy consumption of the Passive House. In addition, an ESAP building „produces at least as much primary energy as it consumes during one year of heating, cooling, lighting, hot water, ventilation and all electric appliances." (Rhônealpénergie, 2010, p.2ff). It thus promotes a rather 'active' approach than the term 'Passive' House.

## 5.3 Killer arguments (K) and opportunities (O)

### Concept and standard

**K:** An essential part of the Passive House concept is its ‚passive' heating. It needs no conventional active heating. The ‚passive' refers to the ability that a Passive House building is controlling its passive energy incomes in such a way that its goals are achieved with minimum effort. E.g. heat is rather kept as efficiently as possible than produced.

**K:** The ‚Passive House Standard' is defined by the building's amount of energy consumption. Thus, a certified label and trademark can be awarded to buildings and building elements (e.g. windows), which perform accordingly.

### Promotions and subsidies

**K:** The term ‚Passive House' was promoted in several European countries during 2005-2008. Thus, awareness has risen and knowledge about the standard and concept is directly linked to the term ‚Passive House'.

**K:** Some cities (e.g. Frankfurt am Main, Germany) commit themselves to the Passive House standard by having decided to build public buildings according to this standard. Also, other cities provide special low-interest loans or other subsidies for builders of Passive Houses. In this way additional costs are compensated for. (cf. Menti, 2009, p.26-32)

### ESAP concept

**O:** Taking the Passive House to the next level, an ESAP building actively produces energy. Its building standard is based on the Passive House standard for energy efficiency and energy conservation (e.g. high performance insulation, compact design). Additionally, it also directly produces at least as much energy as it consumes during one year.

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# 6. Daylighting

**Editor: EURAC**

## 6.1 General framework

As Passive Houses often rely on passive solar gains through their windows to reduce the heating demand, in general, they should be equipped with accordant glazing that also provides good day lighting. If the window surfaces are large, they can collect solar gains well, but the same instance could also result in seasonal overheating. Therefore, a thoughtfully designed shading system in connection with precise application of matching glazing qualities could provide adequate heat protection, while keeping energy inside.

### Bad illumination

#### Objective

The next paragraphs deal with ‚Bad illumination'. As the Passive House needs certain construction methods to achieve its overall energy efficiency, several consequences regarding the illumination are occurring.

The important factors triple glazing, thick window frame, and deep reveals are covered in the following chapters. It is discussed, how these factors contribute to the natural lighting of a Passive House, contextual facts are given, and suggestions, killer arguments and/ or opportunities are pointed out.

#### Presumed problems

Due to energy reasons, the windows of Passive House buildings are usually implemented in triple glazing quality. They do not let daylight pass without influence, since the glass is coated with a low-emissivity film (to reflect a chosen part of the solar spectrum and also interior heat radiation on the inside) and the gap spaces are filled with inert gas to provide the thermal boundary of the envelope with low U-values. Also, the windows come with thick frames that are due to the insulation level of the Passive House standard. Furthermore, as the windows are integrated in thick insulated walls, they create deep reveals that reduce the angle of daylight incidence.

Altogether, these parameters are presumed to compromise both, the quality of daylight on the interior and the amount of incoming daylight.

## 6.2 Analyses

### Architecture

Architecture mediates the boundary between the external environment and the human body, and therefore whether the body is able to fulfil its needs from the environment, such as those for fresh air and light. The human internal clock naturally runs to a different period than the social and solar twenty-four-hour day (Lockley, 2002). Disruption of the circadian system i.e. by insufficient quantity of or inappropriately timed light can cause considerable stress. Daylight is best suited to achieving the spectrum needs of circadian light cues while remaining within comfort levels (Gochenour, 2009).

Architecture becomes an important component when one realizes that many vital components of daylight – intensity, timing, and spectrum – are mediated through the form of surrounding structures. Intensity of light is determined by the size and shape of openings, the light transmitting qualities of the glazing chosen, the presence and sizing of shading, the size and shape of the space being lit, the global location and position of the overall building, and the depth and orientation of the light receptor, such as the eye or a luxmeter. Timing is arbitrated by the orientation of the building and the shape of the openings; for example, a southeastern facade in the northern hemisphere will receive much more morning light than evening light. (Gochenour S. J, 2009).

Floor/window configuration, masking conditions, orientation, presence/absence of a partition, blind usage, distance of the sensor from the window, wall reflectivity, and user viewpoint were the most important design parameters. While it is not new knowledge that white paint leads to a brighter space, it is notable that white paint alone can result in an increase in daylight autonomy of 15,1%, this means there would be 55 more days a year, or almost two months, when circadian needs would be met. The next most powerful single factor in achieving sufficient daylight for circadian cuing was distance from the window.

The drastic improvements observed when going from basement apartment to top floor apartment accounting for the randomized viewpoint suggests that it is unwise to place apartments in the basement at all. Perhaps this space could be used for services, such as laundry facilities or storage. It is also apparent that removing partitions in the living space creates an apartment that is more evenly and more fully lit. It is also recommended to orient living spaces used frequently in the morning – i.e. the kitchen and bedroom – so that occupant viewpoints are most often toward the east. Placing the workspaces, such as counters and sink, on the eastern wall may result in brighter light being received in the morning, a time when circadian rhythms relating to alertness and metabolism are relatively easy to set for the entire day. If this scheme is followed, glare control becomes very important. If possible, living spaces should be oriented south, regardless of primary street orientation. Even if the house at large faces north, what is decided to be the „dominant" living space should probably be placed in the southern half of the building, such that users can receive direct sunlight as well as reflected sunlight through the glazing. (Gochenour, 2009)

**Triple Glazing**

Windows create a connection between the inside and the outside world of a house. While they let sunlight enter the building, they also must keep the heat inside. Especially in the case of a Passive House which provides its heating without conventional heat sources. Thus, the window frames are well-insulated and triple glazing is used.

Standard double-glazed units are coated with ultra-thin silver and filled with inert gas argon; in comparison, excellent triple glazing is filled with krypton. (For an overview refer to the table below.) Considering the quality of daylight, which enters the building via a triple-glazed window, the overall energy transmittance g-value and the light transmittance Tv come into account. As both values are connected - and a low g-value is desirable to keep heat inside the house - the light transmittance also becomes less. As the table shows, the light transmittance is reduced by about 10% (from double-glazed insulation glass to triple-glazed insulation glass).

The German window manufacturer Sanco describes similar values: thermal triple glazing can provide values of light transmission at 73-75%, with an energy transmittance ratio of 60-64%, at an U-value of 0.6-0.8 W/m$^2$K. While improving the thermal performance, triple glazing adds to comfort with its warm inner surface. The room temperature may even be reduced, since there is no longer a significant radiation exchange between the inner surface of the window and the interior air temperature. (cf. Sanco, 2010)

Research on the impact of glazing on human well-being has shown that glass can also act as an optical filter which reduces the spectral transmission asymmetrically and thus shifts the colour temperature. The Centre for Building and Environment of the Danube University Krems tested different types of glazing. While a single pane of float glass almost had no effect on the spectral range, double and triple insulation glazing showed measurable changes. The also tested thermal triple glazing with laminated safety glass showed remarkable filter characteristics which almost completely eliminated certain wavelengths of light. Even the results were revealing. There was no confirmation of any disturbance on the biological perception of time (biological clock) with either type of glazing. If a very efficient thermal glass or lower-graded glazing with different coatings would have been used, this could have had a significant impact. (cf. Pircher et al. 2009, p.92f)

| Type of glass | Glass/ cavity / Glass in mm, # = position of low-e coating | Ug-value W/m$^2$K | g-Value Overall energy transmittance | Tv Light transmittance |
|---|---|---|---|---|
| Double glazing, argon | 4/12-16/#/4 | 1,4 – 1,1 | 0,63 – 0,53 | 0,80 – 0,75 |
| Triple glazing, krypton | 4/#/8-12/4/8-12/#/4 | 0,7 – 0,5 | 0,55 – 0,47 | 0,72 – 0,68 |
| Vacuum | 4/0.7/#/4 | 0,5 | 0,54 | 0,73 |

Typical values of common glazing systems
(The listed vacuum glazing has a relatively high g-value, compared to the triple glazing, since it only makes use of one low-e coating.) (cf. FIZ, 2008, p.3)

As mentioned above, colour and quality of the low-e coating are also responsible for the perception of incoming daylight (i.e. the view to the outside). Low-e coatings provide low emissivity, meaning a high thermal reflection and at the same time a low emission of thermal radiation. In this way, heat influx is reduced in summer while in winter thermal radiation, to a high degree, is kept within the interior. Metallic coatings of e.g. gold, silver or copper reflect infrared radiation, while still allowing the transmittance of visual light. Due to its low change to colour at the highest light transmittance rate, silver coatings are the predominant low-e coating on the market. (cf. Junker, 2006a)

Adjusting the metal alloy for the coating, a ‚selective' low-e coating can also be applied, and thus filter certain portions of the spectrum. (cf. Junker, 2006b)

On the market there also exists glass which uses the ‚electrochrome' effect. Due to its nano structural coating, the electrochromic laminated pane can be tinted blue in several stages if a small amount of electric current is applied. In this way, the light transmittance of a standard insulated glazing can be set between 15-50%. This special effect can be combined with other applications (e.g. coatings) as well. (cf. DMID, 2010) (cf. EControl, 2010)

Tinted glass acts similar to the low-e coatings. Bronze tint or other spectrally selective tint influences the part of the energy spectrum which is reflected and which can transmit the glass. For example, „a glazing designed to minimize summer heat gains, but allow for some natural lighting, would allow most visible light through, but would block all other portions of the solar spectrum" (CSBR, 2007)

The thoughtful consideration of the combination of tint, reflective coatings and low-e coatings, and their order within a glazing unit makes it possible, to react to different situations, directions, climates, and energetic issues. (cf. FIZ, 2009a)

As an alternative to multiple glazing, the „Highly Insulating Window and Façade Systems" research project undertook further development towards vacuum-insulated glass (VIG). The two panes of 3-4mm-thickness with an inter-pane spacing of about 0,7 mm and a low-e coating are bond together. Replacing the conventional gas filling with the vacuum, this construction provides glazing units that are noticeably thinner than current double-glazed units while achieving a heat transfer coefficient of 0,5 W/m$^2$K. To achieve the inert vacuum and still provide mechanical durability, small metal cylinders function as spacers. With a diameter of 0,5 mm, they can only be seen against a low-contrast background and when less than one metre away. The correspondingly developed frame with its larger insertion depth of the glass into the frame prevents temperatures below the dew point at the edge of the pane. (cf. FIZ, 2009a)

### Thick window frames

Even as thermal-insulation properties of glazing have improved, windows still remain one weak point of a thermal envelope of an energy efficient building. While the glazing unit may provide a Ug-value as low as 0,5 W/m$^2$K with, e.g., vacuum-insulated glass or triple glazing with improved spacers, the frame is significantly above this value. Usually Passive House windows with insulated frame constructions rarely achieve UW-values below 0,8 W/m$^2$K and these are mostly systems with larger profiles, fittings, and increased installation depths of about 120-130mm. (cf. FIZ, 2009a) This means their thickness is about twice as much as e.g. a conventional wooden frame window with a depth of about 65mm (cf. Deplazes, 2005, p.195), still the profile elevation is the same as at conventional window frames. (cf. FIZ, 2003)

In general, the frame-to-glass ratio should be chosen as low as possible, since current glazing achieves a significantly lower U-value as the frame. Is the whole window element quite small, its frame portion becomes more important, and the overall Uw-value of the window element is impaired and, thus, less efficient. Using a larger glass surface instead reduces the relative portion of the frame and the whole window element achieves a lower (= better) Uw-value (cf. FIZ, 2009b, p.4). Another main goal is also to reduce the frame thickness that is exposed to cold weather. By trend the overlapping of insulation and window frame is preferred. The available frame profile elevations of 120-140mm are thus reduced to the minimum – the frame becomes hardly visible from the outside. (cf. Ragonesi et al., 2009, p.25, 110, 97)

In search for a sleek and light window frame, the ‚Highly Insulating Window and Façade Systems' research project developed new types of window frames. They consist of a high-pressure foaming core that is covered with a plastic layer, and makes use of vacuum-insulated glass (as mentioned above). Both, the insulation and the functional outer layer are entirely made from polyurethane (PU), hence, producing one piece made of one single material, and, thus, facilitating recycling and sorting. Also, it leaves many design and colour alternatives to choose from.

Since the PU frames can no longer be welded like conventional frames, the corners are cut and glued together, as are the frame and the glazing. The also newly developed adhesive hardens within seconds and achieves its ultimate strength after four to five hours.

This in 2009 newly developed system with the brand name „TopTherm 90" achieves a Uf-value of 0,68 W/m$^2$K. Its depth is 90mm, and it is suitable for glass panes from 9-50mm. Using triple glazing with a Ug of 0.7 W/m$^2$K, the window achieves an overall Uw-value of 0,79 W/m$^2$K, while vacuum-insulated glazing with Ug= 0,5 W/m$^2$K achieves a total Uw-value of 0,67 W/m$^2$K. The use of VIG in this frame even results in positive heat balance if the windows are positioned south. Altogether, the newly developed window system is at the energy efficiency level of Passive House window frames, but it weighs less and is significantly thinner. Pilot production and initial discussions with system manufacturers are currently underway.

On the downside, a profile that is made entirely from plastics cannot support mechanical loading. A thermally optimised mullion-an-transom structure based on aluminium supports is still to be developed. (cf. FIZ, 2009a) (cf. EnOB, 2008)

For example, the Austrian window manufacturer internorm® also produces sleek insulated window frames with profile depths which range from 86 to 97mm and achieve Uw-values of 0,63-0,72 W/m$^2$K (with quadruple glazing Ug = 0,59 W/m$^2$K) to 0,69 W/m$^2$K (with triple glazing Ug = 0,5 W/m$^2$K). (cf. Internorm, 2010)

### Deep reveals

As the Passive House standard is often achieved by thick insulation of the walls, in consequence, deep window and door reveals are created. Thus, one measure could be to reduce the thickness of the insulation without reducing the U-value of the element. For example, the use of vacuum insulation panels would be one option, the reduction of the overall depth of the wall construction another (refer to killer argument ‚Dull architectural design – Thick walls'). A further approach could be to alter the situation of the window within the wall. It could be positioned on the very outside, thus becoming more or less flush with the exterior cladding. It could be set towards the interior side or somewhere in between. From the energetic point of view, the window is supposed to be installed on the inner side of the exterior insulation. Thus it sits close to the centre of the opening in a well-insulated wall and divides the depth. (cf. FIZ, 2003, p.2)

If buildings are retrofitted, whether with Passive House elements or to meet the Passive House standard, the window should be installed as follows to prevent thermal bridges: the insulation should overlap the blind frame of the window to provide optimal thermal efficiency.

„If the windows are renewed (…), they should be fitted in the insulation level in front of the window reveal, so that thermal bridges are avoided and window reveals don't appear to be deeper than before refurbishment." (cf. iPHA, 2010, p..27)

To extend daylight incidence, the exterior reveals and/or interior window sills could also be inclined. The retrofit of a former post office building in Bolzano (the first Passive House office building in Italy) used inclined parts of the 350mm thick insulation to design the variety of the façade, and thus external appearance. (cf. AP Bozen, 2010) (cf. Detail 6/2007, p.618)

As the Passive House standard is set for the entire energy efficiency of the whole building, not optimised installed windows can be compensated for by other measures (e.g. more efficient insulation, maximisation of solar gains, etc.). Built examples as the mentioned post office building in Bolzano, Italy, the Alpine Lodge in Styria, Austria, the Dwellings for Senior Citizens in Domat/Ems, Switzerland, the Secondary School in Brixlegg, Austria, or the Passive-Energy-Standard Housing in Salzburg, Austria show varying results in the matter of window installation. Different designs and integrated approaches can lead to different solutions to place a window, hence avoiding deep reveals. (cf. Detail 6/2007, p.618, 624ff, 634ff, 648ff, 652ff)

## 5.3 Killer arguments (K) and opportunities (O)

**Triple Glazing**

**K:** Triple glazing, and also quadruple glazing, provides reliable thermal insulation at the window openings. The surface at the interior pane stays relatively high. No moisture condenses at the pane and thermal heat radiation exchange is minimised. In this way, a very high comfort level is guaranteed. Also, the acoustical insulation is improved.

Right balance among window surfaces, Ug, g-value and Tv allows to achieve good illumination level while keeping very high insulation level.

**O:** An alternative to multiple glazing, whose inter-pane space is filled with inert gas, are vacuum insulation glazing units. They are remarkably thinner while still keeping up to triple glazing unit's Ug-values and their acoustical insulation.

**O:** Many coatings and tints are available to match each window glazing to its unique situation (e.g. reflection, emissivity, orientation, sun protection, climate). Switchable ‚electrochrome' coatings make it possible to change the light transmittance of a glazing unit according at the push of a button.

**Thick window frames**

**K:** Well-insulated glazing units also call for well-insulated window frames. Since the frame is the weak point of a window opening, it must complete the thermal envelope of the building as well as possible. Adding insulation to a wooden or metal frame improves profile depth. This consequence has to be considered, so that low Uw-values can be achieved. However, further development to reduce the frame thickness is in progress.

**O:** Overlapping insulation and window frame achieves the best thermal connection and also leaves only a small part of the frame to be visible from the outside.

**O:** The ‚Highly Insulating Window and Façade Systems' research project developed polyurethane (PU) frames with durable PU coating. Therefore, it is possible to construct sleeker designs than most of the frames currently used for triple glazing.

**O:** Using fixed glazing also reduces the frame depth. Since in a Passive House ventilation is provided by a MVHR system, window openings do not have to do so as well. Where the function of an opening is not necessarily needed, fixed glazing could be an alternative.

**O:** Wooden frame with (e.g.) cork to decrease frame thickness while keeping insulation level

**O:** reflective insulation to reduce thickness

Deep reveals

**K:** Deep reveals of a Passive House are due to its improved insulation. It is possible to use high reflective finishing materials in order to transport natural light as deep as possible

O: Constructing walls as thin as possible (while still achieving the required U-value) or bevelling the insulation at the reveals would provide more daylight incidence. Shaping reveals leaves also many options to varying designs.

O: Increasing the window's overall size would also provide more daylight incidence while improving the frame-glazing ratio, resulting in a better Uw-value. Glare effect can be avoid through suitable internal shading systems.

**Further opportunities**

K: presence of highly reflective walls make easier the transport daylighting exploitation While it is not new knowledge that white paint leads to a brighter space, it is notable that white paint alone can result in an increase in daylight autonomy of 15.1%, this means there would be 55 more days a year, or almost two months, when circadian needs would be met. The next most powerful single factor in achieving sufficient daylight for circadian cuing was distance from the window. While it is obviously not feasible to only allow occupants to use the floor area closest to the windows in their apartments, it would be possible to encourage developers to place living spaces where daylight is important – bedrooms, living rooms, and kitchens – in the areas closest to the windows.

K: using solar tube to transport the light in the building core, far from the windows.

O: Using large windows also reduces the amount of electric energy used for artificial lighting. If lamps are applied according to the use of spaces, energy can be saved since unused zones do not need to be lit.

O: The use of skylights would also help with day lighting, but as mentioned above, the same factors as with vertical glazing have to be considered (e.g. shading, glazing quality,frame construction, orientation).

O: using architectural (building shape, windows size, interior wall, etc.) and building (plaster painting) choices to better transport the light inside the building. Right balance among window surfaces, reveal finishing, Ug, g-value and Tv allow to achieve good illumination level while keeping very high insulation level.

O: developing cost-effective solar tube: collector, funnel, emission point that reduce space need on the roof and for light distribution

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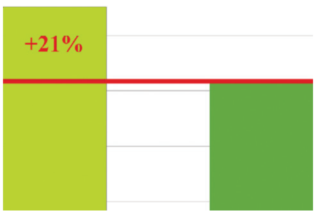


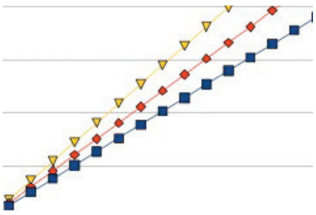

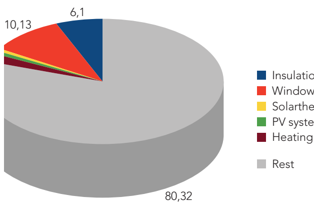


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