EuroPHit

D5.4_FINAL GUIDELINES FOR PRODUCT DEVELOPMENT

INTELLIGENT ENERGY – EUROPE II

Energy efficiency and renewable energy in buildings

IEE/12/070

EuroPHit

[Improving the energy performance of step-by-step refurbishment and integration of renewable energies]

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Table of Content

D5.4: FINAL GUIDELINES FOR PRODUCT DEVELOPMENT 1

Product development for step-by-step refurbishment 4

General 4

Step-By-Step approach 6

A) BUILDING ENVELOPE AND WINDOWS 9

Summary 9

Innovative concepts in envelope and windows 10
Airtight solutions applied from the exterior 11
Prefabricated Façade Elements 12
Integration of technology in the facade 13

B) HEATING, COOLING & HOT WATER 15

Summary 15

Innovative concepts in heating, cooling and hot water 15
Dehumidifying and cooling in hot a humid climates
Solar powered heating, cooling and hot water solutions 18
Ventilation radiators combined with extract ventilation system

C) VENTILATION 21

Summary 21

Innovative concepts in ventilation 22
Placement of ventilation unit 23
Novel air distribution concepts 24
Innovative heat exchangers 25

D) RES INTEGRATION 26

Summary 26

APPENDIX

Certified Passive House Fehler! Textmarke nicht definiert.

EnerPHit and EnerPHit+i 29
Selection of certification protocol 29
Certification based on the requirement for heating demand 29
Certification based on requirements for individual building components 29
Other general requirements 31
Primary energy demand 32
Airtightness 32
Protection against moisture 32

Climate zones in Europe
Climate zones and corresponding sets of component requirements
Method applied

Endnotes 38

Product development for step-by-step refurbishment

General

Step-by-step refurbishments are the usual way of conducting refurbishments. But we do not acknowledge this, it happens more like an afterthought. We exchange windows one year, insulate the façade another year and exchange the boiler when repairing it becomes too expensive. The need for refurbishment is mostly defined by the lifetime of the separate elements, and not by any overall energy efficiency concept, nor any financial lifecycle calculation.

Step-by-step refurbishment is a challenge, not only because of the above mentioned reasons, but also because the building industry and component producers have not taken the implications into account. In a normal refurbishment bad detailing would not matter much. For an EnerPHit refurbishment good thermal bridge solutions, efficient ventilation and hot water installations become crucial for the long-term success of the undertaking.

New products but also new installation concepts are necessary to improve and simplify the situation. The EuroPHit project has been instrumental at looking into existing solutions, but also in discovering new potential.

During the product development project we have come to split it into 4 main categories:

- Envelope (Looking at added insulation, thermal bridges, windows and shading)
- Ventilation (New emerging concepts and technical solutions)
- Heating and Cooling (New emerging installation concepts and products)
- RES integration (especially the role of PV)

Three major documents have been produced:

Summary of Demand

This document provides a list of existing products but also a wish list of possible new concepts and products. Included in the 50+ page document are also a description of PH and EnerPHit criteria and climate zones necessary for a correct product development.

Design Briefs

This document is in fact a compilation of more than a dozen stand-alone product briefs describing in detail some of the concepts we are expecting the industry to develop into final products. Some of these briefs have already been turned into real products available on the market now.

Final Guidelines

This document you are holding in your hands, is a recap of the main advice for step-by-step refurbishment, referring to the two previous documents for more detail.

On top of the creation of these 3 major documents, other activities have been conducted as well:

Product Awards

During the project we have been able to conduct two product awards, one concerning step-by-step window installation and another on ventilation installation in existing flats. Both awards have been instrumental at providing a range of new solutions for window installation and retrofitting ventilation. Both topics are at the core of an energy and cost efficient refurbishment plan.

Meetings with Producers

To be able to provide all this information, multiple meetings with producers have been conducted internationally. A summary of some of these meetings is also an output of this project. Many other meetings have been conducted on the sidelines of different building fairs, conferences and project developments. Experience from product application and construction gained during previous years has also played a major role in determining the most important elements of product development.

Step-By-Step approach

In a step-by-step approach, the effect any change has on other areas of construction usually defines the potential areas for product development. For example looking at the connection between roof and windows/doors leads to the development of a product brief for a roof ladder to the attic that can be installed airtight and without thermal bridges.

Our hope is that producers, by looking at the table below, will be able to define new potential product applications.

The table serves also the architect and/or builder to identify areas that need special care and detailing. It is always important to pose questions as to what effect **any** change in the building has on any other. To understand the interdependence of separate elements during a stretched out refurbishment can save long- and short-term finances.

Table 1: Cross Check for any Building

Step-by-step	Facade	Roof	Windows/ Doors	Heating	Cooling	Ventilation	RES integration	Interior	1-step renovation
Facade	CHECK	Thermal bridges	Airtight connections, Thermal bridges	Facade integrated technologies	Shading optimalisation	Penetrations & Facade integrated technologies	Facade integrated technologies	Optimising building envelope	ALL
Roof		CHECK	Daylight optimization & Shading, Roof access	Roof integrated technologies	Penetrations & Roof integrated technologies	Penetrations & Roof integrated technologies	Roof integrated technologies	Optimising building envelope	ALL
Windows/Doors			CHECK	Window & Facade integrated technologies	Night & Natural Ventilation	Window & Facade integrated technologies	Window & Facade integrated technologies	Daylight optimalisation & Shading	ALL
Heating				CHECK	Cooling/Heating synergies	Ventilation/Heating synergies	RES strategies for Heating	Heating concepts	ALL
Cooling					CHECK	Ventilation/Cooling synergies	RES strategies for Cooling	Cooling concepts	ALL
Ventilation						CHECK	RES strategies for Cooling	Ventilation concepts	ALL
RES integration							CHECK	Energy storage &Conservatio	ALL
New Interior								CHECK	ALL
1-step renovation									CHECK

Huge potential in further research

There is no doubt that further research can lead to highly improved product development. This is especially evident in the area of ventilation and heat recovery. New emerging concepts have the potential to create cost effective solutions that were unthinkable just a few years back. A good example is the Vent-4-Reno approach, in which **one** ventilator not only moves air in **and** out but also recovers heat without the need for frost protection. Such solutions will make refurbishments in Passive House standard much more available than before.

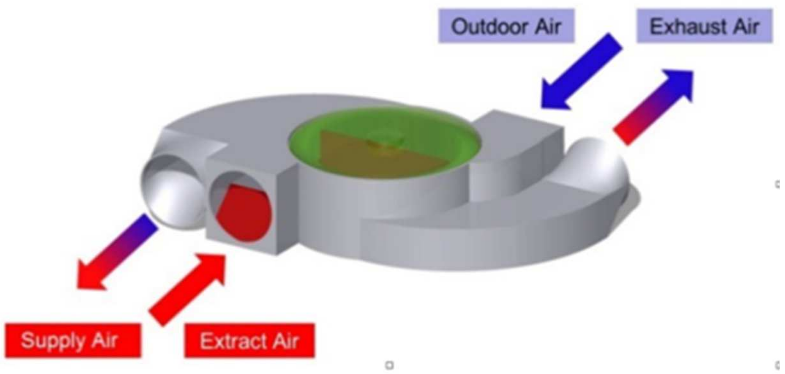


Figure 1: Heat recovery fan – combined fan and heat exchanger for facade integration www.vent4reno.eu [Speer14]

Ventilation is not the only area that has a great potential for new solutions. Usually the potential becomes clear when identifying existing problems that need a solution:

For building envelope and windows:

- Step by step installation of components, especially window to insulation connections
- Thermal bridge solutions for load bearing façade elements
- Airtight layer installation for retrofit

For heating, cooling and hot water:

- Lowering the hot water demand
- Minimizing distribution losses
- Optimization for RES an PV
- Synergies of cooling and heat production
- Synergies between ventilation and heat pumps

For ventilation:

- Efficient air distribution
- Energy saving frost protection
- Avoiding a condense drain
- Minimizing size of the units and practicality of installation
- Silent ventilators and outlets
- Balancing humidity during winter in cold climates

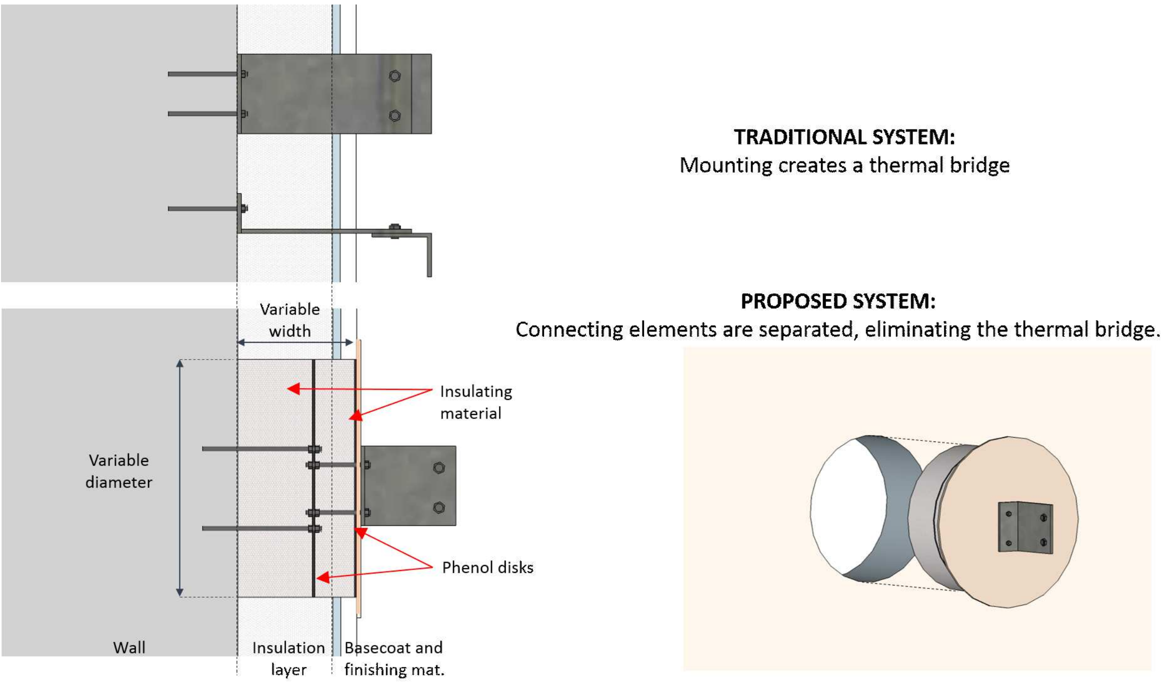
- Cooling and dehumidification in hot and humid climates

For RES integration:

- Energy storage integration
- Visually attractive installations
- Cost effective solutions
- Efficiency increase
- Integration of technical installations and RES in façade
- Supplementary RES integration in a second step

The list above is certainly not final, and a solution in one area (for example an efficiency increase in PV panels) can very quickly lead to new possibilities in other areas of product development.

We suggest producers go through the above-mentioned list together with the corresponding Summary of Demand topics. By comparing existing products and concept ideas with the research potentials above, it will be easily to identify areas of improvement for their own products.



Proposal for a new easy to install mounting bracket for PV curtain wall facades

A) BUILDING ENVELOPE AND WINDOWS

Summary

This section provides a guideline for the latest innovation and possibilities available for the envelope of passive house buildings. Although this is focused on the needs of step-by-step renovation, the identified areas for product development are mostly valid also for 1-step renovations or new buildings.

Step-by-step advice

The overarching step-by-step refurbishment advice would be **to do as much as possible from the outside**. This minimizes upsetting the tenants and reduces costly and invasive measures. Adding insulation and exchanging windows are done routinely today – and thanks to the larger insulation thicknesses and innovation in general, it should be possible to include technical installations as well. Ventilation ducts placed below the insulation and smaller wall integrated units are a good example for this happening already. The development of **PV will further increase the potential to add self-sufficient ventilation, heating or cooling units to the façade**. And modern **3d scanning procedures and CAD/CAM possibilities enable efficient preproduction of façade elements**, complete with windows and technical installations. Through the rise of robotics in the construction industry prefabrication will become the most cost effective solution.

Additional resources

Refer to the document **"Summary of Demands for Product Development"** for existing products and solutions. The corresponding section for building envelope and windows in that document are on page 18-33.

Refer to **product briefs** with a more detailed discussion of what is demanded of these new products:

- External Airtight Insulation and Finishing System EAIFS
- Attic trap doors
- Window connection - Window first
- Window connection - Insulation first
- Glazing with integrated shading
- Window improvement concepts
- Roof to wall connections
- Internal insulation

The products described in the above mentioned product briefs can also be applied in many one step refurbishments as stand alone solutions.

Also refer to the **Product Development Award for Window Integration** – there you will find a range of possible solutions as to how to achieve a correct window design and installation, with best practice examples.

Innovative concepts in envelope and windows

On the following pages we are looking in more detail at some new and promising concepts. They all use the technology in a novel fashion, and pilot projects and testing will be necessary to provide any proof of concept. These **concepts** are:

Airtight solutions applied from the outside: Accessing the interior of a building during refurbishment is not always possible, and development of solutions where the airtight layer is applied from the outside is instrumental to a successful and cost efficient solution.

Prefabricated façade elements: Prefabrication is keeping costs at bay and is becoming an increasingly popular method for refurbishment of for example schools and kindergartens. They have often very short periods of time for refurbishment available.

Integration of technology in the facade: Applying photovoltaic on the roof is fairly usual, but in the future there will be more and more technological products included directly in the façade (ventilation units, heat pumps) with electricity provided directly from the PV facade installations.

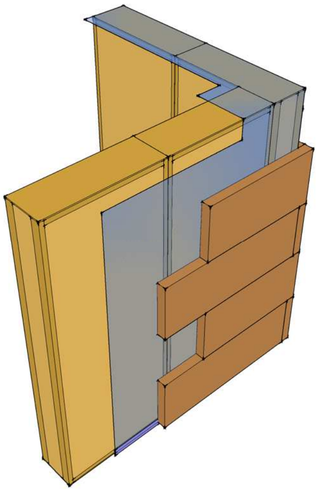
Shading device included in Windows: Good shading is a must to protect from overheating, but the costs of shading are close to 50% of the windows costs. And installation is cumbersome and avoiding thermal bridges difficult. Shading integrated in the glass and electronically dimmable films that do not lower the g value in winter will be the future.

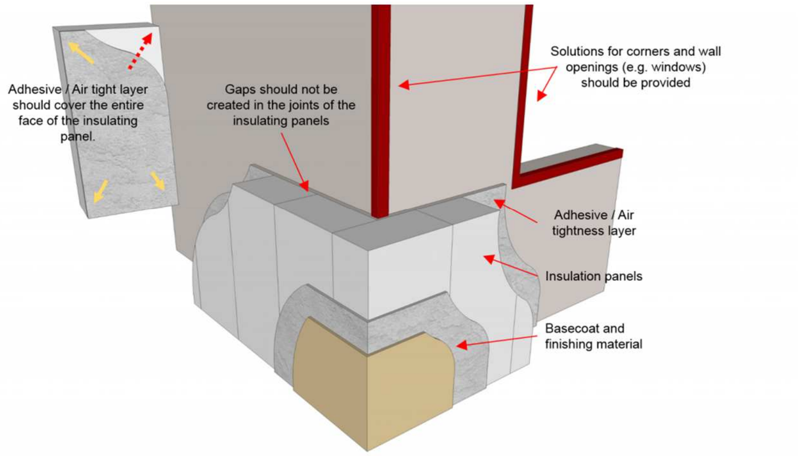
Airtight solutions applied from the exterior

The physically correct placement of an airtight layer in a cold climate is on the inside. The airtight layer slows movement of humidity from the warm inside to the cold exterior to a degree where it can safely evaporate to the outside. Like this no excess humidity can build up in the construction. Good airtightness does not only save energy but also provides longevity for the building.

There are increasingly products that enable the placement of an airtight, but vapor open membrane on the outside, for example on rafters in refurbishments. The rule is that this membrane should be covered with some insulation (preferably woodfibre) on the outside as well.

The company Ecococon, building houses with modular straw panels, uses a system with a completely vapor open (Sd<0,2m) but airtight membrane on the outside. The membrane is then covered with a woodfibre board that transports any excess humidity quickly to the exterior surface.





Ecococon panels wrapped with airtight membrane Sd< 0,2m and covered by woodfibre board and airtight layer on masonry wall before adding insulation

Such approaches need more research but could have a profound impact on how airtight solutions will be solved in the future. Wrapping an airtight layer on the outside of an existing building and insulation instead of installing it on the inside is usually much simpler and cheaper. Refer also to the more detailed design brief “External Airtight Insulation and Finishing System EAIFS” for this Concept. In this design brief the idea is not to add an airtight layer on the very outside but to combine the airtight layer with the application of ETHICS.

Advantages

Quick installation

Usually very reliable BDT results

Risks

Correct installation due to building physics

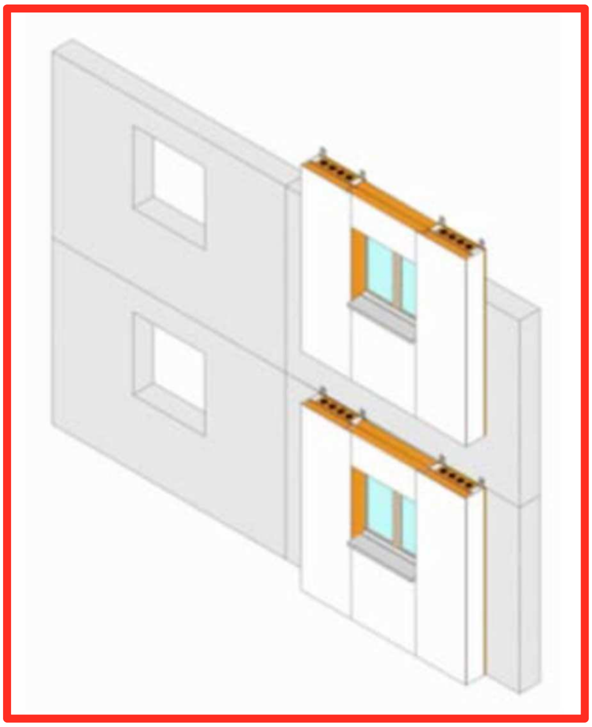
Hidden moisture damages

Missing long-term research

Prefabricated Façade Elements

The use of prefabricated elements is becoming more and more common also in refurbishments. It does not only speed up the refurbishment process, but also enables the integration of windows, cabling, airtight layer and finishes in a protected environment without having employees traveling to a building site. Finalizing the building on site is short and less demanding for existing tenants. In cases such as schools, the only time they can be refurbished is during summer holidays, and speed on the building site is essential.

There are several new technologies that will lead to a more wide spread adoption of this system: One is the emergence of large 3d scanning capabilities (laser based or fotometric) that can easily provide exact 3d measurements of existing facades. Second, the adoption of BIM and 3d design flow in architecture shortens the design process. Third, the resulting 3d data can be fed to robotic systems that will produce individually adapted elements very efficiently. The overall result will be more cost effective solutions.



FARO Focus 3d Laser Scanner

Advantages

Quick installation

Efficient production

Integration of several crafts in a controlled environment

Practical use of renewable materials such as wood and cellulose

Risks

High precision demanded at all stages

Missing know-how and experience

Integration of technology in the facade

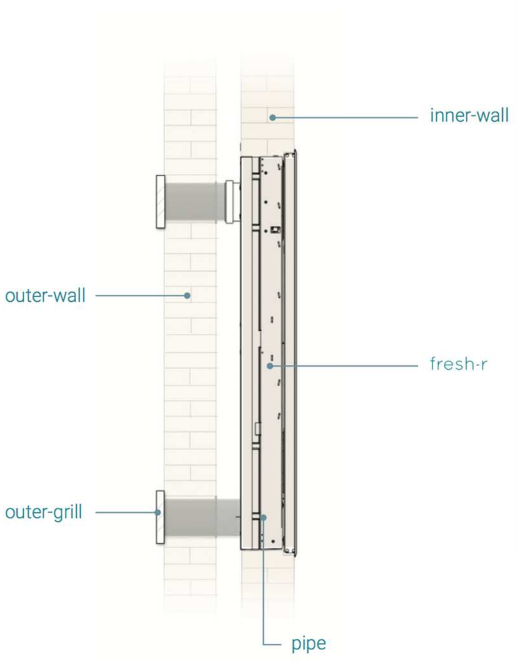
Changes to the interior of a building is much more difficult than adding something to a façade for the outside. The passive houses standard demands fairly thick insulation layers, providing additional space for the placement of ducts and units.

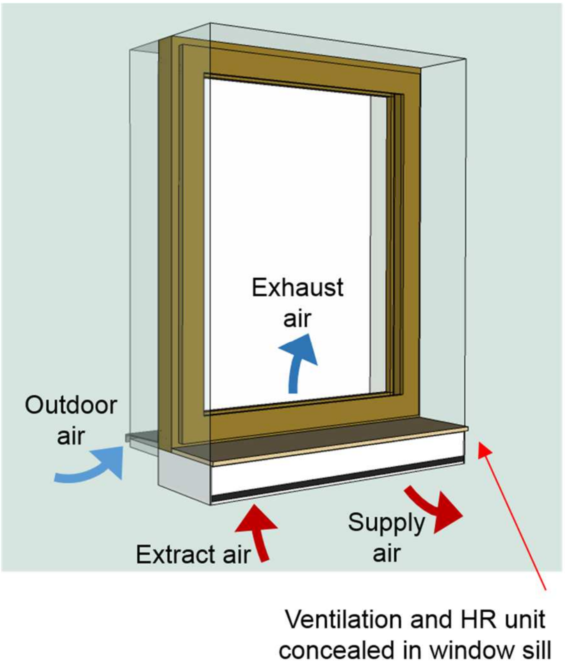
There has been already some successful projects that have used the space between original wall and thermal insulation for ventilation ducts. Ducts on the façade minimize any ducting necessary in the interior.

Other solutions have also seen the integration of ventilation units in wall niches, hidden but easily accessible. Also have units been placed in original or enlarged window openings.

Together with the integration of photovoltaic elements on the façade, we can in future expect smaller façade integrated ventilation units to be completely independent of any additional wiring.

Heating, cooling and hot water is still not a main topic for façade integration, although there could be benefits here as well.





Wall integrated ventilation unit Fresh-R by Vaventis and a concept of a window integrated unit

Advantages

Does not take much additional space inside

Easy to install or retrofit

Smaller decentralized solutions

Risks

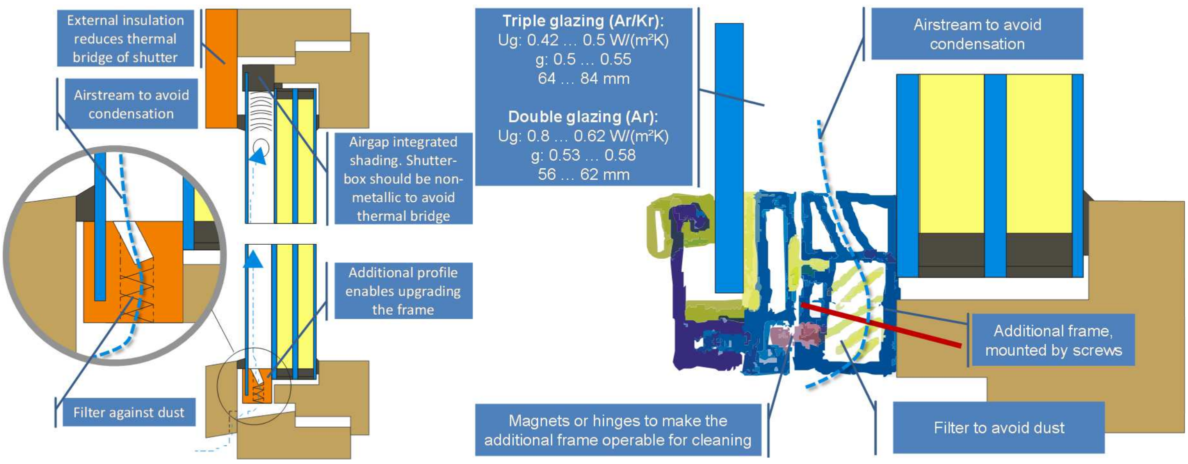
Creation of thermal bridges

Complex integration of several crafts

Shading device included in Windows

Good shading is a must to protect from overheating. Regardless whether it is up to retrofits or new builds, shading- and glare-protective elements have a high share on the overall costs of windows. Cost effective solutions are most desired therefore.

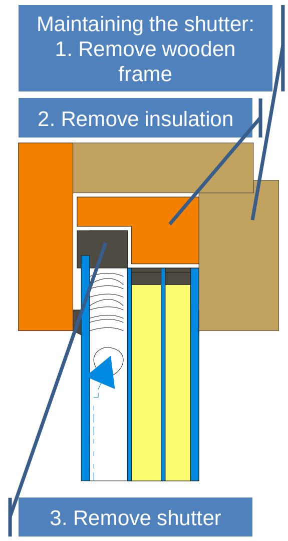
A promising concept is integrated shading, a shading element in between an inside low-e-coated glazing, acting as insulation layer of the window and a weather protection glazing on the outside. This solution promises to be very cost effective in both, investment and maintaining- as well as energy costs.



Left: Airgap integrated shading in principle.

Right: Schematic solution for an additional frame

Below: Principle solution for fixed frames



Advantages

Low costs

Easy to install or retrofit

Lower maintenance costs

Risks

Condensing water within the air gap

Thermal bridge

B) HEATING, COOLING & HOT WATER

Summary

This document provides a guideline for the latest innovation and possibilities available for the heating, hot water and cooling for the Passive House standard. Although this is focused on the needs of step-by-step renovation, the identified areas for product development are mostly valid also for 1-step renovations or new buildings.

Step-by-step advice

The overarching step-by-step refurbishment advice for heating, cooling and hot water would be **to concentrate on synergies that increase efficiency**. Combining cooling and hot water or cooling through dehumidification are good examples of a such approach. Another approach would be to **introduce energy saving measures** – an example can be provided by drain water heat recovery installations. And least but not last would be the use of **low powered energy sources by heat pumps** to meet the main part of heat, cooling or hot water demand.

Additional resources

Refer to the document **"Summary of Demands for Product Development"** for existing products and solutions. The corresponding pages for heating, cooling and hot water in that document are page 34-38.

Refer to **product briefs** with a more detailed discussion of what is demanded of these new products:

- Drain water heat recovery in retrofits - DWHR Systems
- Apartment ventilation radiators

The products described in the product briefs can be applied in many standard refurbishment situations as stand-alone solutions.

Innovative concepts in heating, cooling and hot water

The first imperative when thinking about heating, cooling and hot water should always be **minimalizing demand**. That is where the passive house standard provides the most comprehensive standard adapted to any climatic conditions. It is especially when the demands become very low that new solutions become feasible. We foresee increased innovation happening in these areas:

Increasing efficiency trough synergies: Through combining several technologies and functions in one unit, efficiency can be increased. Today this is done in compact units that use cold air to increase the heat pump efficiency and at the same time provide frost protection[1]. Another good example would be for example cooling supported by evaporation: a small heat pump producing cold air can in combination with a ventilation unit save a lot of energy through simultaneous dehumidification and cooling[2]. Looking at the overall efficiency

[1] See compact unit X2 by Drexel & Weiss

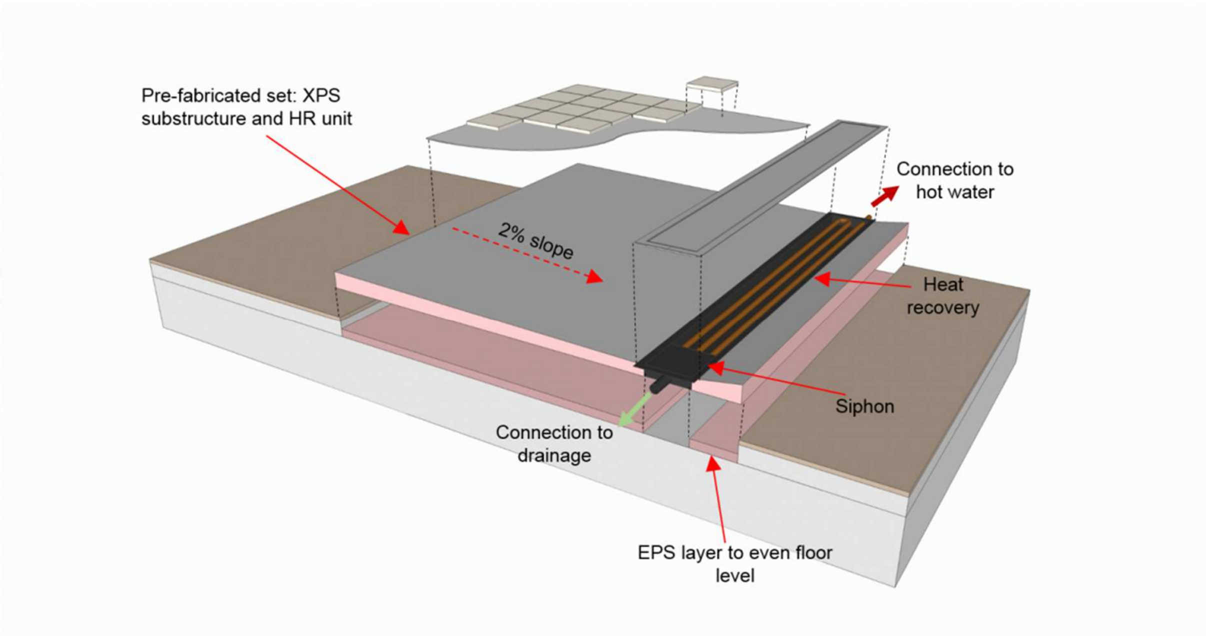
[2] See design brief: Cooling and dehumidifying in Hot and Humid climates

of heating and hot water in apartment blocks very simple step by step solutions can be achieved through ventilation radiators.[3]

Energy saving measures for hot water: The energy use for hot water often exceeds the demand for heating in a passive house. Reducing the energy used can be achieved by lowering the overall use of hot water (water saving faucets and shower heads limited to 6l a minute) or by recovering some of the heat, for example by a drain water heat recovery unit[4].

Use of low powered energy sources: New, decentralized renewable power sources such as PV and wind can be used in a much more efficient way, if even their low energy output can be utilized by micro heat pumps over a longer periods.

Passive houses have always had a wide range of technical solutions available – it seems there will be even more alternatives to choose between in future.



Barrier free shower tab with Drain Water Heat Recovery

[3] See Design Brief: Appartment Radiator-Ventilator

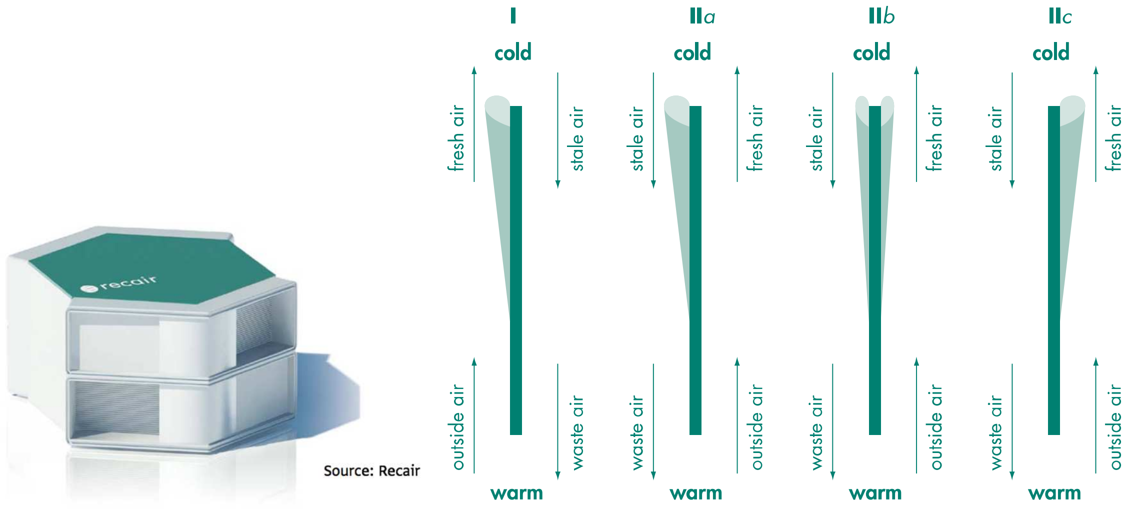
[4] See Design Brief: Drain Water Heat Recovery

Increasing efficiency through synergies

Synergies can usually be found in all areas, if you know what to look for. Cooperation of ventilation, heat pump and renewable energy units' producers is necessary to unlock the hidden potential of energy efficiency.

Additional research is needed for systems optimized for very low energy consumption.

For the Mediterranean but also other areas of Europe that would benefit from active cooling in summer, a new concept is emerging. The system consists of a small heat pump and a heat exchanger that takes advantage of an **alternating air flow**. The cooling power of the heat pump is **magnified by evaporation of previously condensing air humidity**, By alternately inversing the airflow, excess humidity is carried outside by the airstream, dehumidifying the interior. The heat pump ideally provides heat for hot water through the cooling process.



Or, by taking into account the yearly energy use for heating and hot water in an apartment block, **ventilator radiators could in certain climatic conditions** provide a simple and cost effective solution for a step-by-step retrofit solution. Addressing the **overall consumption instead of singular efficiency targets** and the ease of installation were the driving elements for this concept development. It is important to understand, that to find the best synergies, some preconceived ideas have to be rethought in a different context and products have to be developed with the overall target in mind.

See drawing next page: A decentralized ventilation system with local supply air units (ventilator radiators) replacing radiators on outside wall, heating the incoming air via existing heating system. The existing ventilation installation from bath and kitchen is used to extract the air to the roof where the heat is recovered by heat pump. Air and/or solar panel based HP solution for hot water should be included in the concept. RES on roof can be used to generate the necessary energy for ventilators and partly for the heat pump. The system should take into account the overall efficiency for heating **and** hot water for large residential buildings. The efficiency loss for ventilation heat recovery needs to be compensated for by increased hot water efficiency.

Schematic diagram of a ventilation radiator (Source: Myhren 2011)

Advantages:

- Good step by step functionality - stepwise upgrade
- Use of existing heating system
- Possible to use same system for active/passive cooling
- Central extract air to water heat pump installation
- Decentralized/centralized solution with minimized ducting
- RES integration easily possible on roof
- Possibility to combine with heat pipe system

Risks:

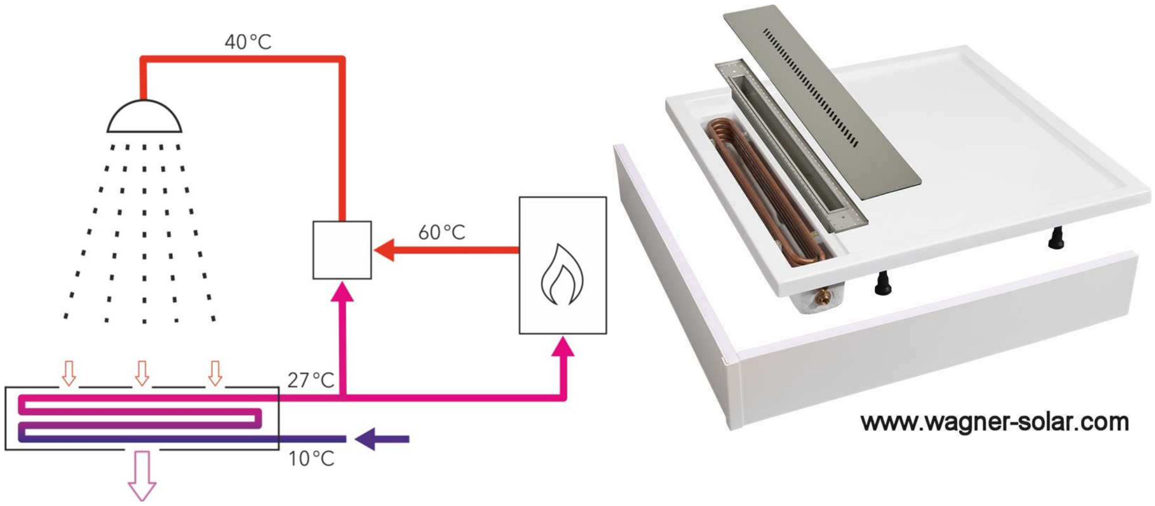
- Thermal loss in distribution, especially cold return flow
- Noise from ventilators
- Balanced air flow
- Low efficiency

Energy saving measures for hot water

The energy use for hot water often exceeds the demand for heating in a passive house. There are three possible solutions to reduce this demand. The first is by lowering the use of hot water in general, the second would be to include heat recovery units. The third approach would be to minimalize heat loss in distribution. These losses have a huge impact on the overall consumption. All three approaches should be implemented to achieve the best results.

Reducing the spent energy by installing water **saving faucets and shower heads** limited to 6l a minute is fairly simple and can easily be done step-by-step. It is important that the comfort of the user is not compromised, as this will not lead to a wide adoption by the the users.

Heat recovery from showers is another fairly efficient measure, where approx. 40% can be saved. The installation should be done every time a shower is remodeled. It probably also makes sense to install such a heat recovery unit under the bath where retrofitting is even easier, as many people use the bath also as a shower.



Minimalizing storage and distribution losses is another not so simple solution. In some cases (low water consumption) it has been shown that even direct electrical heating at the tapping point is preferable over storage and long distribution lines.

Although most passive houses try to place bathrooms, technical rooms and kitchen close to each other, it is not always possible. A possible future approach would be to include decentralized units (for example micro-heatpumps) close to the point of use.

Advantages:

- Good step by step functionality and stepwise upgrade
- Several combinable approaches

Risks:

- Cost of installation
- Maintenance

Use of low powered energy sources

Solar power is becoming increasingly popular in the form of photovoltaics. Although thermal solar panels are very popular in the Mediterranean area for covering hot water demand, they can only be used with difficulties for cooling (Adiabatic solar cooling units). Photovoltaics can provide a much more useful solution if combined with a small air to water heat pump, providing hot water, cooling and heating if necessary.

As for the previously described system, the advantage of using a PV connected heat pump will only manifest itself if the heating and cooling demand of the building is minimalized. There are very few units on the market that are targeted at that segment, if any at all.

A small PV array in the south feeding just 300-400W continuously to a heat pump during a 10h period, can provide approximately 12kWh for hot water per day, sufficient even for a large family. At the same time it can provide a similar amount of cooling power, increasing the interior comfort as a result.

Easily mountable compact roof top units with included heat recovery ventilation could be installed in a similar way as thermal panels with hot water storage are today. The advantage over air conditioning split units would be the integration of secondary hot water production as a result for the active cooling provided.

Another example for a temperate climate would be to better utilize fluctuating energy outputs (for example the 100-400W produced from a 20m^2 PV array during a cloudy day) by making efficient heat pump systems that can transform this into 6-10kWh of heat per day, covering most of the hot water demand for a family.

To make this work, the heat pumps should be able to work in a modulating regime and with a largely variable power input.

Advantages:

- Easy ad-hoc installation
- Synergies possible

Risks:

- Installation on the (cold) outside
- Visible installation

C) VENTILATION

Summary

This document provides a guideline for the latest innovation and possibilities available for the ventilation for the Passive House standard. Although this is focused on the needs of step-by-step renovation, the identified areas for product development are mostly valid also for 1-step renovations or new buildings.

Refer to the document **"Summary of Demands for Product Development"** for existing products and solutions. The corresponding pages for ventilation in that document are page 39-42.

Refer to **product briefs** with a more detailed discussion of what is demanded of these new products:

- Wall integrated ventilation
- Window integrated ventilation
- Active overflow Ventilation systems
- Ventilation duct Tools
- Regenerative MVHR, Alternating Type
- Large decentralized ventilation units

Also refer to the Component Award 2016 - ventilation for residential building – where you will find a range of possible solutions how to achieve a cost effective ventilation with heat recovery installation.

The products described in the product briefs can be applied in many standard refurbishment situations as stand alone solutions. These standard solutions are not discussed here. On the following pages we are looking at a few new and promising concepts. They all use the technology in a novel fashion, and pilot projects and testing will be necessary to provide any proof of concept. These concepts are:

- New placements of the unit
- Novel air distribution systems
- Innovative heat exchangers

Step by step approach, low invasive, possible to do one apartment at the time etc… focus on step by step.

Innovative concepts in ventilation

There are always things that can be done better. Sometimes there are things that can be done different. This is also the case for ventilation with heat recovery. Most ventilation units have changed only incrementally in the last decades. There are not many new ideas that might change the game. But a real improvement would be a cheap, readily available ventilation unit.

There are examples of innovative thinking happening just now, and the first applied results need affirmation and further development.

Innovation is happening in three broad areas:

New placements of the unit: the ventilation unit has traditionally been installed in the technical room, taking up much space and with long ducts that needed insulation. The trend is finding ways how to integrate the unit in the wall, in the facade or close as a part of the windows in order to save valuable living area

Novel air distribution concepts: achieving short ducts has always been an important design criterion in buildings – but how about leaving them out completely? New cascading ventilation concepts, decentralized ventilation or ducting outside of the airtight layer are all practical solutions for refurbishments.

Innovative heat exchangers: Heat exchangers with enthalpy membranes, paper based heat exchanger, fine wire heat exchangers or rotary wheels have the potentials of both improving and simplifying the whole ventilation concept.

It will be interesting to see what a combination of these new concepts and tools will bring for the future. One thing is sure; building Passive Houses goes hand in hand with innovations.

Placement of ventilation unit

New installation should require as little space as possible. A ventilation device that requires a technic room for installation for example wouldn't be a suitable solution for a step by step refurbishment. A logical consequence is placing the ventilation unit at the intersection of outside and inside, that is in the wall or façade. A variation of this would be at the window – where already is an opening that might be used for an easy integration of the ventilation unit.

The advantages of these placements are obvious:

- Air intake and exhaust are part of the ventilation unit, no extra ducting necessary
- There are no cold surfaces to insulate on the inside
- The unit takes up very little space inside
- The unit could be easier and thus cheaper to install

The difficulties/ challenges of these placements are obvious:

- Frost protection needs to be solved
- Drainage of condensate needs to be solved
- Filters might be difficult to access
- Good acoustical performance of the unit is required
- Good air distribution is not so easy

Units can also be placed on the attic, or on the roof. There are certainly concepts that might lead to a higher cost reduction than most of todays common concepts.

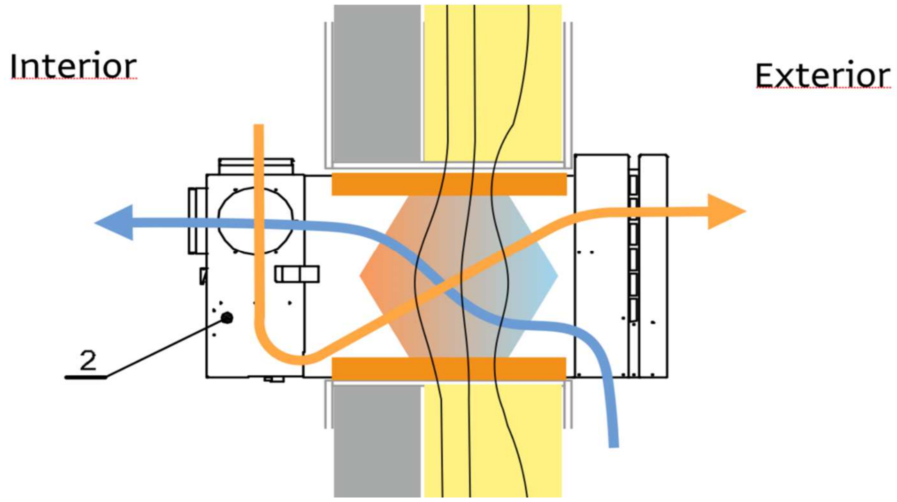


Figure 1 SmartVent Wall installation (Source: Createrra)

Novel air distribution concepts

The traditional ventilation concept for a Passive House is the cross ventilation principle which is based on using the air several times. Fresh air is provided to the living areas and extracted from bath and kitchen. Overflow areas such as corridors provide the „ducting“ for the air supply.

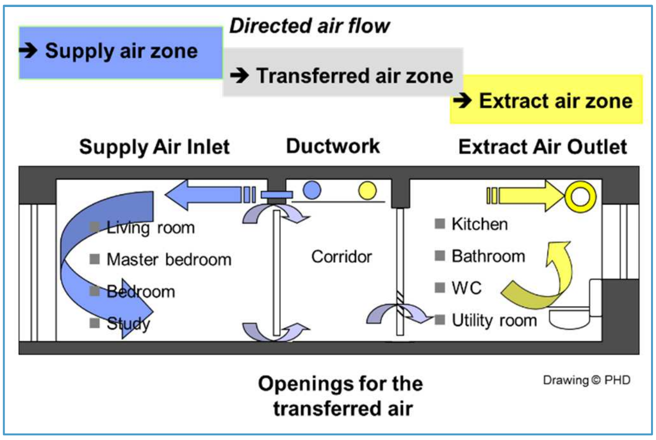


Figure 2 Cross ventilation principle with supply and extract air

An improvement of this concept is the extended **cascade ventilation**, where the living room or other rooms become part of the overflow area. This again minimizes the provided air volume and reduces the amount of ducting. The possibilities of extended cascade ventilation depend a lot on the specific floor plan and can be easily checked with the ventilation tool “Luftführungskonzepte” of the University of Innsbruck (for now only available in German): http://www.phi-ibk.at/luftfuehrung/

Another promising concepts especially for refurbishments is the **active overflow concept,** which can be used for example in dwellings with all rooms connected to one hall**.** The corridor or common rooms become the ducting itself, filled with fresh air, and the fresh air is provided to the rooms through active overflow ventilators. Ducting is required only for the extract air.

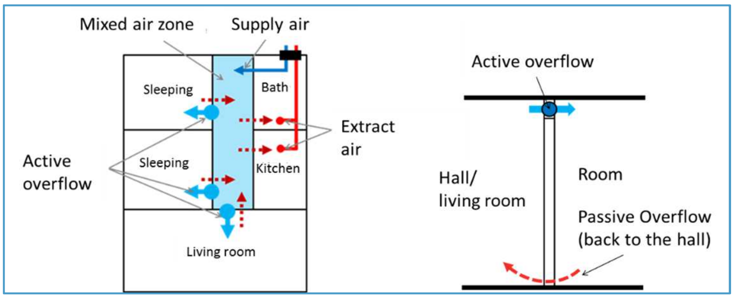


Figure 3 Principle of active overflow, Source: Uni Innsbruck

Beside completely new concepts for the air distribution, there have been some improvements also concerning the **integration of the ducts**. To be mentioned in the context of step by step refurbishments are ducts suitable for the integration in the insulation of the façade as well as ducts inside the thermal envelope that are suitable for visible installation. Both options give the possibility to dispense with costly coverings. Suitable components are already available on the market however the design and availability can still be improved.

Innovative heat exchangers

Innovation of course has to start with the heat exchangers. The standard plate or rotational heat exchanger have now some new contenders that might lead to cheaper solutions.

The most important new characteristics we are looking for are

- Automatic, energy saving frost protection
- No condensate
- Enthalpy function at condensing temperatures

There are several interesting solutions to these problems.

There is for example the **paper based folding heat exchanger** from ProVentecs[i]. The advantage is that the heat exchanger would be cheap and easy to exchange. The question of condensate drainage would already be solved as the heat exchanger provides moisture recovery as well. This ensures also an efficient frost protection as the freezing potential declines.

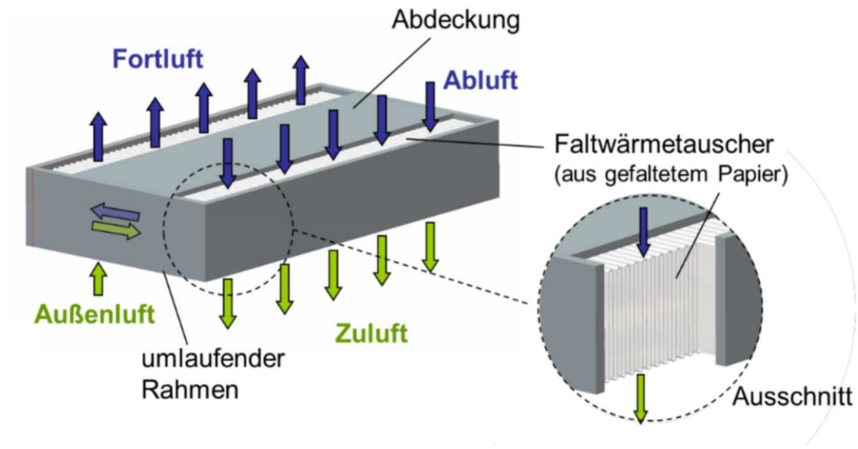


Figure 4 Proventecs Paper heat exchanger source: Proventecs, Rolf Strauß

Another interesting new development is the **fine wire heat exchanger** from Vaventis[ii] that also does not need frost protection, but of course there will be some condensing on the copper heat exchanger. The advantage of their unit seems to be high efficiency, minimal pressure loss and the heat exchanger filters the air and can be rinsed with water.

Recair provides also an innovative solution. An otherwise classical heat exchanger[iii] achieves frostprotection and enthalpy functions by inverting the airflow with the help of integrated flaps. Sensible and latent heat can be recovered. The advantages of this system can also be exploited for very efficient cooling and dehumidification in hot climates.

Last but not least is the innovative **heat recovery ventilator** (heat exchanger and ventilator in one) that is being developed as part of the vent4reno[iv] project by University of Innsbruck. The heat exchanger makes use of very thin gaps between the heat exchanger plates, increasing significantly the heat flow. No condensation has time to build up, as the unit is rotating from cold to warm areas several times per second. This concept solves frost protection, condensations and humidity-transfer function on a minimum of space.

D) RES INTEGRATION

Summary

This document provides a guideline for the latest innovation and possibilities available RES integration in passive house buildings. Although this is focused on the needs of step-by-step renovation, the identified areas for product development are mostly valid also for 1-step renovations or new buildings.

Step-by-step advice

As RES (Renewable Energy Solutions) integration is becoming cheaper, the popularity of such measures are growing. In general, RES can be retrofitted to any building from the outside. The big hurdle are usually the costs involved for installation. Areas of development will concentrate on lowering installation costs in general, and making retrofitting feasible on passive house standard insulated facades. This can be achieved by **new mounting connections** and by **development of lighter elements**. Another area of product development will be the **PV installation on existing glass facades**. Increasing the insulation value and including shading/solar blocking devices at the same time would be ideal. **Storage and direct use of PV produced electricity** in decentralized units will be another important milestone for wide adoption.

Additional resources

Refer to the document **"Summary of Demands for Product Development"** for existing products and solutions. The corresponding pages for RES integration in that document are page 43-51.

Refer to **product briefs** with a more detailed discussion of what is demanded of these new products:

- Retrofitting glass facades with PV panels

The products described in the product briefs can be applied in many standard refurbishment situations as stand alone solutions.

Innovative concepts in RES integration

On the following pages we are looking in more detail at some new and promising concepts. They all use the RES technology in a novel fashion, and pilot projects and testing will be necessary to provide any proof of concept. These **concepts** are:

Retrofitting PV on façade and roof: Thick passive house insulation makes sometimes mounting PV panels on the façade difficult. New load bearing fixtures, lighter panels or even new paint on concepts should be explored. This is true also for roofs, where PV installations sometimes are not possible because of visual aspects.

Storage and direct use of PV produced electricity: Storage of energy will be a main game changer – even if it lasts just for 1 day. A higher percentage of the produced energy can be used directly. This should also lead to the development of decentralized units that can be installed self-sufficiently.

Retrofitting PV on façade and roof

The main three challenges with retrofitting PV panels are:

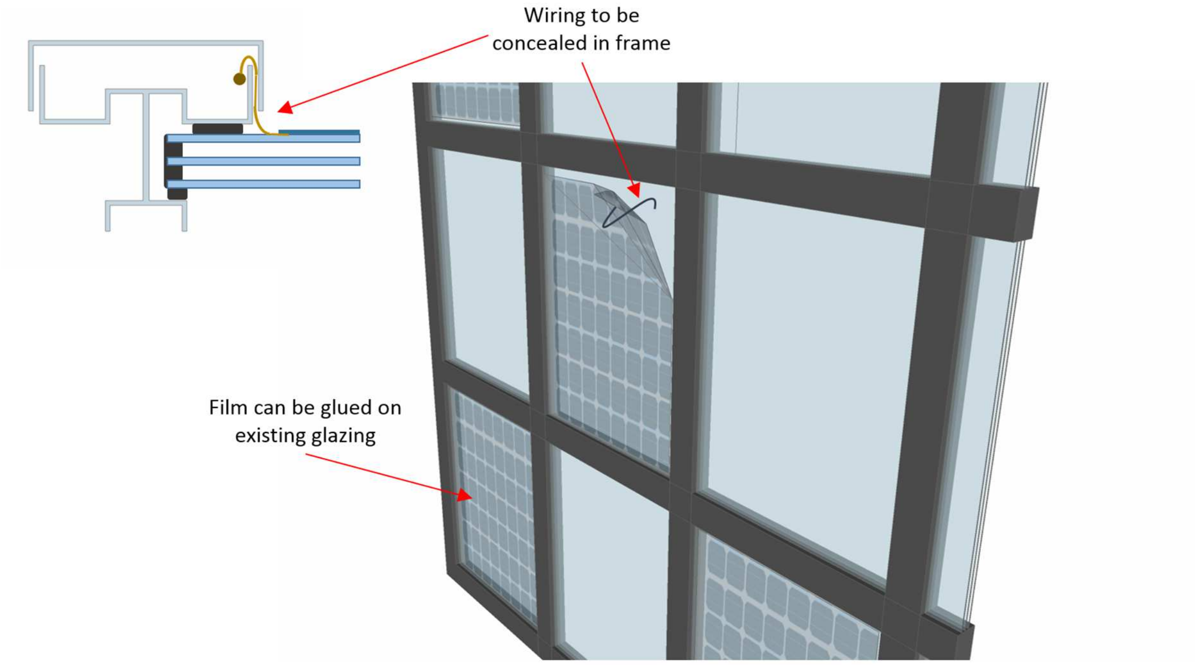
1. Ease of installation
2. Visual impact on the surroundings
3. Retrofitting large glass facades

Retrofitting PV on rooftops are standard procedure. Most producers of roofing covers include products to securely fasten photovoltaic elements retroactively. This is not the case for facades, especially facades that have been retrofitted to passive house standard. PV panels are fairly heavy, and thermal bridges should be avoided. The Design Brief “PV installation on existing highly insulated facades” addresses this problem.

Another problem consists in the visual impact photovoltaic panels might have. In protected historic town areas, PV panels can not be added to the rooftops. The development of roof tiles with an original look but with integrated PV would be a perfect solution. Especially in town centers the roof area is exceptionally high, providing a lot of potentially useful installation surface. The development of new surface coatings that are non-glare and possible to produce in a range of colors will be necessary.

Including photovoltaic panels on existing glass facades could be another game changer. Most Glass facades are badly insulated and suffer from overheating and high cooling loads in Summer. Adding another film, glass or even ridged insulated panel with integrated PV cells to part of the structure, thereby increasing the insulation value and improving the shading at the same time would solve three problems at once.

Producers of glass facades should cooperate with PV manufacturers to include new products to upgrade their existing facades. New research is necessary to achieve transparent PV Cells with an adaptive g value that can be electronically set to the necessary shading level.



Drawing of PV installation on Glass Facades

Storage and direct use of PV produced electricity

A big problem of PV produced electricity is that it needs to be used immediately or stored. New battery technologies and also electric cars will provide for storage capacity in the near future.

Another possibility would be to include storage capacity in the separate devices themselves. For example a PV powered heat pump can store some of the energy as heat by preheating the hot water boiler to higher temperatures. Including a battery and an electronic regulation connected to a web based weather forecast could further improve the overall direct use of solar electricity by the unit.

Similar solution could be achieved for ventilation units. As we foresee ventilation units being installed directly in the wall, connecting them with some PV panels on façade would not be difficult at all. This also makes the electric cabling on the inside superfluous and might not only save costs, but also make the installation more acceptable for the tenants. A small integrated battery could go a long way to make these ventilation units work even for days without need for recharging.

Direct solar electricity for heating can also be stored in the existing building mass. A well insulated PH building usually does not need any additional heating during daytime if the sun is out. But the energy gained during the day could be stored in heavy internal walls to be released 12h later. Although this is not the most energy efficient way to use PV, it is a very cheap and simple solution that might become more viable as the efficiency of solar panels increase.

EnerPHit and EnerPHit+I Certification

Certification Criteria for Energy Retrofits with Passive House Components

If an energy retrofit of an existing building meets Passive House criteria (for new builds), it, too, can be certified as a Certified Passive House.

It is, however, often difficult to feasibly achieve the Passive House Standard in older buildings for a variety of reasons. Passive House technology for relevant building components in such buildings does, nevertheless, lead to considerable improvements with respect to thermal comfort, structural longevity, cost-effectiveness over the building lifecycle and energy use.

Buildings that have been retrofitted with Passive House components and, to a great extent, with exterior wall insulation can achieve EnerPHit certification as evidence of both building quality and fulfilment of specific energy values. The EnerPHit+i designation is applied if more than 25 % of the opaque exterior wall surface has interior insulation.

The certification criteria, current as of October 2014 for cool-temperate European climates, for both standards are described below.

Selection of certification protocol

Certification can take place based on the requirement for the heating demand or on the requirements for individual building components. Compliance with the general requirements is in either case mandatory.

Certification based on the requirement for heating demand

Heating demand: $Q_H \leq 25$ kWh/(m²a) (calculated using the PHPP)

Certification based on requirements for individual building components

Evidence must be provided that all energy-relevant building components for which the PHI has specified Certified Passive House Component certification criteria comply with such criteria. Building component criteria published on www.passivehouse.com apply unless otherwise stipulated in these EnerPHit criteria. For products not certified by the PHI, the applicant is responsible for providing evidence that the specific component criteria have been met. Evidence of compliance must be recorded in writing and confirmed with a legally binding signature; it is the responsibility of the applicant to ensure that this is done.

Required limit values must not be exceeded on average[v] for the entire building. A higher value is permissible in certain areas as long as the absolute upper limit as given in Section 0 is not exceeded.

If the heat transfer resistance (R-value) of existing building components is taken into account for the improvement of the heat transfer coefficients (U-value) of modernised building components, this must be demonstrated in accordance with the accepted technical standards. It is sufficient to adopt a conservative approximation of the thermal conductivity of the present building materials from suitable reference charts. If building component assemblies of existing buildings are not clearly identifiable, standardised estimates according to the year of construction as taken from appropriate component catalogues[vi] can be used as long as these are comparable with the component at hand.

Requirements

In the following section, important requirements[3] for Certified Passive House Components will be repeated for the sake of simplicity. Nevertheless, what follows is subordinate to the current criteria as stated on the PHI website (www.passivehouse.com) under the heading *Certification*.

Additional requirements for EnerPHit certification will also be mentioned.

Opaque building envelope

For exterior insulation: $f_t \cdot U \leq 0.15$ W/(m²K)

For interior insulation[vii]: $f_t \cdot U \leq 0.35$ W/(m²K)

With temperature factor f_t:
in contact with the outdoor air: $f_t = 1$
in contact with the ground: "ground reduction factor " from the PHPP "Ground" Sheet

Use of interior insulation is only advised if exterior insulation is structurally impossible, not legally permitted or clearly uneconomical with regard to lifecycle costs.

In refurbishments of existing buildings, it is not always possible to largely eliminate thermal bridge effects ($\neg_{ext} \leq +0.01$ W/(mK)) with justifiable effort as is necessary for Passive House new builds. Nevertheless, thermal bridge effects must always be avoided or minimised as much as possible while ensuring cost-effectiveness; nevertheless, the requirements given in Section "Protection against Moisture", must always be fulfilled.

Thermal bridges that are part of the standard structure of a building component are taken into account in the evaluation of the heat transfer coefficient.

Window W (window)

For the window as a whole (see EN 10077): $U_{W,installed} \leq 0.85$ W/(m²K)

for g and U_g-value of glazing: $g \cdot 1.6$ W/(m²K) $\geq U_g$

External doors D (door)

$f_t \cdot U_{D,installed} \leq 0.80$ W/(m²K)

with temperature factor f_t:
in contact with the outdoor air: $f_t = 1$

in contact with the unheated basement: f_t = "ground reduction factor " from the PHPP "Ground" Sheet

Ventilation

$|_{HR,eff} \geq 75$ %

Specific electricity consumption of the entire system based on the average volume flow transferred (electrical efficiency): ≤ 0.45 Wh/m³

All rooms within the heated building volume must either be connected to a supply air and extract air system with heat recovery or be part of a transferred air zone. Compliance with $|_{HR,eff}$ for the entire ventilation system is necessary - going over and above the criteria for Certified Passive House Components, i.e. the heat losses from warm ventilation ducts in cold areas or cold ducts in the warm areas should also be included.

Certification seals for EnerPHit retrofits and EnerPHit $^{+I}$ retrofits with internal insulation

Other general requirements

For certification, the valid Certification Criteria (available at www.passivehouse.com) apply and take precedence over the calculation methodology described in the PHPP User Guide and the PHPP application software, which shall apply subordinately.

Due to the large number of requirements for retrofits of existing buildings, it is possible that absolutely precise requirements for some individual energy-related measures are not included in the certification criteria. In this case, the measure should be implemented in such a way that energy efficiency is improved as much as possible, provided that the measure is cost-effective over its lifecycle. The standard of thermal protection necessary for the building component will then be determined by the certifier on a case by case basis (in cooperation with the PHI for highly relevant, exemplary cases).

Primary energy demand

$Q_P \leq 120\ kWh/m^2a + ((Q_H - 15\ kWh/(m^2a)) \cdot 1.2)$

The primary energy demand includes all necessary energy applications for heating, cooling, domestic hot water, auxiliary electricity, lighting, and other electricity uses. The limit value applies for residential buildings, office buildings, schools and other similar uses and further as a preliminary criterion which must be checked for specific uses. In individual cases where a very high energy demand is necessary, this limit value can be exceeded after agreement with the Passive House Institute. For this, evidence of efficient use of electrical energy is necessary, with the exception of existing electricity uses for which an improvement of the electrical efficiency by means of upgrading or renewal would prove uneconomical over the lifecycle.

Airtightness

Limit value: $n_{50} \leq 1.0\ h^{-1}$

Target value: $n_{50} \leq 0.6\ h^{-1}$

If a value of $0.6\ h^{-1}$ is exceeded, comprehensive leak detection must be carried out within the framework of a pressure test during which individual leaks that can cause building damage or impair comfort are sealed. This must be confirmed in writing and signed by the person in charge of the airtightness test.

Protection against moisture

All standard cross-sections and connection details, without exception, must be planned and executed so that excessive moisture on the interior surface or in the building component build-up can be ruled out.

Should there be any uncertainty, evidence of protection against moisture must be provided in accordance with accepted technical standards. An increased heat transfer resistance of R_{si} = 0.25 m²K/W (due to furniture, curtains etc.) and an outdoor design temperature specific to the location (Heating Load "Weather 1" in the PHPP data sets, if available) are used to calculate interior surface temperatures.

Climate zones and corresponding sets of component requirements

The Passive House Standard often cannot be feasibly achieved in older buildings due to various difficulties. Refurbishment to the EnerPHit Standard using Passive House components for all relevant structural elements in such buildings leads to extensive improvements with respect to thermal comfort, structural integrity, cost-effectiveness and energy requirements.

The EnerPHit-Standard can be achieved through compliance with the criteria of the component method (Table 1) or alternatively through compliance with the criteria of the energy demand method (Table 2). Only the criteria of one of these methods must be met. The climate zone to be used for the building's location is automatically determined on the basis of the chosen climate data set in the Passive House Planning Package (PHPP).

As a rule, the criteria mentioned in Table 1 correspond with the criteria for certified Passive House components[5]. The criteria must be complied with at least as an average value[6] for the entire building. A higher value is permissible in certain areas as long as this is compensated for by means of better thermal protection in other areas.

In addition to the criteria in Table 1 or Table 2, the general criteria in **Fehler! Verweisquelle konnte nicht gefunden werden.** must always be met. The EnerPHit categories Classic, Plus or Premium may be achieved depending on the renewable primary energy (PER) demand and generation of renewable energy .

5 The criteria for certified Passive House components and data sheets for all certified components can be found on the Passive House Institute website (www.passivehouse.com).

6 Note: When calculating average U values for insulated building components, the area weighted mean of the U-value, not the average insulation thickness, applies. Thermal bridges must only be taken into account during the calculation of the average value if they are part of the standard structure of the building component (e.g. wall ties). For multiple ventilation systems, the average value weighted by volumetric flow applies.

Table 1 EnerPHit criteria for the building component method

Climate zone according to PHPP	Opaque envelope[1] against...				Windows (including exterior doors)					Ventilation	
	...ground	...ambient air			Overall[4]			Glazing[5]	Solar load[6]		
	Insulation	Exterior insulation	Interior insulation[2]	Exterior paint[3]	Max. heat transfer coefficient ($U_{D/W,installed}$)			Solar heat gain coefficient (g-value)	Max. specific solar load during cooling period	Min. heat recovery rate[7]	Min. humidity recovery rate[8]
	Max. heat transfer coefficient (U-value)			Cool colours							
	[W/(m²K)]			-	[W/(m²K)]			-	[kWh/m²a]	%	
Arctic	Determined in PHPP from project specific heating and cooling degree days against ground.	0.09	0.25	-	0.45	0.50	0.60	$U_g - g*0.7 \le 0$	100	80%	-
Cold		0.12	0.30	-	0.65	0.70	0.80	$U_g - g*1.0 \le 0$		80%	-
Cool-temperate		0.15	0.35	-	0.85	1.00	1.10	$U_g - g*1.6 \le 0$		75%	-
Warm-temperate		0.30	0.50	-	1.05	1.10	1.20	$U_g - g*2.8 \le -1$		75%	-
Warm		0.50	0.75	-	1.25	1.30	1.40	-		-	-
Hot		0.50	0.75	Yes	1.25	1.30	1.40	-		-	60 % (humid climate)
Very hot		0.25	0.45	Yes	1.05	1.10	1.20	-		-	60 % (humid climate)

Opaque building envelope

If the heat transfer resistance (R-value) of existing building components is taken into account for the improvement of the heat transfer coefficients (U-value) of modernised building components, this must be demonstrated in accordance with the accepted technical standards. It is sufficient to adopt a conservative approximation of the thermal conductivity of the present building materials from suitable reference charts. If building component assemblies of existing buildings are not clearly identifiable, standardised estimates according to the year of construction as taken from appropriate component catalogues (e.g. "EnerPHit-Planerhandbuch", PHI 2012, only available in German) can be used as long as these are comparable with the component at hand.

In refurbishments of existing buildings, it is not always possible to achieve absence of thermal bridges with justifiable effort as is necessary for Passive House new builds. Nevertheless, thermal bridge effects must always be avoided or minimised as much as possible while ensuring cost-effectiveness. Thermal bridges that are part of the construction system, e.g. wall ties, must be taken into account in the evaluation of the heat transfer coefficient of this construction.

[2] Interior insulation

An important reason for the lower requirements for interior insulation (compared with exterior insulation) is that it reduces the useable area, therefore in principle only exterior walls are regarded as having interior insulation (if applicable), but roofs, basement ceilings and floor slabs are not.

[3] Exterior colour

Cool colours: colours which have a low absorption coefficient in the infrared part of the solar spectrum.

This criterion is defined by the solar reflectance index (SRI) which is calculated from the absorptivity and emissivity in the PHPP in accordance with the international standard ASTM E1980-11.

Flat roofs (inclination ≤ 10°): SRI ≥ 90

Sloped roofs and walls (inclination > 10° and < 120°): SRI ≥ 50

Measured values of areas exposed to weathering for at least 3 years must be used. If measured values are only available for the new state then the absorptivity should be converted using the auxiliary calculation in the PHPP worksheet "Areas" provided for this purpose. For simplification, the emissivity can be kept as it is.

In the following cases, this criterion does not have to be met:

"greened" surfaces; areas which are covered with rear ventilated solar collectors or photovoltaic panels (including the distance required between the panels); penetrations in building components and the associated equipment; accessible (roof) terraces or paths; areas that are strongly shaded or do not face the sun.
Other measures can also be undertaken as an alternative to the use of cool colours (e.g. increasing the insulation thickness beyond the applicable criterion for the building component), if this does not increase the overall cooling demand compared with the use of cool colours.

[4] Windows, overall

The illustrations show the respective inclination of the installed window. In each case the criterion for inclination of components will apply which most closely approximates the actual inclination of the window. There will be no interpolation between two criteria. However, since the glazing U-value changes with the inclination due to physical processes, the glazing U-value U_g corresponding to the actual inclination must be set for the window itself.
In the case of small windows above an average frame length to window area ratio of 3 m/m² the limit value mentioned in the table is steadily increased . The limit value to be applied is automatically calculated and shown in the PHPP worksheet "Verification" in accordance with the following formula:
Addition to the limit value [W/m²K]: (l/A-3)/20
l: length of window frame
A: window area

[5] Glazing

The limit value only applies for actively heated buildings with a heating demand above 15 kWh/(m²a).

[6] Solar load

The limit value only applies for actively cooled buildings with a sensible cooling demand above 15 kWh/(m²a). It refers to the solar radiation entering the building per m² of glazing area after taking into account all reduction factors due to shading etc., and must be complied with for the average value of all identically aligned windows. If the limit value is exceeded, then suitable measures must be undertaken to reduce the solar load to the point where the limit value can be complied with again. These include movable shading elements, shading overhangs and anti-sun glazing (latter only in pure cooling climates).

[7] Ventilation, minimum heat recovery efficiency

The heat recovery criterion must be complied with beyond the criteria for "Certified Passive House Components" for the entire ventilation system, i.e. also including the heat losses of the warm ventilation ducts located in the cold area and of the cold ducts located in the warm area.

[8] Minimum moisture recovery efficiency A "humid climate" prevails with dry degree hours for dehumidification ≥ 15 kKh (based on a dew-point temperature of 17 °C). This is automatically determined in the PHPP.

Table 2 EnerPHit criteria for the energy demand method (as an alternative to Table 1)

Climate zone according to PHPP	Heating	Cooling
	Max. heating demand	Max. cooling + dehumidification demand
	[kWh/(m²a)]	[kWh/(m²a)]
Arctic	35	equal to Passive House requirement
Cold	30	
Cool-temperate	25	
Warm-temperate	20	
Warm	15	
Hot	-	
Very hot	-	

Method applied

According to the Passive House Standard, set by the Passive House Institute, Darmstadt, a Passive House is (besides some other criteria) a building with an annual heating demand less than 15 kWh/(m²/a) or with a heating load less than 10 W/m². For cooling regions, the same criteria applies, in certain locations, especially in very hot and humid climates, higher values are allowed. That means the requirements to the building components are depending on the climate.

As most relevant parameters, the ambient temperature and the solar radiation were identified. The so called "heating degree hours" (hdh) [kKh/a] and "cooling degree hours" (cdh) [kKh/a] are turned out to be a good indicator for the ambient temperature. In a 3 step iteration process, a climate region indicator for heating and for cooling regions was found. According to this indicators, the climate regions were disposed:

First step: heating and cooling degree hours

To calculate the heating or cooling degree hours, one takes the monthly average ambient temperature of a specific location and subtracts the so called heating- or cooling- limit temperature. That is the ambient temperature beneath which a building has to be heated or above which a building has to be cooled to achieve a comfortable indoor climate.

In this case, iterations carried out, that 16°C ambient temperature fits best as heating limit temperature and 19°C fits best as cooling limit temperature.

So for calculating the heating degree hours of a specific location, 16°C was subtracted by the monthly average temperature in case that this temperature was under 16°C, otherwise the month was not considered as a heating month. This temperature difference was multiplied with the days in the specific month and the 24 hours of the day, and divided by 1000. The result is the monthly heating degree hours. Then this monthly heat degree hours were summed up to the yearly heating degree hours (hdh [kKh/a]).

Similar was done for cooling: The difference between the cooling limit temperature (17°C) and the ambient temperature was calculated in case the ambient temperature was higher than the cooling limit temperature. Then the difference was multiplied by the days in the month and the hours per day and divided by 1000. This monthly cooling degree hours were summed up to the yearly cooling degree hours (cdh [kKh/a]).

Second step: Solar radiation correction factor

At identical heating degree hours, a low solar radiation leads to higher; a high solar radiation leads to lower component requirements. This fact was considered by a solar correction factor (heating): The yearly sum of solar radiation (kWh/(m²a)) was calculated from the monthly values of the climate data set. This value was multiplied with 0.02 (determined by an iterative process making the resulting map of climate zones similar to those designed in 3ENCULT). The product was subtracted from the annual heat degree hours. Result: Heating-region indicator

Similar applies for cooling: For locations with the same cooling degree hours, a low solar radiation results in lower, a high solar radiation in higher component requirements. As for the heating climates, this was considered by the solar radiation factor (cooling): The sum of solar radiation (kWh/(m²a)) was multiplied by 0.05 (which was found by iteration as the best fit) and this value was added to the annual cooling degree hours. Result: Cooling-region indicator.

Third step: Assignment of the indicators to the climate regions

In an iterative process, the heating- and cooling-region indicators were assigned to the climate regions see Table 1**Fehler! Verweisquelle konnte nicht gefunden werden.**. At first, the heating regions (“arctic”, “cold”, “cool, temperate”, “warm, temperate”) were considered, then the cooling regions (“hot”, “very hot”). So far not considered locations are the climate region “warm”. As can be seen in Figure 3, the biggest parts of Europe are defined as heating climates, except for “Warm” mediterranean areas.

Climate	Number	Region	Heating-/ cooling-region indicator
Heating climate	1	Arctic	> 118
	2	Cold	> 53,8
	3	Cool, temperate	> 27
	4	Warm, temperate	> -4
	5	Warm	All others
Cooling climate	6	Hot	> 118
	7	Very Hot	> 139,5

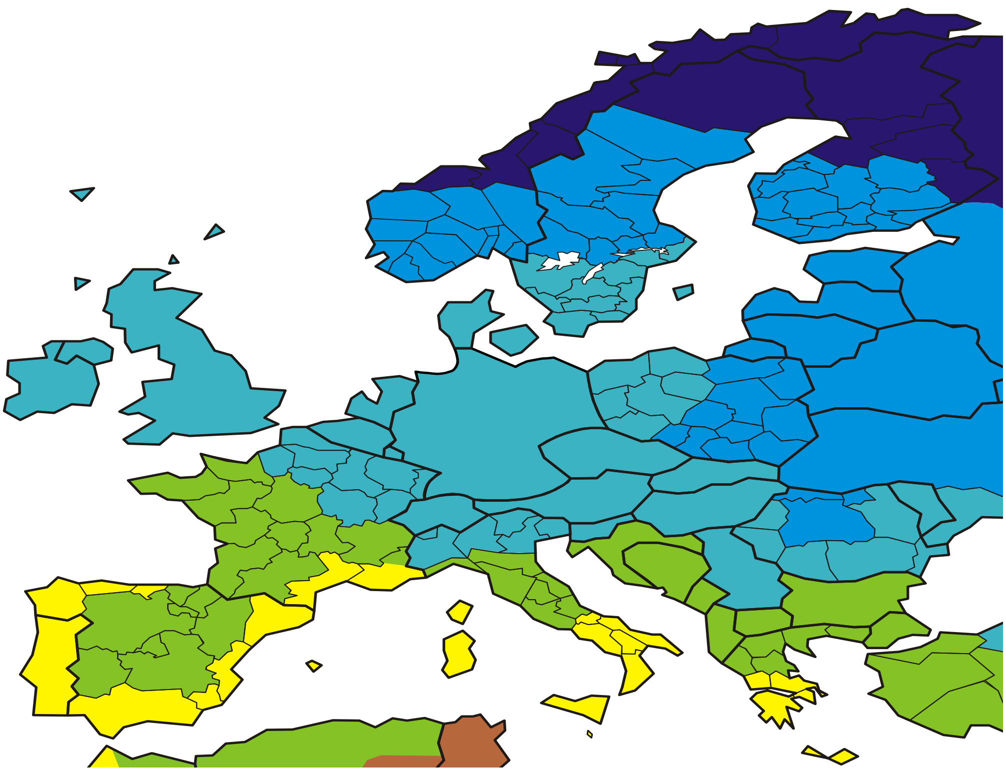


Figure 3: Map of Europe showing regions with similar requirements © PHI 2014

Endnotes

[i] http://www.proventecs.de/produkte/lueftungstechnik/faltwaermetauscher/index.html
[ii] http://www.vaventis.com/fresh-r/
[iii] http://www.recair.com/recair_enthalpy.php
[iv]

[v] Note: When calculating average values for insulated building component assemblies, the area weighted mean of the U-value, not the average insulation thickness, applies. Thermal bridges must only be taken into account during the calculation of the average value if they are part of the standard structure of the building component. For multiple ventilation systems, the average value weighted by volumetric flow applies.

[vi] E.g. "EnerPHit -Planerhandbuch", PHI 2012 (available in German only)

[3] These are only minimum requirements! Enhanced thermal protection often leads to a further reduction in environmental impact and even greater independence from fluctuations in energy prices with the same cost-effectiveness

[vii] Definition of a building component assembly with interior insulation for the component requirements:

Contains at least one solid layer (with λ > 0.2 W/(mK) and THK (thickness) ≥ 100 mm) and at least one layer of insulation (with λ < 0.1 W/(mK) and THK ≥ 10 mm).
The insulation layer is situated on the inside and there is no further layer of insulation (with λ < 0.1 W/(mK) and THK ≥ 10 mm) outside of the innermost solid layer
Only the portion of the layer with the greater share of the surface (e.g. the infill panels and not the wood for half-timbered work) is taken into account.