D5.2_Summary of demands for product development for step-by-step energy efficient refurbishment

INTELLIGENT ENERGY – EUROPE II

Energy efficiency and renewable energy in buildings

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EuroPHit

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

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Abstract

This document is a summary of demands for product development aimed at 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.

To be able to specify which products are crucial and what their characteristics should be, we have looked closer at the intersections of building structure and technologies and have identified synergies that might result in the creation of new products.

By applying a matrix with the typical steps taken during the renovation process, we have identified how specific steps influence other tasks later in the process. These areas of interaction need to be properly assessed and solved before a step-by-step renovation is taking place.

All products developed have to fulfill the criteria set forth by the Passivhaus Institute. These have been listed together with climate zones description at the beginning of the document.

We are looking at five areas of development in more detail:

- Windows & shading
- Ventilation
- Heating, cooling & hot water
- Insulation, thermal bridging & airtightness
- RES integration

Each of these areas are structured in a similar way:

- Concept solutions
- Existing products
- New possible products

Some of the identified solutions are valid for all building types and climates, others are very specific for certain types of buildings and/or climate conditions. These specific demands are especially interesting for new product development. We expect most of the innovation to happen in the area of Thermal bridges, Ventilation, Heating and Cooling, Facade and RES integration. We are also addressing synergies of different technologies that will provide new advantages for user and industry alike.

Possible products that could be developed for use in the proposed solutions will be described in detail in a separate documents called “D5.1. Design Briefs for Products”, clarifying the specific demands they should fulfill:

- How do they work?
- What are the necessary elements?
- What are the constraints?

This document is should provide inspiration for creative minds. It is up to the industry to refine the ideas and concepts that are proposed and turn them into working products.

Scope of this paper

As we are not able to cover all types of buildings in this project, we are concentrating our efforts on products for these building categories:

- Small residential buildings (family houses, row houses etc.)
- Big residential buildings (flats and apartments)
- Office and administrative buildings
- Schools a kindergarten

Each building type will need a different step-by-step approach depending on climate, what building works needs to be done and available finances. Some steps will necessary demand some follow up steps to assure solutions that are correct from the point of view of building physics. (For example we cannot achieve airtightness without also insulating the walls or installing ventilation, mold growth would otherwise be a result of higher humidity inside and low temperatures on the walls.) The right step by step solution and financial considerations are not part of this document, but will be addressed in the following deliverables.

The solutions we are looking for will be different depending on the climate. We are considering five climate zones that are representative for most of Europe

- Warm
- Warm, temperate
- Cool, temperate
- Cold
- Arctic

Read more about climate zones in the dedicated chapter.

Passive House Criteria

Passive Houses are characterised by an especially high level of thermal comfort with minimum energy consumption. In general, the Passive House Standard provides excellent cost-effectiveness particularly in the case of new builds. The categories Passive House Classic, Plus or Premium can be achieved depending on the renewable primary energy (PER) demand and generation of renewable energy.

Table 1 Passive House Criteria

			Criteria[1]			Alternative Criteria[2]
Heating						
Heating demand	[kWh/(m^2a)]	≤	15			-
Heating load[3]	[W/m^2]	≤	-			10
Cooling						
Cooling + dehumidification demand	[kWh/(m^2a)]	≤	15 + dehumidification contribution[4]			variable limit value[5]
Cooling load[6]	[W/m^2]	≤	-			10
Airtightness						
Pressurization test result n_{50}	[1/h]	≤	0.6			
Renewable Primary Energy (PER)[7]			Classic	Plus	Premium	
PER demand[8]	[kWh/(m^2a)]	≤	60	45	30	±15 kWh/(m^2a) deviation from criteria...
Renewable energy generation[9] (with reference to projected building footprint)	[kWh/(m^2a)]	≥	-	60	120	...with compensation of the above deviation by different amount of generation

[1] The criteria and alternative criteria apply for all climates worldwide. The reference area for all limit values is the treated floor area (TFA) calculated according to the latest version of the PHPP Manual (exceptions: generation of renewable energy with reference to projected building footprint and airtightness with reference to the net air volume).

[2] Two alternative criteria which are enclosed by a double line together may replace both of the adjacent criteria on the left which are also enclosed by a double line.

[3] The steady-state heating load calculated in the PHPP is applicable. Loads for heating up after temperature setbacks are not taken into account.

[4] Variable limit value for the dehumidification fraction subject to climate data, necessary air change rate and internal moisture loads (calculation in the PHPP).

[5] Variable limit value for cooling and dehumidification demand subject to climate data, necessary air change rate and internal heat and moisture loads (calculation in the PHPP).

[6] The steady-state cooling load calculated in the PHPP is applicable. In the case of internal heat gains greater than 2.1 W/m^2 the limit value will increase by the difference between the actual internal heat gains and 2.1 W/m^2.

[7] The requirements for the PER demand and generation of renewable energy were first introduced in 2015. As an alternative to these two criteria, evidence for the Passive House Classic Standard can continue to be provided in a transitional phase by proving compliance with the previous requirement for the non-renewable primary energy demand (PE) of $Q_P \leq 120$ kWh/(m^2a). The desired verification method can be selected in the PHPP worksheet "Verification". The primary energy factor profile 1 in the PHPP should be used by default unless PHI has specified other national values.

[8] Energy for heating, cooling, dehumidification, DHW, lighting, auxiliary electricity and electrical appliances is included. The limit value applies for residential buildings and typical educational and administrative buildings. In case of uses deviating from these, if an extremely high electricity demand occurs then the limit value can also be

exceeded after consultation with the Passive House Institute. Evidence of efficient use of electrical energy for all significant devices and systems is necessary for this with the exception of existing devices which have already been owned by the user previously and for which an improvement of the electrical efficiency by means of upgrading or renewal would prove uneconomical over the lifecycle.

[9] Renewable energy generation plants which are not spatially connected to the building may also be taken into account (except for biomass use, waste-to-energy plants, and geothermal energy): only new systems may be included (i.e. systems which did not start operation before the beginning of construction of the building) which are owned by the building owner or the (long-term) users (first-time acquisition).

EnerPHit Criteria

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 2) or alternatively through compliance with the criteria of the energy demand method (Table 3). 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 2 correspond with the criteria for certified Passive House components1. The criteria must be complied with at least as an average value2 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 2 or Table 3, the general criteria in Table 4 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 .

1 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).

2 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 2 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)

[1] **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 3 EnerPHit criteria for the energy demand method (as an alternative to Table 2)

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	-	

Table 4 General EnerPHit criteria (always applicable, irrespective of the chosen method)

			Criteria[1]			Alternative Criteria[2]
Airtightness						
Pressurization test result n_{50}	[1/h]	≤	1.0			
Renewable Primary Energy (PER)[3]			Classic	Plus	Premium	
PER demand[4]	[kWh/(m²a)]	≤	$60 + (Q_H - Q_{H,PH}) \cdot f_{\varnothing PER,H} + (Q_C - Q_{C,PH}) \cdot 1/2$	$45 + (Q_H - Q_{H,PH}) + (Q_C - Q_{C,PH}) \cdot 1/2$	$30 + (Q_H - Q_{H,PH}) + (Q_C - Q_{C,PH}) \cdot 1/2$	±15 kWh/(m²a) deviation from criteria...
Renewable energy generation[5] (with reference to projected building footprint)	[kWh/(m²a)]	≥	-	60	120	...with compensation of the above deviation by different amount of generation

[1] Criteria and alternative criteria apply for all climate zones worldwide. The reference area for all limit values is the treated floor area (TFA) calculated according to the latest version of the PHPP Manual (exceptions: generation of renewable energy with reference to projected building footprint and airtightness with reference to the net air volume).

[2] Two alternative criteria which are enclosed by a double line together may replace both of the adjacent criteria on the left which are also enclosed by a double line.

[3] The requirements for the PER demand and generation of renewable energy were first introduced in 2015. As an alternative to these two criteria evidence for the Passive House Classic Standard can continue to be provided in a transitional phase by proving compliance with the previous requirement for the non-renewable primary energy demand:

$Q_P \leq 120$ kWh/(m²a) + (Q_H - 15 kWh/(m²a)) • 1.2 + Q_C - $Q_{C,\text{ Passive House criterion}}$

In the above mentioned formula if the terms "(Q_H - 15 kWh/(m²a))" and " Q_C - $Q_{C,\text{ Passive House criterion}}$" are smaller than zero, then zero will be adopted as the value.

The desired verification method can be selected in the PHPP worksheet "Verification". The primary energy factor profile 1 in the PHPP should be used by default unless PHI has specified other national values.

[4] Energy for heating, cooling, dehumidification, DHW, lighting, auxiliary electricity and electrical appliances is included. The limit value applies for residential buildings and typical educational and administrative buildings. In case of uses deviating from these, if an extremely high electricity demand occurs then the limit value can also be exceeded after consultation 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.

Q_H: heating demand

$Q_{H,PH}$: Passive House criterion for the heating demand

$f_{\varnothing PER,\, H}$: weighted mean of the PER factors of the heating system of the building

Q_C: cooling demand (incl. dehumidification)

$Q_{C,PH}$: Passive House criterion for the cooling demand

If the terms "(Q_H - $Q_{H,PH}$)" and "(Q_C - $Q_{C,\, PH}$)" are smaller than zero, zero will adopted as the value.

[5] Renewable energy generation plants which are not spatially connected to the building may also be taken into account (except for biomass use, waste-to-energy plants, and geothermal energy): only new systems may be included (i.e. systems which did not start operation before the beginning of construction of the building) which are owned by the building owner or the (long-term) users (first-time acquisition).

Exemptions for EnerPHit

The limit values in Table 2 for the heat transfer coefficients of the exterior envelope building components may be exceeded if absolutely necessary based on one or more of the following compelling reasons:

- ☐ If required by the historical building preservation authorities
- ☐ If the cost-effectiveness of a required measure is no longer assured due to exceptional circumstances or additional requirements
- ☐ Due to legal requirements
- ☐ If implementation of the required standard of thermal insulation would result in unacceptable restriction of the use of the building or adjacent outer areas
- ☐ If special, additional requirements (e.g. fire safety) exist and there are no components available on the market that also comply with the EnerPHit criteria
- ☐ If the heat transfer coefficient (U-value) of windows is increased due to a high thermal transmittance (psi value) of the window installation offset to the insulation layer in a wall that has interior insulation
- ☐ If reliably damage-free construction is only possible with a smaller insulation thickness in the case of interior insulation
- ☐ If other compelling reasons relating to construction are present

If the thickness of the thermal insulation is restricted due to any of the reasons mentioned above, and an exemption is applicable, then the insulation thickness that is still possible must be implemented with a high-performance insulation material with a thermal conductivity l ≤ 0.025 W/(mK) if this can be implemented cost-effectively and in a damage-free way (in the case of interior insulation). In this case, the additional application of a surrounding insulation skirt should be considered in the case of floor slabs and basement ceilings. The measure should be implemented if this is economically viable.

Climate zones in Europe

Climate zones and corresponding sets of component requirements

With respect to the results for the cost-optimized building and its components and under consideration of the thermal comfort of the occupants, the aim was to create a map that is divided into several regions with similar requirements each for all energy-relevant building components like windows, doors, insulation and building services.

First priority: Meeting the comfort criterion

Any suggestions for requirements for sustainable components also have to take the thermal comfort of the users into account at first priority. Optimum thermal comfort can be provided, if the temperature differences between the inner surfaces of the thermal envelope and the operative temperature in the room is not higher than 4.2 K (see e.g. [Feist 1998][3]. If this temperature criterion is met, unpleasant radiant heat losses as well as cold down droughts and cold air lakes do not occur. Since the temperature of interior surfaces depends on both the thermal quality of the building envelope and the outside temperature, the thermal quality of the envelope has to be the higher, the colder the ambient climate gets. The required U-value which represents the thermal quality of the envelope can be determined by the following equation.

$$U \leq \frac{4.2}{R_{si} \cdot (\theta_{op} - \theta_{ext})}$$

Where is:

R_{si}: The internal heat transfer resistance (in case of vertical windows 0,13 m²K/W)

θ_{op}: Operative (perceived) room temperature [°C]

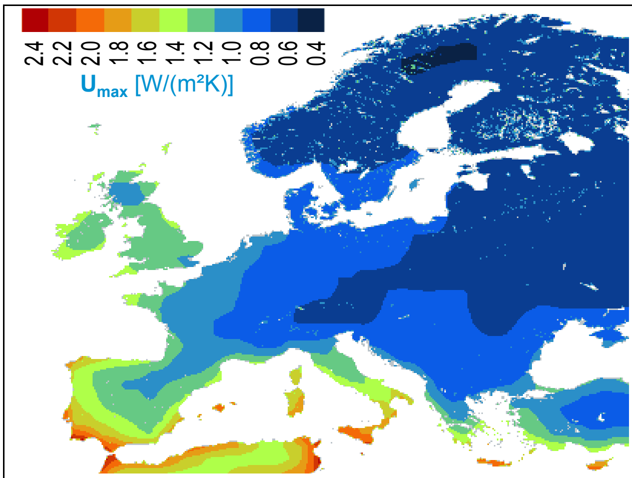
θ_{ext}: Design-outside temperature (minimum temperature of the coldest day in a year) [°C]

This climate dependent U-value has to be achieved by any component of the building envelope. In most cases, Windows, as weakest part of the building are the crucial point in this regard, but in special cases, interior insulation, as an example might be critical too.

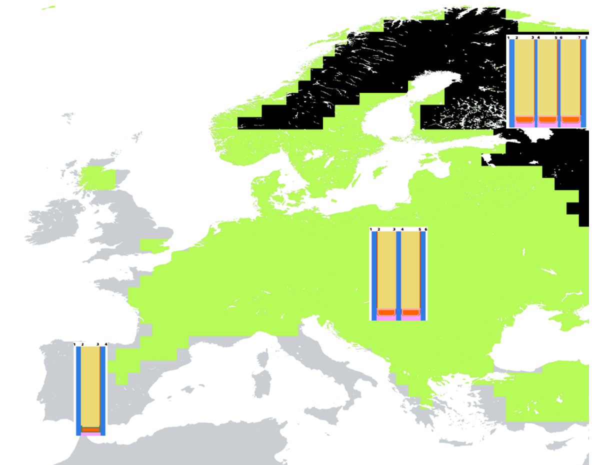
Figure 1 shows a map of Europe with the required U-values for meeting the comfort criterion (on the left). As mentioned, windows are the critical component in most cases for meeting the comfort criterion. Therefore Figure 1Figure 1 shows at its right side the type of glazing needed to meet the criterion. For this it was assumed, that an $U_{W,\ installed}$-value (thermal transmittance of an installed window) of 1.20 W/(m²K) might be

[3] Feist, Wolfgang; Fenster: Schlüsselfunktion für das Passivhaus-Konzept, 14. Arbeitskreis kostengünstige Passivhäuser, Passivhaus Institut Darmstadt; Dezember 1998.

achieved by a window with double-low-e coated glazing. For triple glazing, this U-value is 0.65 W/(m²K), for quadruple glazing 0,45 W/(m²K.



U-values to be achieved in Europe



Glazing type required for meeting the comfort criterion

Figure 1: Catching the comfort criterion in Europe © PHI 2014

It can be seen, that triple glazing is dominating most areas of Europe, if it comes to the comfort criterion. The thermal quality of double glazing is only adequate for mild Mediterranean climates and for parts of the British islands. In the areas of Scandinavia and the north-east of Europe, where triple glazing is not sufficient, quadruple glazing has to be used.

Second priority: Economic considerations

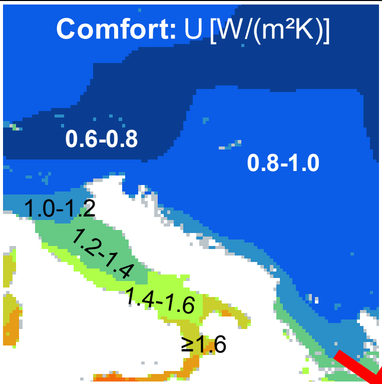
In the economic analyses were carried out, that the thermal quality of the components at the cost-optimum is much higher than the minimum required to meet the comfort criterion for most European locations. In those regions it is reasonable to set the component requirements according to the cost optimum.

Defining regions with similar requirements

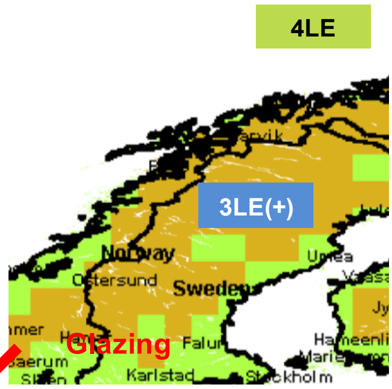
The creation of a map showing the different requirements for Passive House components was necessary for the international EnerPHit certification criteria. However such a map can also be a great help and give a first orientation to those involved in the design process of new Passive Houses.

The definition of such a map of climatic regions with specific sets of requirements is an important work done at PHI for the 3encult project. Besides the parameters comfort and economy, borders of states and nations were taken into account for better orientation and easier handling. Eventually grouping the world's climates in seven regions, and thus seven sets of requirements was most suitable:

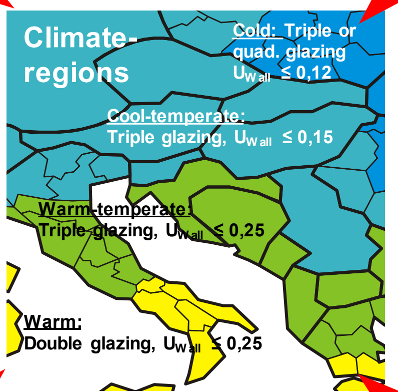
As an example for a region that includes parts of Germany and Italy as well as Austria, the Czech Republic, Slovakia and the Balkan states, the process of designing the map is shown at a simplified level in Figure 2. This procedure was carried out in detail for all of Europe on a detailed, and for the rest of the world on a rough level.



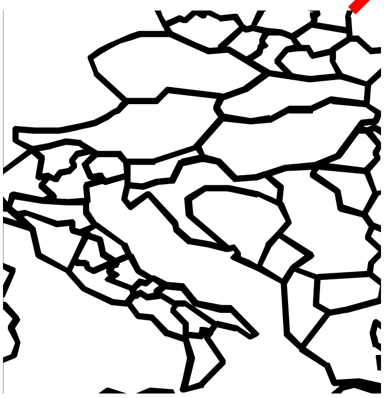
The comfort criterion has the highest priority. All component requirements have to meet this criterion. The alpine region has uniform requirements. The U-values shown in the comfort map are an average which includes the mountain tops. As most buildings are located in the warmer valleys, a higher U-value than shown in the map is acceptable. If a house is build on a summit, there requirement will switch to the next, more ambitious climate class.



At last, the climatic regions were fitted to borders of nations, states or geographic regions for easier handling. The optimum for each building can only be found on the basis of the energy balance calculation related to the specific building. So the map can serve as a starting point for the energy balance and as a set of minimum requirements.



The cost-optimum calculations we-re carried out with future prices of quadruple glazing which is not widely available yet. Additionally there are some technical challenges with argon filled quadruple glazing. In the very south of Europe triple glazing is uncommon and not easily available yet. In these climates, the lifecycle cost difference of triple/ double or quadruple/triple glazing is small, so that in tendency the lower thermal quality is suggested for the map of requirements.



For cold and warm, temperate, climates triple glazing is required. But the requirements for the U-val-ue of the opaque envelope differ. Here 0.15 W/(m²K) is suggested for the cold, and 0.25 W/(m²K) for the warm, temperate climate. 0.50 W/(m²K) is set for the warm climate (which is easy to achieve with a monolithic wall assembly), but depending on the special situation in a specific building a much better insulation might make sense.

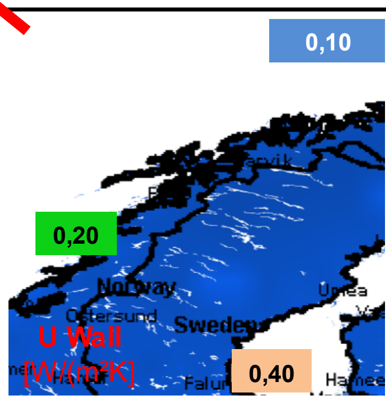


Figure 2: Defining a map of regions with similar requirements (simplified) © PHI 2014

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 1Table 1. 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.

Table 1: Assignment of the climate-region indicators

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

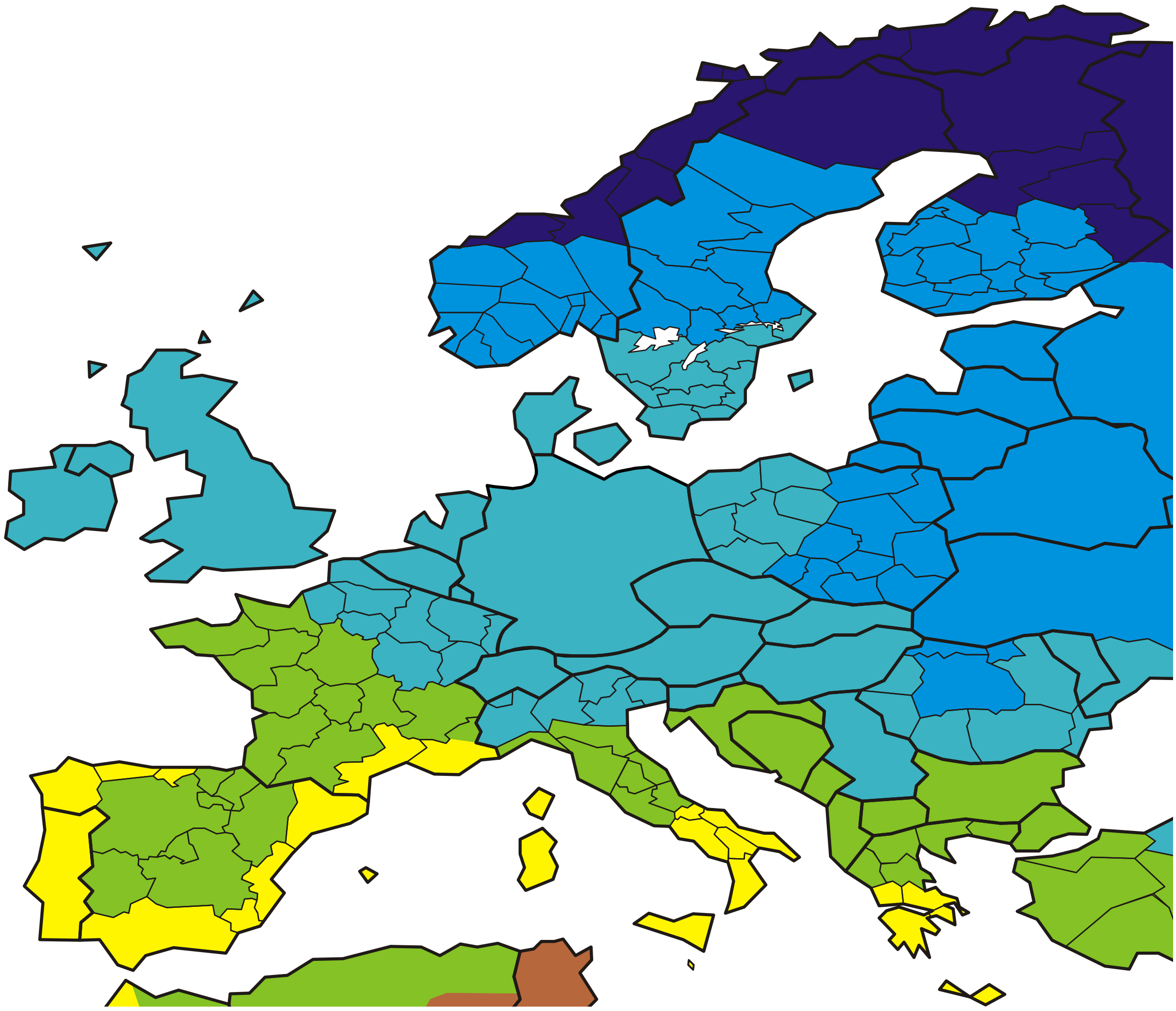


Figure 3: Map of Europe showing regions with similar requirements © PHI 2014

Identifying specific Areas of Demand

In the matrix below the necessary elements that make up the Passive House Standard are listed in a table for cross examination. If you for example want to start with improving the insulation on the roof, you should first (see colored cells):

- Identify Thermal bridges at the connection to the facade
- Optimize daylight and shading if you have roof windows and/or access to the roof
- Consider roof integrated technologies for heating, cooling, ventilation and RES integration
- Take into account potential penetrations of the roof surface by installations
- Think about adding an extra story (extension) to the building envelope

This can be repeated for any other step that needs to be taken. The resulting areas of interest for product development are described in the following pages, with a list of existing products, possible concepts and new products that need development.

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

Insulation, airtightness and thermal bridging

It is possible to use most of the existing insulation materials and airtightness concepts also for step-by-step refurbishment. There is probably less need to develop completely new products, but a demand to apply them in a novel way. There is surely also a potential for new products.

Please study in detail the requirements for opaque building envelope, airtightness and building physics (especially surface temperatures) before embarking on any development.

Identified areas with high product potential

- Partly finished insulation work (walls partly finished, one of several row buildings, connection to roof insulation, connection to foundations)
- Partly finished airtight layer (wall to roof connection, wall to foundation)
- Additional insulation on roof or ceiling above top floor
- Thermal bridge free connection at eaves and attic
- Penetrations of existing walls, ceiling and roofs for technical reasons or access
- Simplified installation of perimeter insulation
- Airtight connection to beams for internal insulation application
- Safe internal insulation solutions with a higher insulation value
- Humidity and temperature sensors for internal insulation control
- Thermal bridge applications on existing insulation layers
- Additional insulation on top of existing insulation layers

Co-funded by the Intelligent Energy Europe Programme of the European Union

Requirements for opaque building envelope, airtightness and building physics

Criteria for building elements depend on the climatic conditions across Europe in order to fulfill minimum comfort and hygenic requirements. The climate conditions in Europe range from 1-Artic up to 5-Warm, as can be seen below in the table of requirements for opaque building envelope components.

Climate Zone			1-arctic	2-cold	3-cool-temperate	4-warm-temperate	5-warm
Efficiency criteria							
External building envelope (U-value)	W/(m²K)	≤	0,09	0,12	0,15	0,30	0,50
External building envelope against ground (U-value)	W/(m²K)	≤	*0,15*	*0,20*	*0,25*	*0,42*	*0,83*
Internal insulation of external walls (U-value)	W/(m²K)	≤	0,25	0,30	0,35	0,50	0,75
Internal insulation of walls against ground (U-value)	W/(m²K)	≤	*0,42*	*0,50*	*0,58*	*0,75*	*1,25*
Temperature factor f_{Rsi} for purely opaque details	$f_{Rsi\ (0,25)}$	≥	0,90	0,88	0,86	0,82	0,74
Hygiene criterion							
Temperature factor f_{Rsi} to prevent growth of mould	$f_{Rsi\ (0,25)}$	≥	0,80	0,75	0,70	0,60	0,55
Airtightness							
Connection details			A concept for airtight connections to other components must be provided.				
Buildings Airtightness	1/h @ 50Pa	≤	For the whole building, the airtightness requirement is ≤ 1,0 1/h @ 50Pa				

Co-funded by the Intelligent Energy Europe Programme of the European Union

External Insulation

Existing products

- Bead cavity insulation: http://www.kore-system.com/kore-products/wall-insulation/kore-fill/what-is-kore-fill/ , http://www.joma.de/anwendungen/sonderloesungen/perlen/
- Spray on insulation and airtight foam: http://www.versifoam.eu/nieuws_info.php?nieuws_id=28&osCsid=747d465bf4ade24ffa3e17a6435fad2f, http://www.biofoamsprayinsulation.ie
- Insulation with minimal thickness, PU or Phenol resin based: http://en.puren.com/construction/, http://www.kingspaninsulation.ie/Products/Kooltherm.aspx
- Modular vacuum panels: Weber Lockplate http://www.starch.dk/private/energy/img/LockPlate_Broschuere_Ansicht.pdf
- Decorative insulated moulding with render finish: http://www.dosteba.com/news/28/Fassadenprofil%20Do-Pro
- Insulating plaster made from Aerogel for historical buildings: http://www.fixit.ch/aerogel/?w=start&lng=en
- External insulation retrofit systems with timber studs: http://www.lignotrend.de/planung/bauteile-und-vorteile/waermedaemmung/
- Rockwool RedAIR external insulating system for ventilated facades. http://www.rockwool.dk/produkter/redair+flex/systembeskrivelse
- Tesenergy facade, prefabricated retrofit system http://www.tesenergyfacade.com/
- Insulation of Attic floors http://www.bauder.de/de/steildach/steildach-produkte/waermedaemmung/innendaemmung/bauderpir-dhw.html

New concepts

- Do-it.yourself step-by-step renovation kits
- Prefabricated envelope and step-by-step kits for occupied buildings
- High performance and fireproof insulation for small (<60-80cm) gaps between adjacent houses in old town quarters.
- Insulation products specific to step-by-step, for example simpler and more cost effective solutions to "mould" an insulated envelope on an existing building
- Better fire-protection solutions for envelopes

New products

- Insulation finishing profile (for half finished walls, building corners etc.)
- Prefab eave insulation for wall-ceiling/roof connection

Internal insulation

Existing products:

- Internal insulation aerogel: http://www.sto.de/media/documents/download_broschuere/innenraum/09661-383de_02_12-12_72dpi.pdf
- Internal insulation - Mineral: http://www.sto.de/de/unternehmen/innovationen/stotherm_in_comfort_/stotherm_in_comfort_innendaemmung.html
- Internal insulation - Woodfibre: http://www.steico.com/produkte/holzfaser-daemmstoffe/steicointernal/ueberblick.html
- Internal insulation PU: http://www.remmers.de/4173.0.html
- Internal insulation foamglas http://de.foamglas.com/de/waermedaemmung/anwendungen/innendaemmsysteme/
- Internal insulation - Cellulose: http://www.isocell.at/hauptmenue/produkte/daemmstoffe/renocell/technische-daten.html
- Calcium silicate panels, eg casiplus panels http://www.casiplus.de/

New concepts

- Phase change material (PCM) boards: This material absorbs heat and releases it afterwards. They could be used as an additional layer or part of the insulation on the internal side of the wall in order to provide insulation and thermal storage.
- Internal insulation of more than 10cm thickness or higher thermal resistance – needs more research and verification.

New products

- Insulation of ceiling to unheated basement with a very thin insulation layer (10-20mm)
- Starch micro-porous material for internal insulation or similar products from other sustainable non-toxic biopolymers produced by plants.

Thermal Bridges

Existing products

- IT-Fix Fiberglass reinforced bolt by IT-Fixing : (http://myriamcaffart.wix.com/it-fixing-gb#!facilities/c66t)
- The thermal break for metal junctions by Armatherm: (http://www.armadillonv.com/index.php/armatherm-fr)
- Array of thermal bridge solutions by Dosteba: www.dosteba.com
- Baumit Klebeanker (Dowels as carrier of the adhesive): http://www.baumit.de/produkte/wdvs-zubehoer/startrack-klebeanker/klebeanker-startrack-red.html
- Thermal breaker with porous concrete for block masonry http://www.cellumat.fr/system/files/document-files/-11-%20BLOCS%20D'ASSISES%20Fiche%20technique%20France_2.pdf
- Insulated window lintels: http://keystonelintels.com/
- Insulated window sills: http://www.passivesills.com/

New concepts

- Retrofitting thermal bridge solution for existing perimeter wall
- Insulation solutions for existing eaves
- Standard solutions for staircases to unheated basement: hot staircase, cold staircase, mitigated thermal bridges
- Renovation of Existing Balcony Connection: Limit thermal bridge with exterior insulation when glazing balconies is not acceptable for the owners/users, and additional beams to support the balcony weight can't be placed (eg balcony on street).

New products

- Pre-formed vacuum insulated panels for historic front doors
- Thermal bridge solution for replacing existing balconies anticipating future exterior insulation of facade
- Thermal bridge free fixing of thick external insulation (especially for higher buildings and in the regions with earthquakes)
- Insulation under slabs in crawl space that is humidity and mold resistant
- Connection details to uprising elements (Chimneys, Installation, Walls)
- Systems, which allow to break existing thermal bridges to foundations with minimal effort

Airtight layers & connections

Existing products

- Airtight Tapes (all types): http://www.isocell.com/de/produkte/products/klebetechnik/universeller+einsatzbereich/cat_111
- Airtight penetrations (all types): http://www.isocell.com/de/produkte/products/klebetechnik/Öffnungen+und+durchrdingungen/cat_123
- Airtight membranes with variable sd value: Isover Vario KM: http://www.isover-airtightness.com/VARIO Proclima Intello: https://proclima.com/products/internal-sealing/intello-plus
- Simple leakage detection: http://www.zephair.pro/
- Air tight joist seals (http://www.manthorpe.co.uk/Building/Products/Air-Leakage/Joist-Seal.html)
- Double side tape (http://www.phstore.co.uk/orcon-line.html)
- Dry Seal Traps (http://www.hepvo.com/)
- Sprayed PH-foam layers by BASF (15mm, also providing some insulation) http://www.polyurethanes.basf.de/pu/solutions/de/content/productbrand/elastospray
- External, self-adhesive airtightness membrane: http://www.proctorgroup.com/products/wraptite-sa

New concepts

- Airtight but completely vapour open (Sd<0,2m) layer applied on the outside of main insulation (is an option in some cases where fibrous materials can help transfer humidity to the exterior – needs more research)
- Airtight solution for ventilation and smoke protection of existing elevators inside thermal envelope
- Airtight concept/product for garage inside insulated envelope
- Airtight connection product for sbs retrofit of gable wall (example : masonry wall with ETHICS then roof with sarking insulation)

New products

- Airtight connection for wooden beams especially in case of internal insulation
- Insulation of ceiling to unheated attic with an included vapour barrier with details for airtight connection on the sides
- Insulated airtight chimney sock and flanking

Foundations

Existing products

- Water resistant XPS insulation to foundations: http://www.basf.de/en/produkte/plastics/schaum/styrodur_startpage.htm
- Earthquake resistant insulation below slab
- Insulating construction boards http://www.jackon-insulation.com/uploads/tx_wwdownloads/JACKOBOARD_Technical_Specifications_GB_02.pdf
- Slab thermal breaker

http://arktic.fr/index.php/produits-rupture-pont-thermique/#fichebas

- Foam glass blocks http://us.foamglas.com/en/building/products/product_overview/foamglas_perinsul/
- Isodrän - combination of external underground insulation and drainage/moisture control: http://www.isodran.se/

New concepts

- Perimeter insulation that is easy to install on uneven surface
- Brick wall insulation by retrofitting with foam glass blocks (thermal and moisture break)

New products

- Ventilated perimeter insulation for moisture control of basement walls

Roof/Ceiling

Existing products

- Attic insulation:
  http://www.isocell.com/broschueren-loesungen/loesung-woodyfix_de.pdf
  http://www.fermacell.de/de/content/dachboden-element_nf.php
  http://www.rockwool.de/produkte/u/4471/Decke/Tegarock+Plus
  http://www.bauder.de/de/steildach/steildach-produkte/waermedaemmung/innendaemmung/bauderpir-dhw.html
  http://www.brillux.de/anwendungen-und-loesungen/waermedaemmung/dachbodendaemmung/
  http://www.isover.de/Home/Produktwelt/Produkte/ISOVER-EPS/Dachboden-032-DEO/ISOVER-EPS-Dachbodendaemmelement-032-DEO-mit-Spanplatte.aspx
- Green roofs: http://www.zinco-greenroof.com/EN/index.php
- Spray insulation by BASF (PU-foam-based, 20-40mm?) providing additional airtightness
  http://www.polyurethanes.basf.de/pu/solutions/de/content/productbrand/elastospray
- Roof insulation with photovoltaic membrane:
  http://applications.foamglas.com/__/frontend/handler/document.php?id=2431
- Insulated and airtight attic trap door

http://www.estfeller.com/it/scale-retrattili/termoisolata/

New concepts

- Retrofit kits for roofs

New products

- Solution for easy and proper insulation of eaves

Windows & shading

Good windows do not only provide light and views, but in any highly insulated building works also as a heating element. The overall heat gains from south oriented windows will usually surpass the losses during heating season. They also contribute to the highest heat losses per m2 in a building during winter. In summer the same windows can easily lead to overheating if not shaded properly.

Identified areas with high product potential

- Variable position of built in window (before and after insulation)
- Blindframe installation – easier exchange of windows at a later time
- Integrated shading in Window frame (between glass panes)
- Smartglass or Switchglass (Glass with variable solar heat gain coefficient)

Example: DOW thermochromic glazing (does not change with light, like those sunglasses, but with temperature – which still allows for solar gain in winter, when the sun is shining bright):
https://www.dowcorning.com/content/construction/constructiondesigninspire/switchable-glazing.aspx

Requirements for windows and shading

Criteria for building elements depend on the climatic conditions across Europe in order to fulfill minimum comfort and hygenic requirements. The climate conditions in Europe range from 1-Artic up to 5-Warm, as can be seen below in the table of requirements for transparent building envelope components.

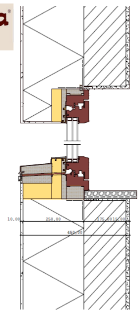
Climate Zone			1-arctic	2-cold	3-cool-temperate	4-warm-temperate	5-warm
Efficiency criteria							
Windows and entrance doors, installed (U-Value)	W/(m²K)	≤	0,45	0,65	0,85	1,05	1,25
Roof (inclined) windows, installed (U-Value)	W/(m²K)	≤	0,50	0,70	1,00	1,10	1,30
Flat roof (horizontal) windows, installed (U-Value)	W/(m²K)	≤	0,60	0,80	1,10	1,20	1,40
Hygiene criterion							
Temperature factor f_{Rsi} to prevent growth of mould	$f_{Rsi\ (0,25)}$	≥	0,80	0,75	0,70	0,60	0,55
Airtightness							
Connection details			A concept for airtight connections to other components must be provided.				
Buildings Airtightness	1/h @ 50Pa	≤	For the whole building, the airtightness requirement is ≤ 1,0 1/h @ 50Pa				

Windows

Existing products

- Windows for old buildings (SmartWin Historic) http://www.propassivhausfenster.net/en/products/smart-win1.html
- Switchable Glass & Electrochromic Glass, http://sageglass.com/
- Insulated window reveal mesh (www.wemico.com)
- Insulated Parapet (www.wemico.com)
- Insulated window sills that look like concrete cills: http://www.dosteba.com/c/16/fensterbänkebr-aus-glasfaserbeton
- Low conductivity structural window nailer or support:
- Fanzola, Null Fenster, Window frame completely covered by external insulation (incuding bottom profile)

Fanzola FENSTER

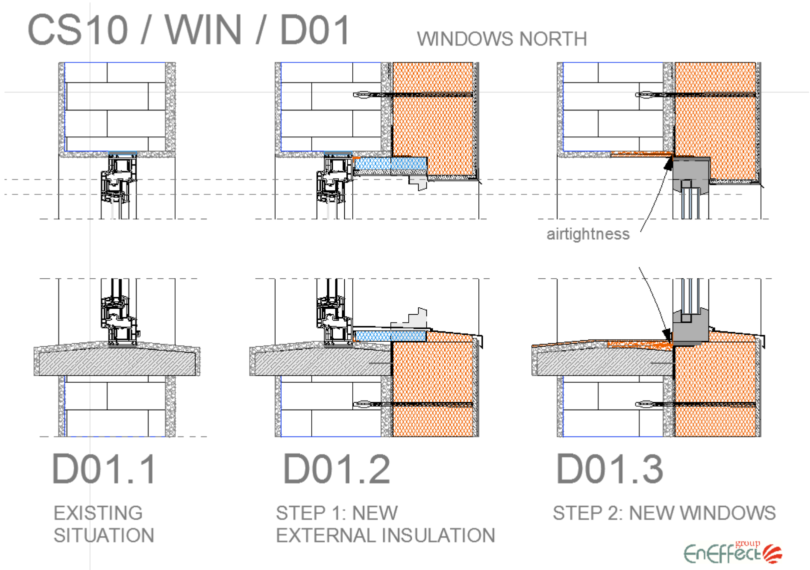


http://www.fanzola.it/NULL-FENSTER.html

New concepts

- Blindframe for installation of window without the need for insulation/facade
- Eps/insulation blindframes, might be fixed externally to the walls, to insulate now and carry the new windows later
- Window restoration techniques for monument-protected buildings
- Electro or thermal chromatic shading
- Blindframe concepts - different positions of glass
- Handles on Window not intuitive (new opening solutions for traditional buildings)
- Internal secondary glazing (to keep historical windows) that prevents condensation build up between the two windows (existing and new).
- Simple, affordable solutions for mounting windows without thermal bridges, extra fitting of insulation etc. Some solutions have the weakness that you cannot fix them close to the side/edge of a concrete slab.
- New window technology using glass evacuated tubes. The vacuum tubes can provide a much lower U-value (below 0.7 W/m2K) than conventional vacuum glazing.

- Movable window fixing for internal installation, when we already have fixed external insulation.
  The new windows has to be fixed from inside, without any damages on the external insulation. It will be difficult to move it through the opening to the right position without some system, may be similar to this:
  http://www.sidey.co.uk/tncsite/newbuild/off-site-construction.php
- The new system has to allow fixing of the airtight sealing from the inside. (see the detail)



- For PVC windows - The bottom profiles of the PVC windows have openings for ventilation, which do not allow covering them with insulation (to reduce the thermal bridge). The window's sill (aluminium or PVC), clipped under the profile makes the thermal bridge even higher. We need a bottom profile, which we can cover with at least 4 cm. insulation with some clips for sill covering. (see the detail)

New products

- Insulated and airtight trapdoor to the attic
- Energy efficient glazed fire doors (outward opening and affordable). Out-swing Fire Escape Glazed Double & Single Doors - Passive House standard doors that open outwards as they are for fire escape purpose. That can achieve an overall U-Value of 0.85W/m2K and an installation Psi value of no higher then 0.04 W/mK. Available in different colours and finish materials as well as affordable.

Window integrated technologies

Existing products

- Ceramic heat exchanger http://www.weru.de/de/privatkunden/produkte/fenster/fenster-lueftung/lueftung-mit-waermerueckgewinnung.html
- Window frame integrated ventilation: http://www.schueco.com/web/de/architekten/fenster_und_tueren/produkte/lueftungssysteme/kunststoff/Schueco_VentoTherm

  http://www.internorm.com/at/produkte/studio/s-innovationen/s-lueftung.html

  http://www.beck-heun.de/AIRFOX.1254.0.html

  http://www.rehau.com/de-de/bau/fenster-fassadensysteme/fenstersysteme/geneo-inovent/geneo-inovent/1398768
- PV Curtain wall: Traditional glass used in building curtain walls can be replaced by photovoltaic glass, optimizing the envelope performance and allowing on-site energy generation.http://www.onyxsolar.com/photovoltaic-curtain-wall.html
- Intelliglass: ttp://www.intelliglass.es/index.php?option=com_content&view=article&id=110&Itemid=171&lang=en
- Self-cleaning glazing (especially for high buildings – or fixed glazing respectively outward opening windows, hard to access for cleaning) https://www.pilkington.com/en-gb/uk/householders/types-of-glass/self-cleaning-glass

New concepts

- Ventilation integration with higher efficiency
- Shading integration in window frame
- Shading, still with high daylight gains (diffusing sunlight to the ceiling with less overheating)

New products

- Integrated, PV-driven summer ventilation (with air & noise filter), heat recovery mode for winter.
- Active sound attenuator integrated in window frame for daily natural ventilation in offices
- Window frame assembly integrating decentralised MVHR, and PV on blinds or overhang
- Windows that thermally induce natural ventilation (through solar thermal or PV heat)
- Windows producing energy from difference between cold sky radiant temperature and hot interior radiant temperature (Peltier Thermoelectric Module)

Daylight optimization

Existing products

- Sun Tubes : http://www.velux.ie/private/products/sun_tunnel
- Insulated Glass Blocks : http://www.sevesglassblock.com/thermal-insulation-glass.html
- High efficiency zenithal lighting system: http://www.lamilux.fr/fileadmin/user_upload/dateien/Lokalisierung/FR/Tageslichtsysteme/Brochure_CI_declairage_zenithal_en_verre_type_PR60_08102013.pdf
- Fiber optic lighting: http://www.echy.fr/fiber-optic-lighting/technology/?lang=en
- Translucent concrete, e.g. http://www.zdnet.com/article/concrete-you-can-see-through/
- Insulation board that allows sun light to go though. It can be used to take advantage of the thermal mass of the masonry wall behind it: http://www.sto.com/evo/web/sto/100114_DE-PDF-2009-0179en_01-07-09_72dpi.pdf
- “Nachleuchtfarben & fluoreszierende Farben”; reduce lighting demand by the use of such paints… e.g. http://kremer-pigmente.de/nachleuchtpigmente.htm
- http://www.praktika.physik.uni-bayreuth.de/OLED.pdf

New concepts

- Affordable, airtight and super insulated sun tube with thermal bridge free installation
- Airtight glass blocks with an overall U value no higher than 0.85W/m2K
- Highly energy efficient translucent insulation.

New products

- Window exterior reveals that reflect back natural light into the office without risk of glare

Shading

Existing products

- PV exterior venetian blind: A photovoltaic brise soleil is a constructive solution that combines power generation with solar protection properties against adverse weather conditions and shading. http://www.onyxsolar.com/projects/onyxsolar-bipv-projects.html
- PV coated textile shading elements
http://www.windturbine.cc/photovoltaik-markise.html
http://iland-solar.com/de/content/112/46/startseite/
- Skylight with smart venetian blind :
http://www.hexadome.com/fr/lanterneau/remplissages-et-options/remplissages-pour-lanterneaux-et-denfc/solution-brise-soleil-1
- Smart shading management for PV, adapted for system retrofit - solar edge, http://www.solaredge.com/groups/solutions/retrofit
- Self-cleaning external venetian blind: http://cornerstaraluminium.com/hanse-haus-installation/
- Glass pane integrated ventian blinds: http://www.internorm.com/uk/products/home-pure/home-pure-windows/timberaluminium/system/show/System/hv-350-1.html

New concepts

- PV panels that change their opacity depending on the solar intensity.
- Solar gain change based on inside temperature change
- Thermochromic glazing

New products

- Frame integrated shading
- PV film to be glued to a glazing in a later step, same concept as shading film to be glued on windows
- External retrofit PV shutter including
http://www.altenergymag.com/content.php?post_type=1663
http://www.sunthink.de/produkt.php
- Combined shading and cooling exterior unit at window lintel

Night & natural ventilation

Existing products

- Trickle vents http://www.passivent.com/files_product/28_aircool_vents_db0f.pdf
- Glazing-lamellas: www.glasbau-hahn.de, they should be airtight however
- Offset window sashes, for inner-city retrofits, avoiding burglary but allowing ventilation
- Smart natural ventilation management system : http://www.souchier.fr/AeroPack-R-V2-Ventilation.html
- Opening systems http://www.windowmaster.dk/vores-loesninger/facadeloesninger
- Thermal stack: http://sustainabilityworkshop.autodesk.com/buildings/stack-ventilation-and-bernoullis-principle

New concepts

- Airtight and insulated trickle vent in a PH certified window
- Intelligent system that allows for a high volume of natural night ventilation which doesn’t compromise security and internal movement of objects causing the setting off alarms.
- Passive night ventilation of concrete floors using ducts within it
- Natural ventilation with heat recovery, use of mechanical ventilator only when no wind or solar energy is available
- Venturi-based opaque components to induce natural airflow (http://repository.tudelft.nl/assets/uuid:d1b76039-5d9e-4325-8b0f-67dff3718384/281811.pdf)

New products

- Night ventilation through window frames or the shutter box
- “Blind windows”, i.e. window/door made with a vacuum panel filling and a PH-window frame with a relatively low U-value possible to open at night
- Airtight natural ventilation system for servers in small/medium offices
- Wind-assisted ventilators

Heating, cooling and hot water

For a Passivhaus, the demand for heating and cooling is usually lower than for hot water. This demands a rethinking about how to create an efficient solution. Moreover there are possibilities to achieve synergies together with the ventilation concept, as air can transport and provide a source of heat and cold respectively.

Identified areas with high product potential

- Façade integrated micro heat pump systems
- Solar powered heat pump solutions (roof or façade mounted)
- Thermal solar panels for historic buildings (under roof tiles)
- Ventilation radiators
- Wastewater heat recovery systems for retrofit
- Dehumidifying and cooling units combined with ventilation
- PCM in hot water storage tanks to increase solar fraction

Requirements for heating, cooling and hot water

<table>
<tr><td>Water use per day</td><td colspan="5">25 l/person/day</td></tr>
<tr><td>Temperature requirements</td><td colspan="5">60 degrees Celsius used for energy demand calculation. For lower temperature systems a legionella free system needs to be demonstrated</td></tr>
<tr><td>Boiler heat loss</td><td colspan="5">Max. 3W/K</td></tr>
<tr><td>Efficiency for shower heat recovery systems</td><td colspan="5">Min. 30%</td></tr>
<tr><td rowspan="3">Insulation of hot water tubes</td><td colspan="5">Thermal conductivity: 0,035 W/mK</td></tr>
<tr><td>Diameter</td><td>Up to 25mm</td><td>From 32mm</td><td>To 50mm</td><td>100mm</td></tr>
<tr><td>Insulation thickness</td><td>2x Diameter</td><td>60mm</td><td>60mm</td><td>100mm</td></tr>
<tr><td>Noise protection</td><td colspan="5">Acceptable noise emissions to allow indoor placement:
Max: 25db in Living quarters
Max: 35dB in technical rooms</td></tr>
<tr><td>Cooling</td><td colspan="5">Requirements for split units still in evaluation. PER values should be fulfilled.</td></tr>
<tr><td>Condensation</td><td colspan="5">Condensate is to be connected to the sewage, not disposed of directly to the exterior.</td></tr>
</table>

Heating/Hot Water

Existing products

- Hot-water tank combined with small heat pump air/water http://www.sinclair-solutions.com/en/products/heat-pumps/sanitary-water-heaters/27-swh-35-300tsl.html
- Hot water heaters combined with photovoltaic: http://www.dzd.cz/en/ohrivace-vody-bojlery/photovoltaic-water-heaters http://www.logitex.sk/8/index.php?ver=en&acid=6vmache6gpkmdjh2ootdk77pr0
- Capillary mats for heating and cooling: http://www.beka-klima.de/en/capillary-mats-k.html
- Decentralised grey hot water heat exchanger, supplying preheated cold water to fixtures and DHW generators: http://www.ehtech.fr/#!obox/cjg9
- Solar Slate roofs: http://www.solexenergy.co.uk/
- Wastewater heat recovery systems for retrofit for water saving and heat recovery: https://orbital-systems.com/en-eu/explore/
- Paraffin can be doped and adapted to different phase change temperatures. Heat and cold can be stored – between -200°C and +400°C : http://www.latentspeicher.com/sites/default/files/downloads/2014-stc-technologie-1.pdf

New concepts

- Air-water heatpump integrated in facade for temperate climates
- Solar powered HP for roof mounting (heating/hot water/cooling) in hot climates
- Solar thermal panels for historical environment (not changing architectural expression drastically), e.g. PV slates
- Waste water heat recovery solutions for step-by-step retrofit of heat&hot water systems, coupling with RES
- clip-on pipe insulation for T-pieces etc.
- efficient DHW circulation systems (pumps, pipes-in-pipe systems)
- waste water heat recovery
- low output gas boilers and radiators (optimizing internal space)
- PCM in hot water storage tanks to increase solar fraction
- Micro energy harvesting – e.g. Seebeck generator (thermoelectric element) for efficient heating and DHW systems
- Micro-wind-power with Savonius generators – work in urban situation and low wind speeds; e.g. http://www.mikro-windkraft.de
- Modulating Heat Pump system for heating, cooling and ventilation to be connected to a PV array

New products

- Split Air conditioning unit with modulating output and very quiet (25db)
- Cooling combined with hot water production and ventilation. Micro heat pump running 24h in hot climates
- Hybrid gas boiler / CO_2 heat pump (building on boostheat.com)
- Hybrid fuel cell / condensing gas boiler (build on project ene.field) adapted to passive house energy demands
- Methane micro generation and storage from building/neighbourhood biowaste for seasonal storage

Cooling concepts

Existing products

- Active chilled beams for cooling system(hospital, larger building): http://www.troxusa.com/usa/products/air_water_systems/active_chilled_beams/
- Capillary mats for heating and cooling: http://www.beka-klima.de/en/capillary-mats-k.html
- Absorption chiller (http://sortech.de/en/technology/about-our-technology/
- Cooling combined with ventilation and dehumidification: http://www.recair.com/upload/fck/file/REC%2013041%20BRO%20Enthalpy%20EN.pdf
- Nanotech paint: http://enovatekenergy.com/energy-solutions/planet-supra/

New concepts

- Dessicant cooling to provide efficient solar thermal cooling
- Solar all-in-one heat pump rooftop for retrofit (HVAC+DHW)
- ORC-devices (Organic Rankine Cycle) – which can do (DHW) heating, cooling and electricity production in one go… These kind of turbines generate the power there: http://www.infinityturbine.com/ORC/IT10_ORC_System.html
- Concept for Zero-Energy-buildings: http://www.kcorc.org/en/rd-projects/test-mini-orc-turbo/
- Compressorless systems for cooling only without need of electricity: http://www.treehugger.com/culture/challenge-build-the-solar-powered-air-conditioner.html

New products

- Develop devices for the above suggestions

Ventilation

Ventilation for step-by–step refurbishment is demanding and needs new solutions. Most old buildings do not have the space or the infrastructure to make ventilation installation easy. There is a high demand for new, decentralized solutions and flow patterns inside the building.

The task is especially difficult as other demands such as frost protection, humidifying/dehumidifying and sound protection has to be met. Fortunately, there are many new promising and innovative solutions in early development.

Identified areas with high product potential

- Window, wall and facade integrated ventilation
- Decentralized ventilation units
- New innovative heat exchangers
- Active overflow units
- Ducting in the façade insulation

Climate Zone			1-arctic	2-cold	3-cool-temperate	4-warm-temperate	5-warm
Efficiency criteria							
Effective heat recovery efficiency of the ventilation system (including heat losses / gains through ventilation ducts)	$\eta_{WRG,t,eff}$	≤	80%	80%	75%	75%	-
Noise protection							
Sound emission		≤	35 dB(A)	35 dB(A)	35 dB(A)	35 dB(A)	35 dB(A)
Airtightness							
Connection details	$f_{Rsi\ (0,25)}$		A concept for airtight connections to other components must be provided.				
Buildings Airtightness	1/h @ 50Pa	≤	For the whole building, the airtightness requirement is ≤ 1,0 1/h @ 50Pa				

Ventilation

Existing products

- Frame integrated ventilation:
  http://www.internorm.com/uk/tipsinfos/i-tec-innovations.html
  http://www.schueco.com/web/de/partner/fenster_und_tueren/produkte/lueftungssysteme/kunststoff/Schueco_VentoTherm

- Decentralised ventilation system
  http://www.lunos.de/en/product/
  http://www.inventer.eu
  http://www.elektrodesign.cz/web/en/product/eco-room-100-430-heat-recovery-unit

  BluMartin free air 100, http://www.blumartin.de/lueftungsgeraete/

  ComfoAir 70, http://www.zehnder-systems.de/Produkte-und-Systeme/Komfortable-Wohnraumlueftung/zehnder-comfoair-70

- Centralized ventilation system with VAV regulation device for larger building: http://www.drexel-weiss.at/produkte-und-loesungen/wohnungs-und-gewerbebau/vbox/

- Duct system from EPP material –hard and flexible: http://www.air-lab.de/einleitung.html

- PTC electrical coils for ventilation units or duct system: http://www.air-lab.de/ptc-waermeelemente.html

- Ventilation system with active heat recovery: http://www.nilan.dk/en-gb/frontpage/solutions/domestic-solutions/ventilation-sanitary-hot-water/vp-18-cooling-solar

- ZooFans, ventilation systems for high ceilings: http://www.zoofans.com/engineering/

- Smoke extraction and ventilation of lift shafts : http://www.bluekit.international/wp-content/uploads/2015/01/EN_BLUEKIT_DATASHEET_BKAIO_20150127.pdf

New concepts

- Window integrated ventilation unit (LiLu) = (Licht+Luft)
- Wall integrated ventilation unit
- Decentralised solar-powered ventilation units
- Ventilation concept with less ducting for schools (Innsbruck example by Atrea)
- Decentralized ventilation with active overflow (AKKP44)
- Cascade ventilation with lower costs
- Washable filters or filter-free units or low-costs filter
- Compact decentralized HRV
- Intermediary natural ventilation concept
- Removable plugs in the wall for future services
- Ducting in general (simplified) aesthetics
- HRV/ERV switchable units

- Energy efficient frost protection
- Pre-made door or architrave head transfer grills

New products

- Small hidden ventilation systems to be installed as some sort of furniture
- Wall integrated ventilation units
- Active overflow units
- Window (opening) integrated units
- Façade integrated units
- Heat exchangers without need for condensation drainage
- Heat exchangers without need for frost protection
- New enthalpy concepts
- Thinly but highly insulated ducting elements easy to install

Heating/Cooling/Ventilation synergies

Existing products

- Circulation-air heating/cooling with heat recovery ventilation system in one device: http://www.atrea.cz/cz/teplovzdusne-vytapeni-vetrani-a-chlazeni
- Combination of standard wall radiator with air inlet device for under pressure ventilation without heat recovery: http://theradiatorfactory.com/en/radiators/jaga-oxygen
- TABS (Thermally Activated Building System): through a network of water pipes embedded in the structural concrete slabs, the heating and cooling demand decreases thanks to the use of the thermal mass of concrete walls and floors of a building. https://www.uponor.co.uk/office-buildings/radiant-heating-and-cooling/specialist-applications/thermally-active-building-systems.aspx
- SunSource, HVAC System: http://www.lennox.com/products/ultimate-comfort-system/
- Seasonal storage (PCM or – if space permits – water), alternatively brine exchange systems which cool in summer by charging up the ground and raise the efficiency of the heat pump in winter by higher temperature levels in the ground. https://www.youtube.com/watch?v=KyYor3Zm36I

New concepts

- Hot water production combined with cooling output in warm climates
- Natural ventilation and passive heating/cooling. Passive systems, such as solar chimneys, could be utilized for provision of fresh air and thermal comfort in specific climates.
- Using Recair enthalpy system to create a unit that dehumidifies, cools the air and at the same time produces hot water for warm climates
- Apartment refurbishment with ventilation radiators, using extract air to increase heat pump efficiency during the non heating season to compensate for higher losses during heating season

1.1.1. New products

- Compact unit for warm climates that makes use of the Recair enthalpy system to dehumidify, cool the air and produce hot water
- Combined gas cogeneration heating-DHW/solar cooling www.iasks.org/sites/default/files/ijtee20120402157164.pdf

RES integration

With the increase in efficiency of Photovoltaics, the Integration of Renewable Energy Sources will grow in importance. Buildings have a lot of surface area that can be used for Photovoltaics. Increasing heights of buildings should also enable the integration of efficient wind based RES systems.

Building integrated photovoltaic solutions are capable of fully replacing conventional construction materials for the building envelope such as skylights, façades, windows, curtain walls, roofs, balcony railings and floors. These multifunctional bioclimatic solutions combine both active and passive properties, providing greater acoustic and thermal insulation and at the same time producing clean energy on site. The use of components with photovoltaic materials on retrofitting projects is highly recommended because it improves the energy efficiency of the obsolete buildings that did not follow the modernized patterns of sustainability.

Identified areas with high product potential

- Variety of facades with PV integration
- Variety of roof covers with PV integration
- Paint-on Photovoltaics
- Glass with integrated PV cells
- Special roof tiles for historic town centers with integrated PV
- Small PV units for decentralized power production for blinds, ventilation or heat pumps

RES strategies for Heating

Existing products

- Baxi Senertec Micro CHP with gas condenser boiler http://www.baxi.co.uk/renewables/combined-heat-and-power/senertec-dachs.htm
- Aedomia Cythelia : Roof-Integrated PV-T supplying preheated air to a water/water Heat Pump through a air/water heat exchanger. Provides heat or cooling. http://www.cythelia.fr/images/revue%20CVC.pdf
- Parabolic Solar Collectors http://www.solitem.de/
- Biomass boiler systems (carbon net-zero value): http://www.baxi.co.uk/renewables/biomass.htm

New concepts

- PV connected modulating Heat Pump for heating, cooling and hot
- Use direct electricity peak loads that can not be used for short term heat accumulation
- Bifacial PV systems (20% efficiency, use of reflected solar radiation) http://www.mega-group.it/megacell/en/home-en/
- DC current electric system for load plugs, feeded by PV
- Advanced evacuated tube solar collectors. This system could form a component of roofing and facade structure for heating hot water and as a heat source for heat recovery.

New products

- Heat recovery customized mechanism to use the warm air generated in the air chamber of a ventilated façade for heating systems : http://www.e2vent.eu/project-description, http://solarwall.com/en/products/uses-and-applications.php

- Slate solar thermal roof panel : integrated solution for facades and roofs (sloped and flat), which generates energy for the production of heat, sanitary hot water, and for heating swimming pools.http://www.cupapizarras.com/int/products/thermoslate

RES strategies for Cooling

Existing products

- Solar cooling collectors: this technology can also be applied to operations of sub-zero cooling. In this case, single-cycle absorption coolers, rather than double-cycle systems, are used. The system produces favorable results when combined with a pre-existing low-temperature mechanism.http://www.solitem.de/

New concepts

- PV Integrated shading
- Peltier based cooling concept in sunny climates

New products

- Roof pond cooling for hot areas
- Solar dessicant cooling for hot and humid climate
- Hybrid geothermal/solar heat pump cooling

RES strategies for appliances and energy storage

Existing products

- Small wind turbines provides electricity generation thanks to the wind http://www.kliux.com/en/
- Wind turbine: http://www.freepowerwindturbines.com/honeywell_wind_turbine.html
- Battery storage: http://www.teslamotors.com/powerwall, http://bosch-solar-storage.com/the-battery/lithium-battery/

New concepts

- Direct use of renewables for domestic appliances
- PEM Fuel cells: The idea is to use hydrogen as energy vector (saving energy that can be later liberated in a controlled way, taking into account the higher quantity of energy used to produce it): http://www.fuelcells.org/base.cgim?template=types_of_fuel_cells

New products

- PEM fuel cells for domestic applications: dwellings and buildings
- Electric car surplus RES energy storage

Roof integrated technologies

Existing products

- PV skylight: A photovoltaic skylight ensures optimization of the photovoltaic generation providing at the same time bioclimatic properties of thermal comfort inside the building, as most of the ultraviolet and infrared rays are absorbed by a silicon-based material that acts as a sunscreen. In addition, it is possible to design and manufacture double glazing where the outer glass is photovoltaic and the passage of natural light is allowed.http://www.onyxsolar.com/photovoltaic-skylight.html
- PV roof tiles: http://www.tractile.com.au/TractileProducts/TractileSolarBIPV-TRoofTiles.aspx
- Roof tile integrated PV: http://www.jetsongreen.com/2009/11/srs-energy-us-tile-clay-solar-roof-tile.html
- Water tight EPDM rubber roll with photovoltaics collection plates: http://www.giscosa.com/eng/minisite/pdf/dossier_eng.pdf

New concepts

- Plant on dormers with integrated PV panels
- Roof lights with integrated clear PV panels
- Roof ventilation space that would be heated by the sun during the day and cooled in the evening – incorporate into ventilation system
- Rain water filter system to potable & grey water – connection to cold water storage tank
- Insulated cold water storage tank and lid to avoid freezing in cold temps
- Force of rainwater into gutters & downpipes used to convert to electricity-water dame effect.

New products

- Combined PV panels and green roof systems: http://www.greenrooftechnology.com/Solar_PV_Greenroofs
- Solar roof system that generates electricity as well as heat: http://reneweconomy.com.au/2014/bluescope-unveils-world-first-solar-roof-with-heat-and-power-32417
- Flexible PV panels: develop a competitive product, viable and scalable

Facade integrated technologies

Existing products

Photovoltaic spandrel http://www.onyxsolar.com/photovoltaic-spandrel.html

Photovoltaic ventilated façade http://www.onyxsolar.com/photovoltaic-ventilated-facade.html

Photovoltaic curtain wall http://www.onyxsolar.com/photovoltaic-curtain-wall.html

Solar thermal integration: integrated evacuated tube collectors generate solar heat at a high temperature level, and provide even, semi-transparent light and protection against the sun for indoor areas without impairing the view http://www.bine.info/en/topics/renewable-energy-sources/solar-heat/publikation/fassadenkollektoren-mit-durchblick/?type=333

New concepts

- PV Ventilated (Multi-functional) facades that would provide solar electricity generation, daylighting, insulation and heat recovery. These facades could be in a form of double skin facade but integrated with a transparent photovoltaic device and energy recovery mechanism for preheating/cooling of supply air and/or facilitating natural ventilation.

New products

Efficient photovoltaic painting: develop a competitive product, viable and scalable

Titanium dioxide material for coating: The application of this photocatalytic coating could reduce the heat loss resulting from rainwater absorption by conventional façade materials.

Energy conservation

Existing products

- SMA Webbox : http://www.sma.de/en/products/monitoring-control/sunny-webbox.html
- http://boxofenergy.se/english
- http://www.iflscience.com/technology/new-liquid-metal-battery-will-make-renewables-competitive ; http://www2.technologyreview.com/article/412190/tr10-liquid-battery/
- http://www.solarpanelsplus.com/solar-battery/ saltwater battery
- Store solar electricity in electric car (or scooter) batteries
- Flywheel short-term storage: e.g. http://cdn.intechopen.com/pdfs-wm/20363.pdf
- Co-generation: http://www.okofen-e.com/en/open_innovation/IDnews=115 ; http://www.okofen-e.com/en/open_innovation/IDnews=102 (Stirling engine)
- Schneider electric electrical energy storage system, smart grid solution (passive house project in France, http://www2.schneider-electric.com/sites/corporate/en/products-services/smart-grid-solutions/prosumer-microgrid-solutions/kergrid-sdem.page)
- Shower tray heat recovery units:

http://www.meanderhr.com/about/page/2/

http://www.treehugger.com/clean-technology/next-generation-heat-exchanger-captures-waste-heat-drain-shower.html

http://buildingservicesnews.com/news/zypho-shower-water-heat-recovery/

http://www.ageekyworld.com/unique-drain-heat-exchanger-the-ecodrain/

http://www.greentherm.ie/product/zypho-shower-waste-water-heat-recovery-unit/

http://thenauhaus.com/blog/systems/mechanical/plumbing/2009/ecodrain-wastewater-heat-exchanger/

http://aloaqua.co.nz/heat-recovery/smart-shower/

https://ecodrain.ca/en/news/

http://aloaqua.co.nz/2015/07/17/shower-water-heat-recovery/

http://www.greenplanetled.co.uk/zypho-shower-heat-recovery-system-398-p.asp

New concepts

- Storing energy long-term/short-term
- Monitoring
- Building load management system to maximize renewable fraction
- More efficient appliances

New products

- Monitoring devices that can be easily retrofitted
- Efficient household appliances – solar energy optimized
- Water saving shower heads optimized for 6l/min

Optimising building envelope

Existing products

- Prefabricated refurbishment
  http://www.volkerwessels.com/nl/nieuws/detail/energienotanul-renovatie-in-een-dag-uitgevoerd
- Glass covered court yards
  http://www.lamilux.fr/fileadmin/user_upload/dateien/Lokalisierung/FR/Tageslichtsysteme/Brochure_CI_declairage_zenithal_en_verre_type_PR60_08102013.pdf

New concepts

- Computer aided design for add-on facades, from digital measurement to automatic production of panels
- Cheap, translucent envelope for whole buildings, including a large airspace between new envelope and original building, creating a secondary conditioned area

New products

- Thermal bridge free, prefabricated balconies