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

IEE PassREg

PASSIVE HOUSE REGIONS WITH RENEWABLE ENERGY

Brief report

Boundary conditions for energy balance calculation

Deliverable D5.3.2 "Adapted boundary conditions for energy balance calculation"

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in collaboration with the PassREg consortium

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INTRODUCTION

The Passive House concept is a widely recognised basis for the design of energy efficient buildings in many parts of Europe. The energy balance and Passive House Design tool PHPP, or Passive House Planning Package, has proved successful in practice. Numerous built examples across Europe acknowledge this and show the close correlation between monitored energy consumption and calculated energy demand. Furthermore, PHPP has also developed into a tool for the verification of EnerPHit projects which apply Passive House components in existing buildings.

The boundary conditions used for the energy balance calculation are being assessed within the EU project PassREg. Up till now the Passive House Institute has assumed (with good reason) that the boundary conditions in other countries do not vary so much from those in Germany. Subtask 5.3.2 is intended to shed more light on this under the specific aspects of specific climates, norms, regulations, habits, economic conditions and supply structure.

2

PARAMETERS

National norms and regulations are boundary conditions which need to be fulfilled for each project and do not actually directly influence the energy balance. Since the start of the PassREg project, the PHPP has been supplemented by worksheets which enable local translator/reseller partners to implement national norms and regulations easily by adding additional worksheets to the PHPP or by using the import/export interface which has been created for this purpose. This ensures transparency of calculation methodologies. This was successfully updated for the German EnEV regulations and KfW subsidy programmes. Local adaptations such as unit conversions to suit local needs can also be integrated. This is an ongoing process and is carried out by local translator/reseller partners and takes place independently of the PassREg project.

The following boundary conditions influence a building’s energy balance:

1) climatic conditions

2) interior temperature setpoints in winter and in summer

3) humidity setpoints (relevant for dehumidification only)

4) user habits also under the aspect of economic conditions

5) supply structure and utilisation of renewable energy

First of all the climatic boundary conditions are investigated for each partner region and for the partner countries. The outcomes and results are described in a separate report together with the set of climate data (task 5.3.1.). The resulting climate data are incorporated into the PHPP.

The second and the third points are not investigated further here for various reasons:

- Appropriate climate data needs to be used in any case. The PHPP applies local climate data for every project. Regional climate data are covered in Task 5.3.1 *Set of climate data for energy balance calculation*. Please refer to the report on *climate data delivered* for further information.

- Temperature and humidity setpoints can be assumed to be identical in all countries as long as the desired level of thermal comfort is affordable. The comfort range can be derived from physiological models as described in [Fanger 1972]. There is some confusion about whether people would possibly accept higher indoor temperatures in summer if the ambient temperatures are also higher. This question has been discussed in [Schnieders 2009], leading to the conclusion that the temperature and humidity setpoints in the PHPP are applicable independently of ambient conditions.

The fourth point concerning user habits plays a role in the building's energy balance e.g. use of electrical appliances, producing other internal heat gains, ventilation or shading of windows.

Lastly, point 5 assesses the supply structure and utilisation of renewable energy. This report focuses on two points/aspects. Firstly, the seasonal gap and secondly, ongoing research on the development of PER factors which reflect sustainability.

3

User habits and economic conditions

A detailed investigation of user habits regarding ventilation and usage of shading devices is beyond the scope of this task. To deal with user habits and economic conditions, this report focuses on an evaluation of statistical data which might influence the amount of internal heat gains. Do internal heat gains differ between different countries and regions? Are country-specific assumptions justified? The project partners were asked to look into national statistics and provide information about the following topics:

- average number of persons per m² of living area

- average size of dwelling units

- average household electricity consumption (without heating and hot water)

- average total water consumption

- average domestic hot water consumption

- the fraction of households equipped with certain electrical appliances

Some partners were able to provide data on these topics within the available time frame, while others could not find the respective information. Therefore we additionally resorted to information that was accessible on an international level.

The major influencing factors for internal heat gains in residential buildings are

- sensible heat released from people

- electricity consumption by household appliances like freezers and washing machines, lighting, and miscellaneous equipment

- mains water entering the building envelope at a lower temperature and heating up before leaving the envelope

- heat released from the domestic hot water (DHW) system

- evaporation

The last two points were not considered in greater detail here. Heat from the hot water system is an important contribution and is, therefore, explicitly considered within the PHPP depending on the actual DHW storage and distribution system. Evaporation from towels, plants, clothes, etc. is a relevant contribution on the same order of magnitude as the heat released from people, but this could not be quantified in more detail within the scope of this project as more detailed studies would be required for the quantification.

Three factors remain: heat released from people, electricity consumption, and heat absorbed by cold water. These factors are evaluated in the following section.

Statistical evaluation

To begin with, it must be noted that the accuracy of the statistical data used here is limited. Depending on the choice of the sample, the reference time and the definition of the statistical data, we found typical differences of ±20% between data for apparently identical parameters. This needs to be taken into account in the interpretation of the following results.

The number of square meters of living area per person, being an indicator of the heat released by people, is shown in Figure 1. The standard deviation estimated from these data is 24%. As it might be expected, there is a tendency for higher occupancy rates (i.e. less square meters per person) in countries with a lower gross domestic product during the last decades, and vice versa.

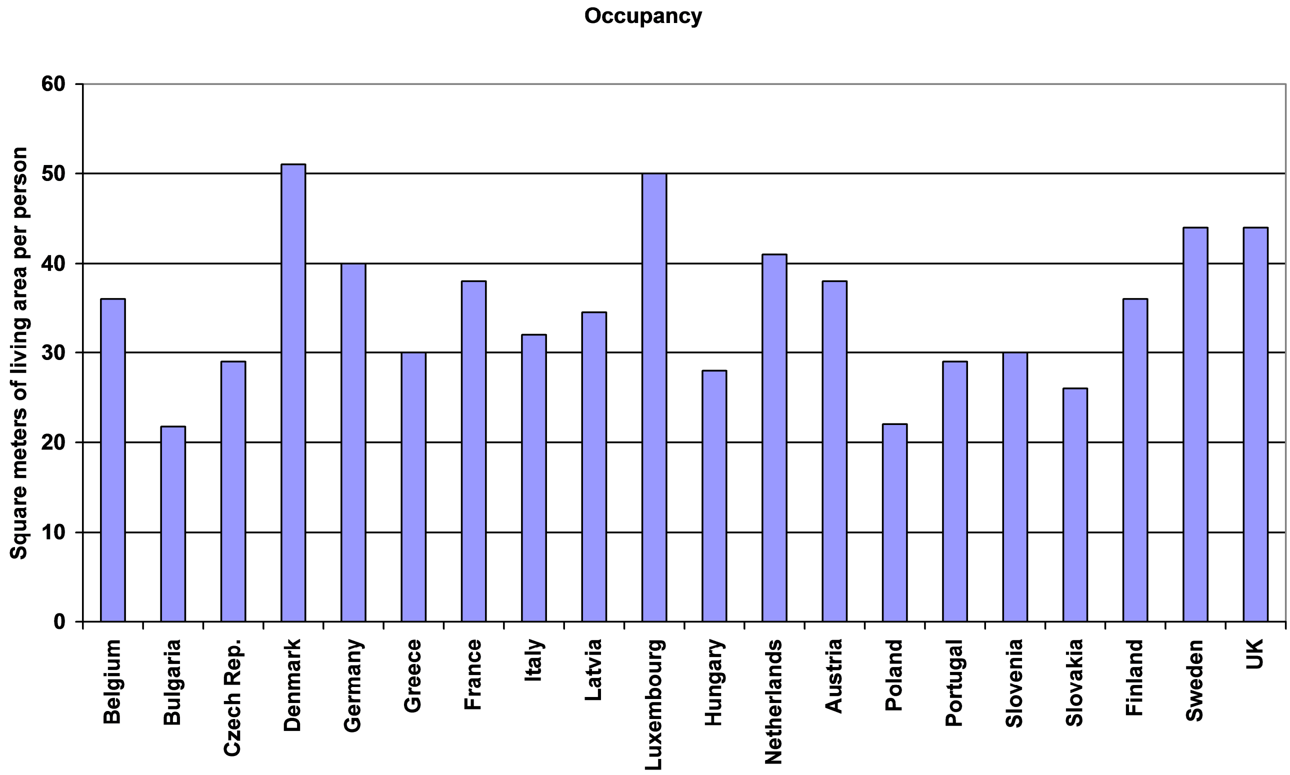


Figure 1: Occupancy rates in different European countries

The current PHPP standard value of 35 m^2 per person is slowly becoming too small for countries like Denmark, Luxembourg, UK or Sweden. On the other hand, the average of the present data from different European countries, weighted by living area, is 37.9 m^2 per person.

The total electricity consumption for appliances and lighting per household has been investigated in the Remodece project. Figure 2 shows the results, complemented by data provided by PassREg partners and converted to kWh/(m^2a) by use of population data from other sources. The standard deviation is estimated to be 25% of the average, with the highest values in the Mediterranean countries Greece, Italy and Portugal, and the lowest values in the Eastern European countries Latvia and Czech Republic.

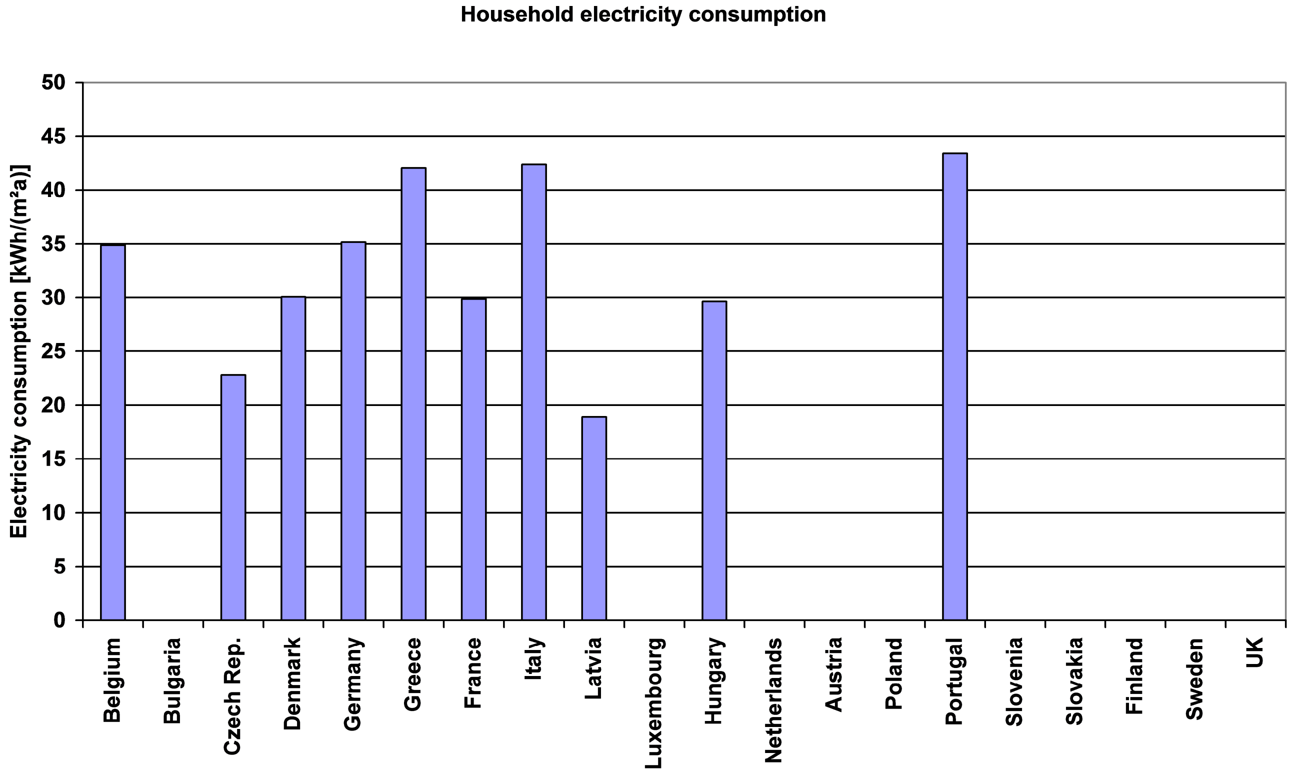


Figure 2: Electricity consumption for appliances and lighting in different European countries

It might be expected that the average income is influencing both occupancy and electricity demand, with higher income resulting in more square meters per person, more and bigger appliances and higher electricity consumption. In reality, the relationship appears to be more complex; there is absolutely no statistical correlation between both parameters (r^2 = 0.07). This means that the variations of occupancy and electricity demand can be treated as independent.

Data for cold water use is usually given as an aggregate sum for services and private households. These data are shown in Figure 3. An average daily water consumption of 110 l per person results, similar to the PHPP assumption of 100 l cold water per person per day. The standard deviation estimated from the data is 29%.

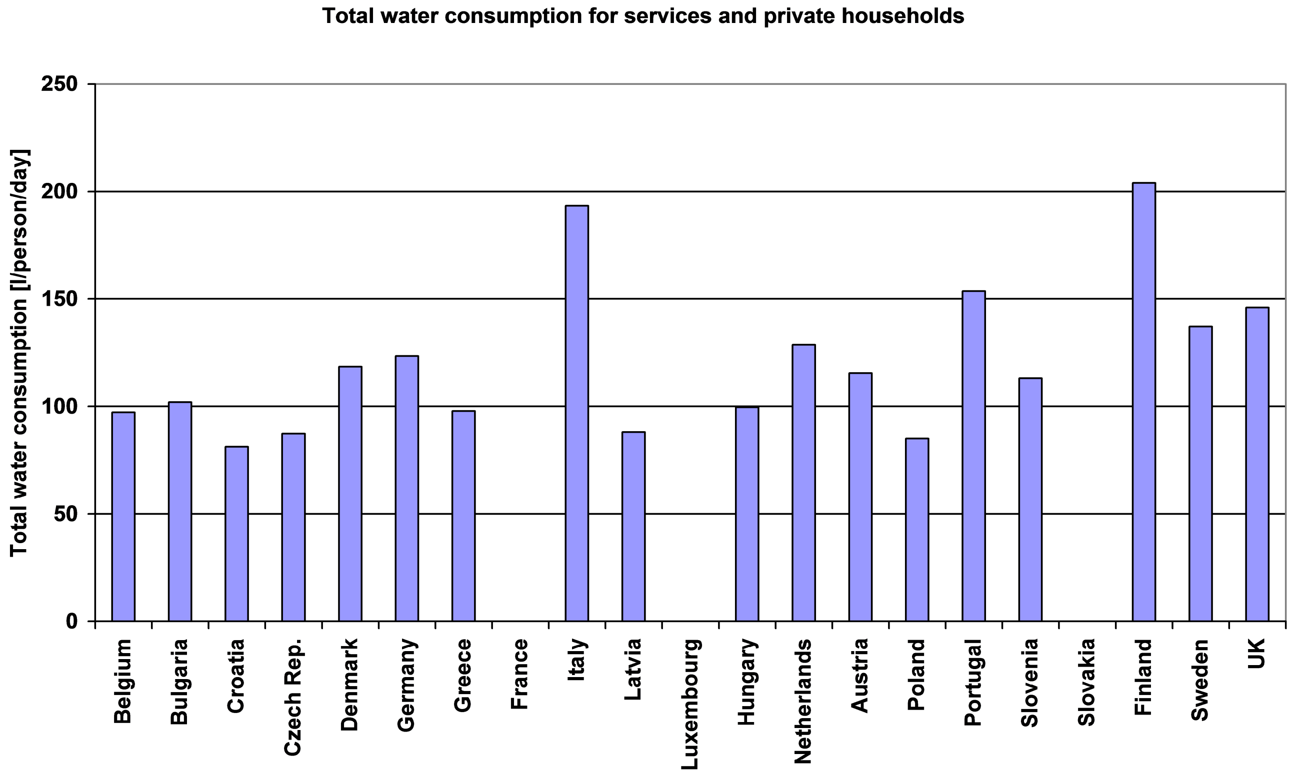


Figure 3: Water consumption in different European countries

There are some countries like Italy and Finland which have higher specific water consumptions. It may be speculated that high consumptions are due to low prices; in fact water is comparatively cheap in Italy and Finland. No difference is made in the statistical data for water being used in the building, mainly for toilet flushing, and for water used for irrigation, car washing, etc., that would not affect the heat balance of the building.

4

Evaluation of integrated RE supply

This chapter "evaluation of integrated renewable energy supply" looks into the topics of PE factors and the issue of a seasonal gap.

4.1 Energy supply in a state of flux

The energy supply in Europe is still mainly based on non-renewable energy sources. A transition to renewable energy sources is accepted as being necessary and politically desirable.

Compared to the old supply system we can see significant differences that will occur when switching to the new energy supply system:

Until now, electricity generation has followed demand to a large extent. The output of the electricity generation system is increased as much and as soon as possible and as required by the demand.

However, large power stations, e.g. coal or nuclear power plants, react very slow. It is hardly possible to balance daily fluctuations with these plants. For this purpose, for example pump storage plants are used; at times of low demand, e.g. at nighttime, water is pumped from a lower situated reservoir to one on a higher level. If demand temporarily exceeds the power from power plants, water flows downwards to generate electricity via turbines.

In contrast to this, the electricity generation from renewable energy sources cannot be based on demand but follows the naturally fluctuating energy generated by the wind and sun. In countries which already have a higher share of renewable electricity, an imbalance can be seen between renewable energies and the old structures: the grid and generation system cannot react to the change fast enough in order to incorporate the renewable energy supply. Despite the preference for renewable energies, it happens too often today that wind and solar power plants are disconnected from the grid, as the grid is already being supplied by slow-responding, fossil power plants. In other words, the grid is already “blocked up“.

These issues can be resolved by faster reacting gas power plants and by a higher construction rate of short term storage, e.g. pump storage hydropower plants, and to a certain extent by adapting demand to (power) generation as well.

Through a clever combination of energy sources and short term storage, it is quite easy to cover a constant annual energy demand. This is the case with household electricity or domestic hot water, for example. A much bigger problem is becoming apparent if we focus on the seasonally occurring fluctuation in the energy demand. There are energy applications which occur strongly concentrated at a certain time of the year e.g. the energy demand for the building’s heating system: heating energy is concentrated and nearly only required in winter while no renewable energy source is available which offers a similar profile. Energy generation and energy demand do not match in this case. It is necessary to have storage which provides energy in winter according to demand and which can be charged during the rest of the year.

4.2 Current evaluation of the energy demand

The evaluation of a building’s energy demand often uses the non-renewable primary energy demand. This primary energy principle includes evaluation of the generation and the supply chain of the final energy carriers. For example, energy losses occur on the way from the oil spring in the Saudi Arabian dessert to the oil storage tank at home due to transport and refinement of raw oil to heating oil. These losses are assessed via the primary energy factor. According to the German regulations for energy saving in buildings and building systems (EnEV) for example, heating oil has a PE factor of 1.1. This factor corresponds to losses of 10% along the generation chain. However, the PE factors are generally determined not by exact science but by politics and they are used to evaluate the energy demand of buildings in accordance with the EnEV. This worked reliably enough as long as the energy supply system was based mainly on non-renewable sources, but the situation changes with the politically desirable higher share of renewable energies:

So far, only non-renewable primary energy has been considered accurately. Let us look at the example of wood in form of split logs. It mainly consists of renewable primary energy, namely the energy from the sun that the tree stored in the form of carbon during its growth. Only a small fraction of the energy used to produce wood in the form of split logs comes from non-renewable sources e.g. for cutting, chopping and transportation. Based on current knowledge, the renewable primary energy factor is actually approximately 0.05. According to the EnEV however, a factor of 0.2 has to be used. The result is as follows: if wood is used for heating a building, more energy may be consumed than if oil was used. However wood, too, is a resource that is limited in its availability.

Electricity is a mix of renewable and non-renewable sources. Old coal power plants produce electricity with a non-renewable primary energy factor of about 3. To produce one part electricity, three parts primary energy coal are burnt. No fossil energy is required for electricity generated by wind and solar plants. For this type of electricity, the primary energy factor is 0. If the share of renewable and non-renewable power sources changes the mix , then the resulting non-renewable primary energy factor for electricity also changes. According to EnEV, the factor has been reduced from 3.0 to 2.7 and 2.6 in the past, to 2.4 today. In the year 2016 it will further decrease to 1.8. If we follow these thoughts, the non-renewable primary energy factor will tend towards zero and will become zero as soon as the energy transition towards 100% renewables has been accomplished. At that moment in time, every building, regardless of its actual final energy demand, would have a primary energy demand of zero. This chain of thoughts already shows that using the non-renewable primary energy demand as the sole scaling system has become inappropriate for the sustainable evaluation of energy efficiency in buildings.

4.3 Future evaluation of the energy supply: PER-system

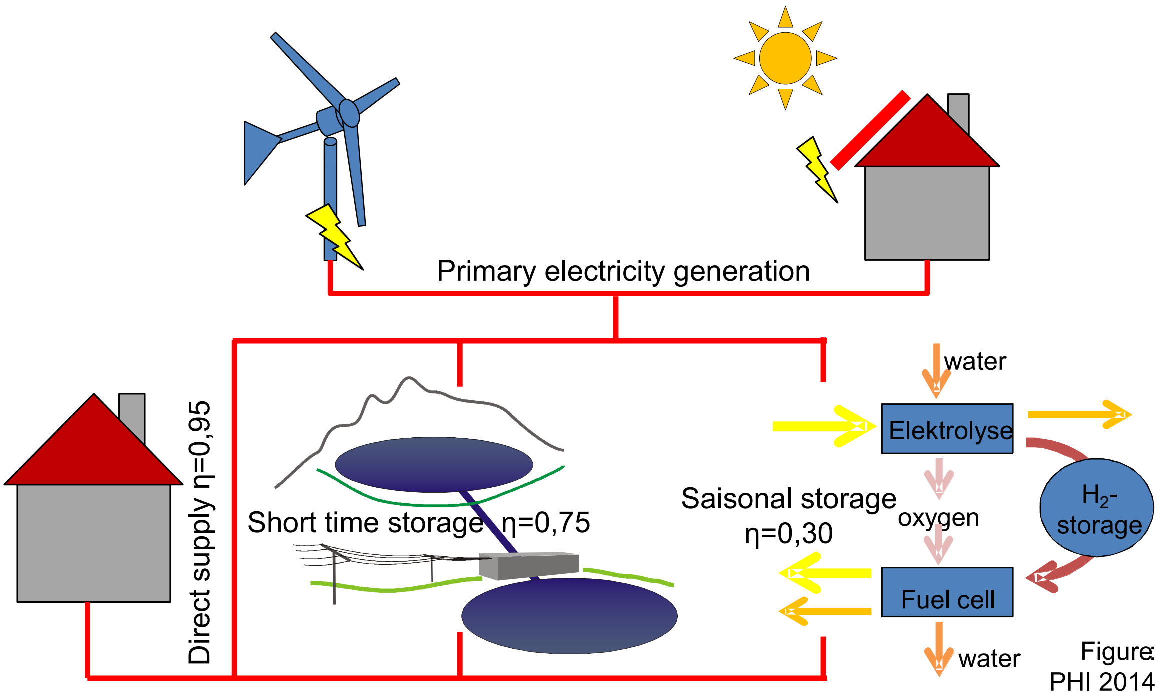
Total primary energy demand is also inadequate as a possible solution: In principle, one possible solution could be to add the renewable primary energy demand to the non-renewable primary energy demand. In this case, wind energy would have a total primary energy factor of 1, wood would have a factor of 1.2 according to DIN V 18599-1. At first glance, this solution seems viable. However, renewable and non-renewable energies cannot be compared with each other; while the use of non-renewables necessarily leads to dramatic and partially irreversible damage (climate change, air pollution, nuclear risks, limitations), the problems resulting from the use of renewable energies are often only of aesthetic nature (visual impacts on landscapes through the massive implementation of wind parks, reflective effect of solar panels on roofs) or could be resolved in principle (e.g. food or fuel-discussion). Considering the unforeseeable and, in principle, resolvable consequences it is evident that simple addition of renewable and non-renewable primary energy is out of the question.

Solution for a renewable primary energy demand: The solution proposed by the Passive House Institute is really simple. In this scenario, it is assumed that the energy transition has taken place successfully and a model of a system has been developed where only renewable energies are being used. These are mainly wind and sun, from which the so-called primary electricity is being produced, along with some water and biomass plants. This system also has losses along the generation and the supply chain, which are evaluated via PER factors (PER = Primary Energy Renewable). A renewable primary energy factor (PER-factor) of 1 is defined for the so-called primary electricity produced from the renewable sources wind, water and sun.

Some of this primary electricity can be directly used via the grid, but in times when the demand does not match the supply, energy storage facilities have to be used to balance supply and demand. This model comprises two types of storage systems. These are short-term storage systems, represented e.g. by pump storage hydropower plants, and long-term storage systems, which are based, for example, on the path from power to hydrogen to methane.

In times of surplus energy generation the short-term storage is charged before the long-term systems. The efficiency factors of pump storage hydropower plants are currently between 75-80%. Once the short-term storage is fully charged, the energy surplus is converted via electrolysis into hydrogen (H2) and/or further into methane (CH4) and fed into the existing grid for natural gas (Power-to-Gas, PtG). Today we already have sufficiently large storage capacities for natural gas to ensure a secure energy supply in an optimised system with high efficiency.

If insufficient renewable electricity is available, energy will first be drawn from the short-term storage and then from the long-term storage. With 30-40%, although the efficiency of the long-term storage is significantly lower than the efficiency of the short-term storage, the resulting PER factor is still within the range of the PE factor of current electricity generation without the renewable share (current PE factor for electricity 2.4, PER from electricity via long-term storage: 1/0.4 = 2.5).



Different PER-factors for different applications: For example, the hot water demand is relatively constant over the course of a year. To minimise the burden on the storage as much as possible, an optimal combination of wind and sun fractions can be determined for this constant demand. There is more wind in winter, and in summer solar energy availability is higher. These two primary energy carriers complement each other quite well. In addition, hot water can be stored locally in storage tanks which are already commonly used today. Thus the possibility already exists for bridging times with a low renewable energy supply and charging the hot water storage during times of surplus renewable energy supply. PER factors depend on the energy sources available on a regional level and therefore on the regional climate. The Passive House Institute has calculated the PER factor for electricity used for DHW supply as ca. 1.3 in Central European climates.

Similarly constant over the course of a year is the household electricity demand. However, buildings do not offer storage possibilities for this and therefore storages connected to the grid have to be used. This results in a PER factor of approx. 1.4 for Central Europe.

The space heating demand is concentrated in winter. In the completely renewable scenario, gas heating will cover the total demand with the PtG strategy from the long-term storage with a PER factor of about 1.7 in Central European climates. The following figure shows PER factors for some appliances compared to the (non-renewable) PE factors used in the EnEV 2016.

Appliance	Energy carrier	PER-factor*	PE-factor**
	Primary electricity	1.0	-
DHW	Electricity	1.3	1.8
Household	Electricity	1.4	1.8
Heating	Electricity	1.7	1.8
Heating	EE- Methane	1.8	1.1 (Gas/oil)
	Biomass	1.1	0.2

*Values vor central Europe ** not renewable, German EnEV (2016)

An electricity-based heating system also puts a lot of pressure on the long-term storage with its low efficiency. Here, the primary electricity mix is wind-dominated as this energy source performs better in winter than the sun. Therefore, a PER factor of 2.2 can be calculated for the electricity-based heating system of buildings. If a heat pump with an annual performance factor of, for example, 2.5 is used for heating, then 1/(1.7/2.5)=1.47 parts “heat” can be produced from one part primary electricity. Thus, the heat pump has a better result than a gas boiler (natural gas won't be available in the system anymore, so methane will be directly drawn from the long time storage) which produces 1/1.75=0.57 from one part primary electricity. As a result, the heat pump will be the preferred heating system in the future; this is already influencing the decisions being made today – since the buildings built or retrofitted today will still be there when the energy transition has been accomplished.

4.4 Classification of buildings according to PER demand

Efficiency first approach: Independently of the development of the energy supply structure, the efficient use of energy in buildings remains primarily important. From the beginning, this “efficiency first” approach lies in the focus of the work carried out by the Passive House Institute as well as of the Passive House Standard developed by PHI, next to comfort and hygiene requirements.

Space heating demand: As an example, a maximum annual space heating demand of 15 kWh/(m²a) is required, which is generally the economic optimum in Central Europe. At the same time, the required energy on such a low level can be easily supplied in a sustainable manner. In South Europe, the economic optimum leads to even lower space heating demands, but it has to be taken into account that the graph of the cost/space heating demand has a very flat optimum in this climate zone. Furthermore, there are regions in Europe where the classic Passive House does not constitute the economic optimum yet. Reasons for this may be the lack of components or excessive costs for components, lack of know-how and subsidised energy prices.

Overall energy demand: The space heating demand is not the dominant energy demand in highly efficient buildings. In Passive Houses, for example, it is in the range of the domestic hot water demand. The demand for household electricity is generally much higher. There are efficiency potentials to be found in this area, also in combination with the chosen heating and DHW system. Additional evaluation is thus required for comprehending the total energy demand of a building. As described in this study, the PER system has been applied for carrying out this evaluation.

Integration of renewable energies: Generation onsite or nearby and use of renewable energy sources for building appliances makes sense and is also required by the European Buildings Directive. However, buildings should not be reduced to energy generation plants. Approaches which directly offset generation and demand in the annual balance will inevitably lead to misguided optimisations because generation of solar electricity in summer cannot directly offset demand in winter. The reason is that there is a chain of transition, storage and transition again between generation and demand.

So it is quite easy to transform a one-story bungalow into a plus energy house if the annual energy balance is taken as a basis. A large roof area is available compared with the useful area, which, when covered with a photovoltaics system, allows for high solar generation during the summer. The building does not need to be very efficient in order to achieve equilibrium in the annual energy balance based on the space heating demand; however, the storage losses are not included in this equation. A multi-story building which has a small environmental footprint obtains a better rating in terms of ecological aspects because it consumes less natural ground area, but it will be much harder for it to accomplish an equilibrium in the energy balance due to the less favorable roof-to-useful-area ratio.

In this aspect, the PER system offers a solution for correctly considering and offsetting generation and demand. Electricity produced by the PV system is primary electricity and will be evaluated with a PER factor of 1 (instead of today's approach as so-called "displacement electricity" with a PE factor of up to 3), and application-dependent PER factors are assigned to the demand. Calculation of the scenario is accurate when the factors are considered in this way.

Taking the above described PER factors into account, the disadvantage of multi-storey buildings with a poor roof-to useful-area ratio still remains, which needs to be resolved in the new scenario. A building has a certain ground area, the building's footprint, with the result that this area is no longer publicly available. However, through the generation of energy, it is possible to make use of this area for the public again. At Passive House Institute therefore **energy generation** refers to the building's footprint and not the useful area (or living area or treated floor area).

Following from the thoughts described above, the Passive House Institute has **introduced the new Passive House Classes**. These classes are based on the PER system for evaluating buildings according to demand and generation:

- **Passive House Classic**, which is the traditional Passive House;
- **Passive House Plus**, in which additional energy is generated, for example from photovoltaics. Such buildings are said to produce about as much energy as the occupants consume, at least in a – admittedly somewhat misleading – net calculation over the year.
- The **Passive House Premium** class is designed for the avant-garde. Those buildings are in their basic construction still Passive Houses, but are said to produce annually more than 120 kWh/m² (ground area) from renewables sources and have a renewable primary energy demand of less than 30 kWh/m² (treated floor area). They are far more ambitious than the other classes.

In order to fulfill the requirements of a specific class it will be possible to compensate lower energy generation by a higher efficiency of the building envelope and the building services and vice versa.

The new classes – mostly unchanged (?)!

Most people probably think of a single number when they hear the term Passive House: 15 kWh/(m²a). It describes the maximum demand for annual heating energy for compliance with the Passive House Standard. This figure is still included in all of the classes in the new evaluation system because it provides a starting point by limiting the amount of useful energy made available for indoor heating purposes. The useful energy demand for cooling, airtightness, and the criteria for comfort and hygiene also remain the same. But a heating energy demand does not tell the whole story; after all, the heating energy demand is roughly equal to the hot water demand in Passive Houses. The demand for household electricity is usually much higher. A building's total energy demand – including the energy needed to provide the building with final energy – therefore also needs to be taken into account. This is where the new Passive House classes come in. They divide buildings into categories based on the renewable primary energy demand and their own renewable primary power production.

The new Passive House classes Classic, Plus, and Premium. Requirements for PER demand and renewable energy generation.

Classic is the current Passive House Standard. Higher classes require lower renewable primary energy demand and additional renewable energy generation.

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Generation and demand remain separated

Power from a solar roof for example is considered primary electricity with a PER of 1.0. It is exported to the grid and is not calculated against the building's energy demand. The PER model is used to calculate demand. For example, solar power generated in the summer should not be treated as though it directly offsets heating energy in the winter because energy from the summer would need to be stored seasonally for the winter, a process that entails additional losses. If this factor is not taken into consideration during planning, buildings are not properly optimised. By taking account of renewable primary energy, the new system allows the building to be made future-proof.

Energy generation relative to the building's ground area

Often, energy demand and generation are stated with reference to a building's treated floor area. If a building has a photovoltaic array, it can produce a certain amount of energy, but the amount per square meter of floor area decreases as the number of stories (and hence floor area) increases. Single-storey bungalows thus seem to perform better than terraced houses and duplexes/complexes, although bungalows actually consume much more area and resources per resident. Stating renewable energy production in terms of floor area can thus also lead to improper optimisations. In the new concept, energy generation is instead stated relative to the building's projected thermal footprint, defined as the vertical projection of the thermal envelope towards ground (for details, please see PHPP 9 Manual). Whether a bungalow or a complex is built, the assessment is therefore the same in terms of energy generation. This approach is better because the space a building takes up is then no longer available for other types of usage. If this area is used to generate electricity, there are additional benefits, and these benefits are then assessed in terms of this area. After all, the sun shines on the roof, not on the treated floor area on every storey.

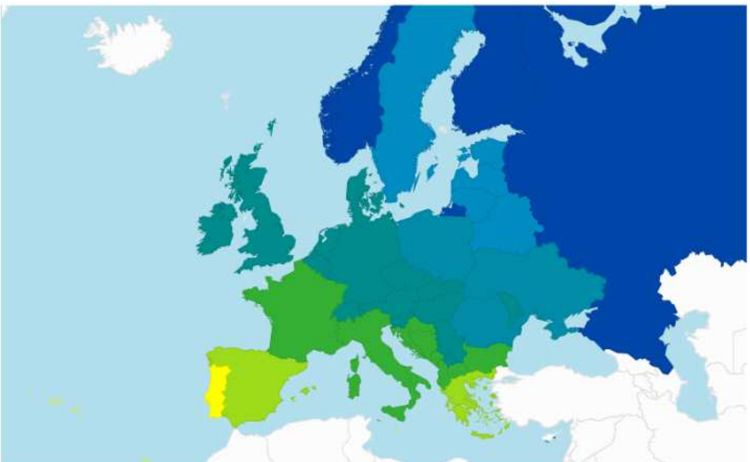
5

Clickable map as component guideline for European climates

In Task 5.2.2 a clickable map was developed for the building services. This map was supplemented with the components of the building envelope which are exterior insulation, glazing, window frames and shading. This integral component guideline was developed from exemplary buildings in the different European climate zones and covers appropriate integration of renewables as well.

In this stage the clickable map can be used by architects and engineers as a starting point for the integral PHPP energy balance calculation of NZEBs using the Passive House Standard and renewables both for new builds and retrofits.

It also can be used by non-technicians like politicians and investors to provide guidelines for appropriate components for their region/climate zone.



Component guidelines for cost-optimal Passive Houses and EnerPHit retrofits

Climate zone	Regions	Building envelope				Building services					Example buildigs
		Exterior wall insulation with λ value of ca. 0.035 W/(m·K)	Glazing	Window frame	Shading	Heating installation	Cooling strategy	Ventilation concept	Domestic hot water system	Renewables	
Warm temperate	Bulgaria	14 cm	Triple or rarely double insulated glazing	Possibly insulated, phC class or better	Roof overhang, exterior shading device	Supply air heating is possible	Night ventilation (not in humid climates), possibly cool colours	With heat recovery, possibly with dehumidification, possibly with frost protection	Boiler or compact unit (ventilation, dhw boiler, heating/cooling in one unit)	Photovoltaic solar panels as much as possible	Example project 2996

Integral component guideline for the European climate zones

6

PHPP DEVELOPMENT

The new PHPP 9, released in April 2015 (German version, other languages will follow soon) is a great step forward. Many new functions and options have been added. Some are listed and explained here:

Implementation of the PER concept and the new Passive House classes

- For the implementation of the PER system, more than 400 (current state of development, April 2015) climate data sets including the new regional PER factors were generated and integrated.
- The PE worksheet was completely redesigned and renamed into PER. In this sheet, the building services can be selected, the biomass contingent is set here, different sets of PER and CO2 factors can be chosen. All demands and renewable energy generation are displayed here and assessed according to PER, PE and CO2 systems.

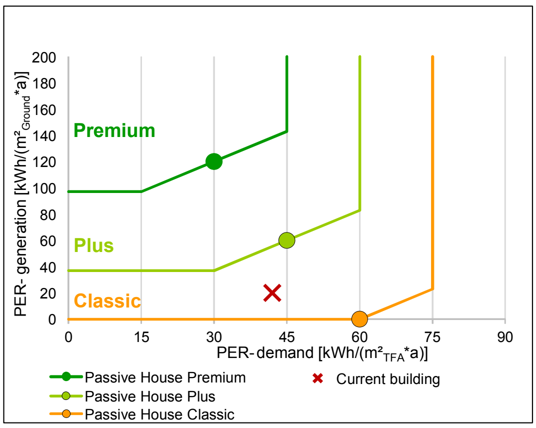
Erneuerbare Primärenergie PER — Passivhaus mit PHPP Version 9.2

Passivhaus-Reihenendhaus / Klima: PHPP-Standard / EBF: 156 m² / Heizen: 12,5 kWh/(m²a) / Übertemperatur: 1 % / PER: 30 kWh/(m²a)

Auswahl Wärmerzeugungssystem	Deckungsbeitrag (Nutzenergie)					
				Objekttyp:	Reihenhaus	
				Energiebezugsfläche A_{EB}:	156	m²
				Überbaute Fläche A_{Grund}:	81	m²
Primärer Wärmeerzeuger	Heizung	Warmwasser	Weitere Eingaben in den Blättern	Heizwärmebedarf inkl. Verteilung u. hydr. Frostschutz:	13	kWh/(m²a)
2-Wärmepumpe	100%	100%	WP, evtl. WP Erde	Nutzkältebedarf inkl. Entfeuchtung:		kWh/(m²a)
Sekundärer Wärmerzeuger (optional)				Warmwasserbedarf inkl. Verteilung:	24	kWh/(m²a)
-	0%	0%	-			

Energiebedarf Bezug: Energiebezugsfläche	Endenergie Deckungsanteil (Endenergie)	Endenergie Endenergie-bedarf kWh/(m²a)	PER PER-Faktor kWh/kWh	PER PER-Faktor effektiv (mit Bio-massekontingent) kWh/kWh	PER PER-Kennwert kWh/(m²a)	PE PE-Faktor kWh/kWh	PE PE-Kennwert kWh/(m²a)	CO_2 CO_2-Emissions-faktor (CO_2-eq) kg/kWh	CO_2 CO_2eq-Emissionen kg/(m²a)
						1-PE-Faktoren (nicht regenerativ) PHI Zertifizierung		1-CO2-Faktoren GEMIS 4.6 (Deutschland)	
					30,0		54,5		15,1
Heizung				1,10	11,2	2,40	24,5		6,6
Strom (WP Kompaktgerät)			1,80			2,40		0,644	
Strom (Wärmepumpe)	100%	7,7	1,80	1,10	8,5	2,40	18,6	0,644	5,0
Nah-/ Fernwärme: 20-Gas-BHKW (70% KWK)			0,85|1,39|1,01			0,70		-0,070	
Holz und andere Biomasse			1,10			-		-	
Erdgas / EE-Gas			1,75			1,10		0,253	
Heizöl / EE-Methanol			2,30			1,10		0,321	
Thermische Solaranlage						0,00		0,045	
Strom (direkt über WW Wärmespeicher)			1,80			2,40		0,644	
Strom (direkt über Widerstandsheizung)			1,80			2,40		0,644	
Hilfsstrom (Lüftung Winter, Enteisung WT, Umwälzpumpe, Kessel heiz, S		2,5	1,80	1,10	2,7	2,40	5,9	0,644	1,6

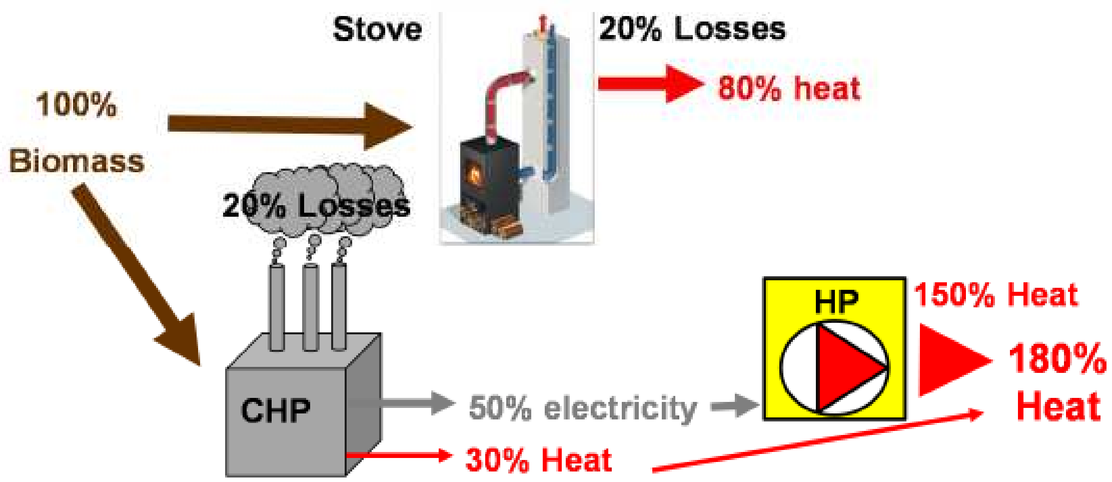
- The PER sheet also shows a chart in which the current building (red x) is displayed with its demand and generation in relation to the new Passive House classes. In this way, the results of further optimisations of a building can easily be tracked by following the red cross.



Biomass contingent

Both in Germany and worldwide, biomass is only available in limited amounts. There is a clear usage hierarchy for biomass: 1) food production, 2) materials, and 3) energy [Krick 2012]. Because biomass can be stored and has a high energy density, it will mainly be needed in mobile applications (transport). Only a small amount will be left over for consumption in buildings. The PHPP 9 sets the amount of renewable primary energy left over at 20 kWh/(m²a) PER. The PER factor is set at 1.10 for biomass in general. Because biomass can be used to generate electricity and produce liquids or gases, the contingent can be used in any supply system, so it is credited to all supply variants. And because biomass can be stored, it is perfect for use in the winter. The contingent is then prioritized as follows: heating, hot water in the winter, and household electricity. For instance, if a building has a condensation boiler (PER of renewable gas: 1.75), the first 20 kWh/(m²a) of PER demand is calculated with the PER factor of 1.10 for biomass. The PER factor of 1.75 for renewable synthetic gas is then applied for subsequent applications. If the PER demand for heating is lower than 20 kWh/(m²a), the rest of the contingent is applied to hot water supply, followed by household power demand. If biomass is used to cover this demand (in Pellet- or Log-boilers ore stoves), it is only available within this contingent. Furthermore, the PER factor of electricity is used if the demand is higher than the contingent.

Note that it is more efficient to generate electricity with biomass first and then use a heat pump for heat supply second. If some of the biomass is combusted in a household stove, around 80 percent of the primary energy can be converted into useful heat. If biomass is consumed in a cogeneration unit, around 50 percent of the energy is used to produce electricity and 30 percent to produce useful heat, with 20 percent losses. A heat pump allows three units of heat to be generated from a single unit of electricity. In this case, 50 percent electricity becomes 150 percent heat in addition to the 30 percent useful heat from the cogeneration unit. As a result, biomass produces 180 percent useful heat in combination with a heat pump instead of 80 percent useful heat from direct combustion. Nonetheless, Passive House buildings can continue to have biomass heating systems; the overall PER demand will simply be relatively high in such cases.



Photovoltaic electricity generation

The worksheet PV has been improved. Five different PV systems can now be calculated. It is now possible to choose the wall or roof, on which the arrays are to be mounted. Inclination and orientation is automatically recognised or can be chosen manually.

Photovoltaik - Anlagen

Passivhaus mit PHPP Version 9.2

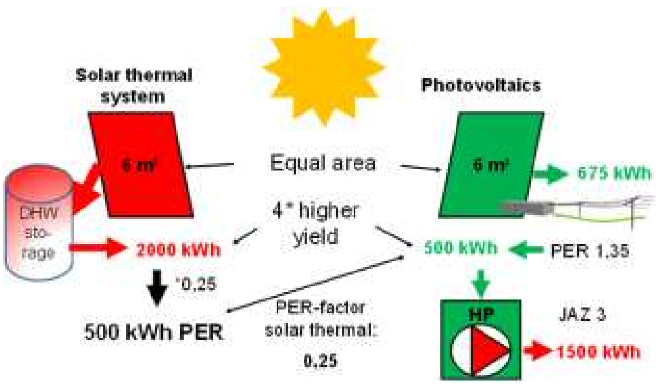
Passivhaus-Reihenendhaus / Klima: PHPP-Standard / EBF: 156 m² / Heizen: 12,5 kWh/(m²a) / Übertemperatur: 1 % / PER: 30 kWh/(m²a)

Klimadatensatz	DE-9999-PHPP-Standard
Objekttyp:	Reihenhaus
Überbaute Fläche	80,9 m²

Anlagenbezeichnung		Anlage 1	Anlage 2				PV-Referenzanlage		
Standort: Auswahl aus dem Blatt Flächen		4-Dach	1-Außenwand Süd				4-Dach		
Größe der ausgewählten Fläche		83,4	43,1				83,4		m²
Abweichung zur Nordrichtung		180	180				180		°
Neigung gegen die Horizontale		30	90				45		°
Alternative Eingabe: Abweichung zur Nordrichtung		180							°
Alternative Eingabe: Neigung gegen die Horizontale		30							°
Angaben aus dem Moduldatenblatt									
Technologie		4-Mono-Si	2-Amorph-Si				4-Mono-Si		
Nennstrom	I_{MPP0}	7,71	7,71				7,71		A
Nennspannung	U_{MPP0}	30,50	30,50				30,50		V
Nennleistung	P_n	235	235	0	0	0	235		W_p
Temperaturkoeffizient des Kurzschlussstroms	α	0,040	0,040				0,040		%/K
Temperaturkoeffizient der Leerlaufspannung	β	-0,340	-0,340				-0,340		%/K
Modulabmessssungen: Höhe		1,658	1,658				1,658		m
Modulabmessungen: Breite		0,994	0,994				0,994		m
							1,6		Modulfläche [m²]
Weitere Angaben									
Modulanzahl	n_M	40	10				3,3		
Höhe des Modulfelds		2,0	3,0				1		m
Höhe des Horizonts	h_{Hori}		5,0				0		m
Horizontentfernung	a_{Hori}		20,0				1000,0		m
zusätzlicher Abminderungsfaktor Verschattung	r_{so}	95%	90%						
Wirkungsgrad des Wechselrichters	η_{WR}	95%	95%				95%		
Ergebnisse									
Fläche des Modulfeldes		65,9	16,5	0,0	0,0	0,0	5,4		m²
Freie Fläche auf dem ausgewählten Bauteil		12,1	26,6				12,1		m²
Belegung des Bauteils		86%	38%				86%		
Jahresverluste durch Verschattung		424	305				0		kWh
								Summe	
Jahres-Stromertrag nach Wechselrichter Absolut		8056	1128				693	9184	kWh/a
Bezogen auf die überbaute Fläche		99,5	13,9				8,6	113	$kWh/m^2_{AGrund}*a$
Spezifischer PE-Faktor (nicht erneuerbare Primärenergie)		0,46	0,55				0,4		kWh_{prim_ne}/kWh_{End}
Spezifischer CO_2-Äquivalent-Emissionskennwert der Anlage		69,4	79,3				66,1		g/kWh
CO2-Äquivalent-Emissions nach 1-CO2-Faktoren GEMIS 4.6 (Deutschland		1079,5	117,3				92,9	1196,8	kg/a

Primary energy factor for solar thermal systems

Per square meter, a solar thermal array produces more energy than a photovoltaic array. In the location under review, for instance, a solar thermal array of six square meters produces 2000 kWh/a of heat for hot water supply. This figure already includes storage and stagnation losses.



Depending on the inverter, a photovoltaic array of the same size only produces 675 kWh/a. Line and storage losses would then also need to be deducted. The PER factor (1.35) takes account of these losses. The resulting amount of heat produced is
675 kWh/a / 1.35 = 500 kWh/a (which a heat pump can easily increase to 1500 kWh/a). The solar thermal array thus produces four times more energy, thereby making much better use of the area; in this respect, it is preferable. Therefore, the PER factor has been standardised

in PHPP for solar thermal arrays in terms of area efficiency based on a reference PV system of the same size, orientation, and shading for the level of this reference array.

$$f_{PER,solth} = \frac{\frac{Q_{PVref}}{PER_{DHW}}}{Q_{solth}} = \frac{\frac{675\ kWh/a}{1.35}}{2000\ kWh/a} = 0.25$$

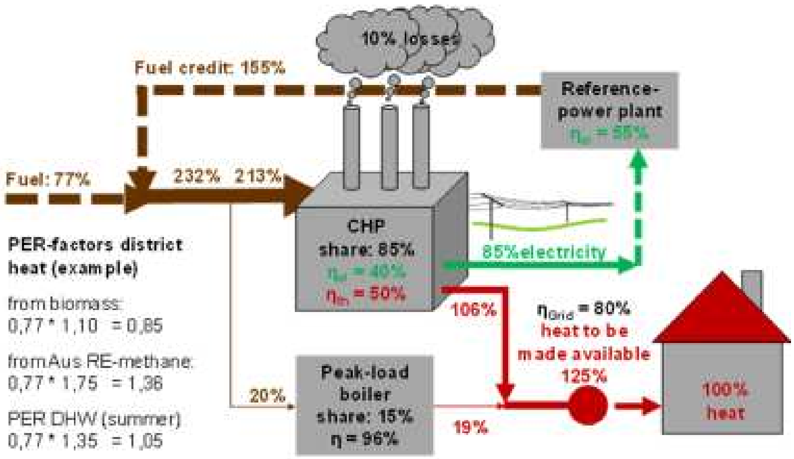
If a much larger solar array is used, such as one with 18 square meters of collector area, area efficiency drops considerably because more heat is produced in the summer than is needed. The output of the solar thermal array increases from 2000 kWh/a to 2600 kWh/a when the area is three times larger, while power from the PV array grows in linear fashion because storage in the PER system's grid is assumed to be of sufficient size to absorb the excess energy in the summer for the winter. The PER factor is used as follows for the calculation of storage losses:

$$f_{PER,solth} = \frac{\frac{Q_{PVref}}{PER_{DHW}}}{Q_{solth}} = \frac{\frac{2025\ kWh/a}{1.35}}{2600\ kWh/a} = 0.58$$

In this case, a PV array in combination with a heat pump can generate more heat than the solar thermal array can: 2025 kWh/a / 1.35 = 1500 kWh/a. At a COP of 3, we have 4500 kWh/a instead of 2600 kWh/a of heat. In terms of area efficiency, the best option is a small solar thermal system in combination with PV + heat pump (Ochs 2013). The larger the system, the better the calculation looks for photovoltaics.

District heat and cogeneration

Cogeneration is a crucial pillar of the PER system. In the winter, these systems generate electricity from green methane originally produced in the summer. During the power production process, the waste heat can be recovered for use in district heat networks. In PHPP, the efficiency of the district heat network has to be entered to determine the PER factor (see Figure 6). If it is 80 percent, then network losses amount to 20 percent, so 125 percent of heat demand needs to be input into the network. For instance, 85 percent of this amount can come from cogeneration, with the other 15 percent from a peak boiler. The boiler's efficiency of 96 percent leads to 20 percent fuel consumption. If the cogeneration unit has a thermal efficiency of 50 percent and an electrical efficiency of 40 percent, 85 percent electricity is produced in addition to heat. Fuel consumption is then 213 percent, resulting in 232 percent in this example for both cogeneration and the peak boiler.



In order to assign a defined share of the total fuel consumption to the two products heat and electricity, we first calculate the electricity share via a reference power plant. Then, the remaining fuel consumption is assigned to heat.

The PHPP assumes the reference power plant to be a combined-cycle gas turbine with an electrical efficiency of 55 percent. To generate the same amount of electricity (85 percent), fuel consumption would reach 155 percent in the reference power plant. This 155 percent is then credited to the cogeneration system, producing overall fuel consumption of
232 % - 155 % = 77 %.

When this figure is multiplied by the energy source’s PER factor, we get the PER factor for heat from the district network. Within the biomass budget: 1.1 * 0.77 = 0.85; beyond the budget: renewable methane: 1.75 * 0.77 = 1.36. Hot water in the summer: to simplify the calculation, the PER factor of electricity for hot water is used: 1.35 * 0.77 = 1.05.

7
CONCLUSION

Based on the findings from statistical data and local stakeholders, the following conclusions in terms of evaluation of the boundary conditions for energy balance calculations with PHPP can be drawn.

Local climatic data are of established relevance for the results and need to be taken into account (ref. D5.3.1 and integration of new climate data sets in the PHPP).

Passive House limit values are constant throughout most of Europe, adjustment of the requirements occurs only in climates with higher cooling demands. This issue has been dealt with in other previous and parallel research projects.

After consideration of accuracies and complexity, it was decided not to change other input values in dependence on other boundary conditions in the different countries or regions.

All in all, the latest findings have been incorporated into the PHPP 9.0 as in the case of PER factors in order to illustrate how the transition to renewable energy sources is possible and assessable in a transparent way. This will highlight the fact that energy efficiency and the application of renewable energies are not competing with each other but complement one another perfectly and will lead to sustainable solutions which can be explored in detail by the PHPP user.

8
SOURCES

National information

Researched from various national statistics by the PassREg partners.

Statistics and research

Eurostat
http://epp.eurostat.ec.europa.eu

Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe
http://remodece.isr.uc.pt/

Statistical data on households and occupancy rates
http://www.calcon.de/sites/default/files/BundesBauBlatt0412.pdf

Housing statistics in the European Union http://www.bmwfw.gv.at/Wirtschaftspolitik/Wohnungspolitik/Documents/housing_statistics_in_the_european_union_2010.pdf

Database of economic statistics of countries, markets and companies
http://www.statinfo.biz/Geomap.aspx

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[Krick 2012] Krick, Benjamin: Evaluation of the energy demand of Passive House buildings in the future. In Protocol Volume No. 46 of the Research Group for Cost-effective Passive Houses: Sustainable energy supply with Passive Houses) PHI Darmstadt 2012

[Ochs 2013] Ochs, Dermentzis, Feist: Energetic and Economic Optimization of the Renewable Energy Yield of Multi-Storey PHs. In Feist, Wolfgang (Hrsg.): Tagungsband zur 17. Internationalen Passivhaustagung (Conference Proceedings of the 17th International Passive House Conference) 2013 in Frankfurt/Main. PHI Darmstadt 2013

[Schnieders 2009] Schnieders, Jürgen: Passive Houses in South West Europe. A quantitative investigation of some passive and active space conditioning techniques for highly energy efficient dwellings in the South West European region. 2nd, corrected edition. Darmstadt, Passivhaus Institute, 2009