Bundesministerium
für Umwelt, Naturschutz,
Bau und Reaktorsicherheit

Plus Effizienzhaus

FORSCHUNGSINITIATIVE ZukunftBAU

What makes an Efficiency House Plus?

Foreword

Dr. Barbara Hendricks

One of the key elements of Germany's *Energiewende*, the transformation of the energy system, is establishing a new approach to energy in the construction sector and in the home. It will only be possible to achieve a virtually climate-neutral building stock by 2050 if we gradually bring new technologies to the market that provide the highest level of efficiency – both in terms of energy and cost. The Efficiency House Plus is a development that offers a valuable and innovative way of achieving this in the buildings sector.

The scheme demonstrates how buildings in the future can work as micro power plants that, calculated over the entire year, produce more energy than they use without compromising aesthetic appeal or quality of life. The idea is to use the surplus energy for electromobility or for the neighbourhood's energy needs. In 2011, the German government set up its own pilot project in Berlin – an Efficiency House Plus with electromobility, designed to test this new standard and at the same time explore possible synergy effects between the new generation of buildings and electric vehicles. The results are really quite impressive.

The aim of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety is not just to carry out one-off beacon projects but to work within a network of different solutions to try out and optimise different technologies. Overall, 35 buildings are currently part of the Efficiency House Plus network and of a scientific monitoring programme. Many were completed in 2013 and some will be ready for occupation over the course of 2014 and will then be incorporated into the monitoring scheme. The demonstration buildings selected do not have to use any specific kind of technology. This makes it possible to put different approaches to the test and ascertain how efficient and economical they are.

This brochure provides information about the new building standard and the latest results from the network.

In addition to the 35 new builds, there is also a modernisation project in Neu-Ulm, in which 1930s apartment blocks that have an energy demand of over 500 kWh/m²a are being converted into Plus Energy Houses.

I would like to invite you to get to know these new technologies and possibly use them yourself. We intend to give our full support to this innovation in the buildings sector.

Barbara Hendricks

Dr. Barbara Hendricks
Federal Minister for the Environment, Nature Conservation, Building and Nuclear Safety

Today's pioneers are tomorrow's market leaders

The history of humankind is a history of pioneers (which the dictionary defines as trailblazers or forerunners), without whom nothing new would have ever been invented or further developed in any area of life.

As a result of intensive research and development efforts in recent years on the part of the building and engineering industry, it has become possible to design new buildings in a way that they no longer need fossil energy; on the contrary, taken over a whole year, they are able to feed surplus energy into the public grid.

The Efficiency House Plus enables innovative partners in the construction industry to put their pioneering spirit into practice in actual buildings, which in turn enables them to demonstrate their market leadership. The Efficiency House Plus is the built response to the challenges facing our generation and future generations and that means it is highly sustainable.

Knowing is not enough;
we must apply.
Willing is not enough;
we must do.
Johann Wolfgang von Goethe

The Plus Energy Houses at TU Darmstadt (Prof. Hegger)

Solar Decathlon winner 2007

Solar Decathlon winner 2009

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The history of energy-saving buildings

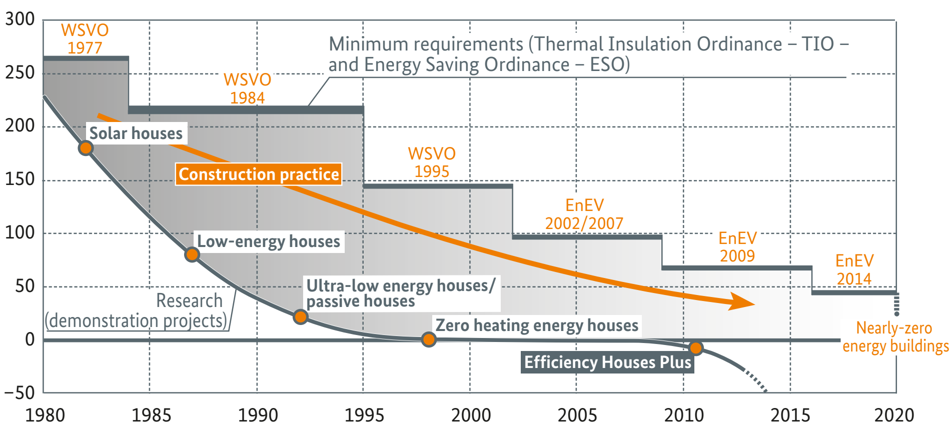
There is a long tradition of energy-saving buildings in Germany. Research into the building of the future that can be inhabited without having any impact on the climate has been ongoing for over 30 years. The low-energy building has been a statutory minimum requirement for new builds for over 15 years. Intensive research and development have meant that buildings have advanced to a point where they no longer just consume energy but also generate it. The Efficiency House Plus is able to produce more energy in a year than the building and its users consume.

In 2007, Technische Universität (TU) Darmstadt developed a Plus Energy House as part of its Zukunft Bau research initiative, to enable it to take part in the renowned Solar Decathlon competition in Washington DC (USA), which is open to scientific institutions and universities worldwide. The competition looks at the performance of the demonstration buildings in ten different areas but the most important goal is that they produce more energy than they consume when fully used. TU Darmstadt won this competition in 2007 and 2009. The German building ministry of the time - BMVBS – erected its own pavilion based on TU Darmstadt's 2007 building and used it for presentations and an exhibition about the scheme during a unique tour of Germany that went to six metropolitan regions between 2009 and 2011. The building's final location is the Phoenix-see development in Dortmund.

The Efficiency House Plus is not restricted to any particular technology, but can be achieved in a diverse range of ways by intelligently combining energy-efficient construction technologies and renewable energy generation systems. In other words, it is an approach that embraces all possible technologies.

The Plus Energy House presentation and exhibition pavilion, pictured here in Munich in 2009

Primary energy demand for a semi-detached house – heating [kWh/m²a]



The graph shows how the primary energy demand for semi-detached houses has developed over the last 30 years. The bottom curve shows exemplary research projects that were instigated to introduce a better energy level to the market, whereas the top curve records the statutory minimum requirements. Innovative construction practice is somewhere between these two curves. It can be seen that a market launch phase of 10 to 15 years between different standards being piloted and becoming a legal requirement is common.

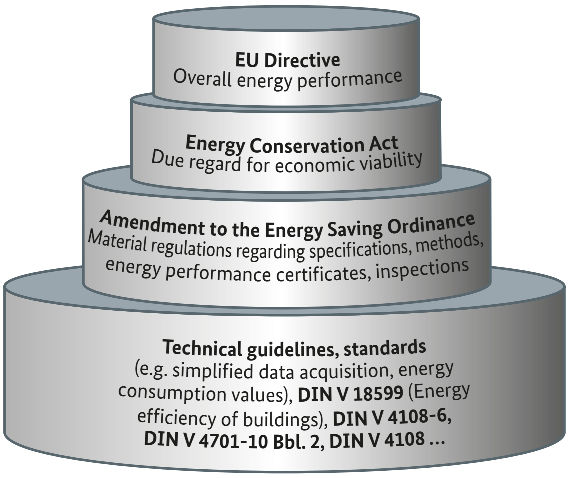
The legal framework

In Germany the provisions of the EU Directive on the Energy Performance of Buildings are implemented by the Energy Saving Ordinance (EnEV). It specifies maximum values for annual primary energy demand and specific transmission heat loss for new residential buildings that must be complied with. Calculation of annual primary energy demand is based on DIN V 18599. Alternatively DIN V 4108-6, in conjunction with DIN V 4701-10, can be used for the calculation.

Furthermore, new builds must also comply with the requirements of the Act on the Promotion of Renewable Energies in the Heat Sector (Renewable Energies Heat Act, EEWärmeG). This requires owners of new buildings to meet some of their heat demand from renewable energy sources.

As a result of their high energy standards, Efficiency House Plus buildings meet both these requirements. Nevertheless, they also have to provide evidence of their energy performance as required under the Energy Saving Ordinance and Renewable Energies Heat Act.

Legislation implementing the EU Buildings Directive in Germany



European legislation on energy-efficient buildings and its transposition into German law

Requirements of the Energy Saving Ordinance

A new residential building's maximum annual primary energy demand must not exceed that of a reference building that has the same geometrical configuration, aspect and use and meets certain specifications regarding its envelope and services.

Annual primary energy demand
This is the amount of energy needed to meet the annual heating energy demand Q_H and energy required to deliver hot water Q_{HW} (both the actual energy required and the energy used by the heating and hot water system itself). It also includes the additional amounts of energy used by upstream processes beyond the building itself to extract, convert and distribute the particular fuel used.

Requirements of the Renewable Energies Heat Act

100 % compliance with the Renewable Energies Heat Act based on		Minimum requirement
Renewable energy	Solar radiation	15 %
	Solid biomass	50 %
	Liquid biomass	50 %
	Gaseous biomass in CHP	30 %
	Geothermal and ambient heat	50 %
Acceptable alternatives	Waste heat recovery systems	50 %
	CHP units	50 %
	Energy saving measures	~15 %
	Local or district heating with renewable energy in the above-mentioned percentages or acceptable alternatives	

ENERGIEAUSWEIS [1] für Wohngebäude

zusätzliche Informationen gemäß § 17, Absatz 4 der Energieeinsparverordnung (EnEV)

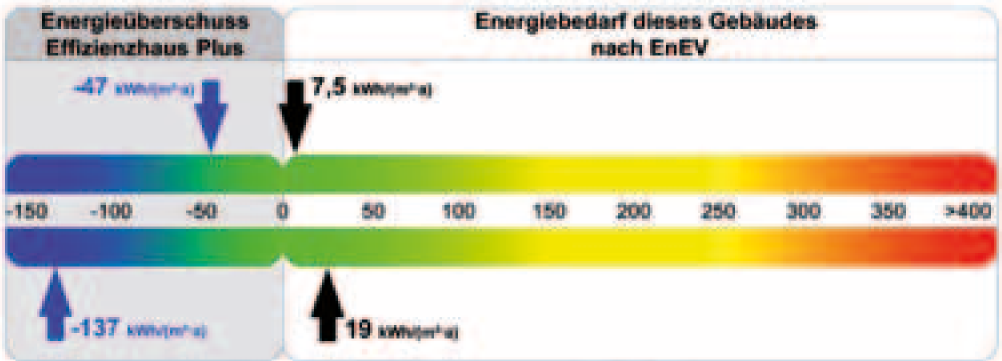
Berechneter Energiebedarf des Gebäudes

Adresse, Gebäudeteil
Fasanenstraße 87, 10623 Berlin

2

Energieüberschuss Effizienzhaus Plus und Energiebedarf nach EnEV

Endenergie:



Primärenergie:

Für Energiebedarfsrechnungen verwendetes Verfahren

Nach Effizienzhaus-Plus Bewertung (DIN V 18599)

Energieüberschuss

Endenergie -47,4 kWh/(m² a)

Primärenergie -137,4 kWh/(m² a)

Anforderungen gemäß EnEV [2]

Primärenergiebedarf

Ist-Wert 19,4 kWh/(m² a) Anforderungswert 86,9 kWh/(m² a)

Energetische Qualität der Gebäudehülle H'ₜ

Ist-Wert 0,33 W/(m² K) Anforderungswert 0,40 W/(m² K)

Endenergie in kWh/(m² · a)

Energieträger	Jährlicher Endenergiebedarf nach EnEV				Zusätzliche Elemente			Endenergie-überschuss (gesamt)
	Heizung	Warmwasser	Hilfsgeräte [3]	Gesamt	Beleuchtung	Haushaltsgeräte	Netzeinspeisung	
Strom	6,5	0,97	-	7,5	0,62	3,5	-59,0	-47,4

Vergleichswerte Endenergiebedarf

[4]

Erläuterungen zum Berechnungsverfahren

Die Berechnungen erfolgen mit einem erweiterten EnEV-Nachweis nach DIN V 18599, zuzüglich eines normierten Energiebedarfs für Beleuchtung und Haushaltsgeräte und abzüglich netzeingespeister, innerhalb der Bilanzgrenze erzeugter, regenerativer Energieüberschüsse (gemäß BMVBS-Broschüre „Wege zum Effizienzhaus Plus"). Insbesondere wegen standardisierter Randbedingungen erlauben die angegebenen Werte keine Rückschlüsse auf den tatsächlichen Energieverbrauch. Die ausgewiesenen Bedarfswerte sind spezifische Werte pro Quadratmeter Gebäudenutzflächen (A_N).

[1] Gemäß BMVBS-Broschüre „Wege zum Effizienzhaus Plus"
[3] ggf. einschließlich Kühlung
[2] Bei Neubau sowie bei Modernisierung im Falle des § 16 Abs. 1 Satz 2 EnEV
[4] EFH: Einfamilienhäuser, MFH: Mehrfamilienhäuser

Page of additional information supplementing the energy performance certificate for Efficiency Houses Plus as required under Section 17 of the Energy Saving Ordinance (can be generated using the calculation tool)

Definition: Efficiency House Plus

Efficiency House Plus:[1] definition

The Efficiency House Plus standard[2] is deemed to have been achieved if a building has both a negative annual primary energy demand ($\sum Q_p < 0$ kWh/m²a) and a negative annual final energy demand ($\sum Q_e < 0$ kWh/m²a). All other requirements of the Energy Saving Ordinance, such as those relating to insulation to improve summer performance, must also be complied with.

Evaluation method: extended Energy Saving Ordinance certificate as specified under DIN V 18599

The 2014 Energy Saving Ordinance (EnEV) requires that certification be provided as set out in DIN V 18599. It must be based on the "average location in Germany" as defined in the Energy Saving Ordinance. However, in addition to the requirements under this certification procedure, the final and primary energy demand for interior lighting and household appliances has to be included in the calculations. An overall final energy demand of 20 kWh/m²a (of which lighting: 3 kWh/m²a; household appliances: 10 kWh/m²a; cooking: 3 kWh/m²a; other: 4 kWh/m²a) is assumed, not exceeding a maximum of 2 500 kWh/a per housing unit.

Boundary for the purpose of the performance assessment: boundary of the property

The boundaries used in the performance assessment (also for the purposes of including renewable energy facilities) are the boundaries of the plot on which the house is to be built. As an extension to the area for assessment as defined in the Energy Saving Ordinance (as being directly connected to the building), the sum total of all the energy generated from renewable sources within the site boundaries (on-site generation) can be counted. The site boundary is the boundary of the property as entered in the land registry. If there are several buildings on a plot, the amount of renewable energy generated on site will be allocated proportionally to the individual buildings, based on the usable floor area of those buildings.

Supplementary requirement: use appliances with the best energy efficiency rating

Any building to be funded should be equipped throughout with smart meters and with appliances that have the highest possible energy efficiency rating (usually labelled A++ or better under the Energy Consumption Labelling Ordinance of 30 October 1997 [Federal Law Gazette I p. 2616], last amended by Section 1 of the Ordinance of 19 February 2004 [Federal Law Gazette I p. 311]).

Additional information required on the certificate: the percentage of the renewable energy generated that is used on site

In addition to the single values – annual primary energy demand and annual final energy demand – the ratio of renewable energy generated to energy used within the boundaries of the area covered by the performance certificate must be shown. The calculation must be done as set out in the Energy Saving Ordinance on the basis of monthly performance.

Calculation tool

The standardised calculations for an Efficiency House can be carried out using free online software (www.effizienzhaus-plus-rechner.de).

1 The Efficiency House Plus is also known in common parlance as the "Plus Energy House".

2 Notification by the former Federal Ministry of Transport, Building and Urban Development on award of grants for demonstration projects built to the Efficiency House Plus standard

The component parts: energy efficiency and renewable energy

By comparison with traditional building practices, the Efficiency House Plus is based on three key principles:

- increase the building's energy efficiency as much as possible
- lower the energy demand of the household processes as much as possible
- use renewable energy to meet the remaining energy requirement

Since this design concept requires all the energy needed in the building to be supplied from renewable sources in the building's immediate surroundings, it makes sense to reduce the amount of energy needed by improving energy efficiency as far as possible.

Energy demand is influenced by building design (compact building form, optimum orientation), thermal insulation (highly efficient windows and thermal insulation systems for the building envelope), optimised workmanship (no thermal bridges (with zero tolerance) and airtight structures and structural connections) and energy-conscious behaviour on the part of the occupants (energy use displays, smart metering). At the same time, occupant comfort is usually increased by the measures to reduce energy demand, since the warm surfaces produced generate a greater feeling of comfort in the rooms.

Energy efficiency can be further increased by low system temperatures (resulting in lower heat losses) in the heating system, short pipe runs for heating, hot water and ventilation systems (which in turn mean lower heat losses and lower amounts of energy needed to operate pumps and fans), by heat recovery systems in the ventilation and waste water systems, hydronic balancing in all systems (which means lower amounts of energy needed to operate pumps and fans), demand-controlled heating and ventilation systems (avoiding the oversupply of fresh air and heating energy to rooms), household appliances that have the highest energy efficiency rating (A++) and efficient room lighting (LEDs or low-energy bulbs in conjunction with demand-controlled systems).

Renewable energy can be actively and passively used in the building. On the one hand, passive solar gains through the windows can be used at no cost at all to reduce the need for heating energy and the need for artificial lighting can be reduced by making use of daylighting. Renewable energy can also be actively harnessed using thermal solar collectors, biogenic fuels, geothermal and ambient heat. What puts the "plus" into the buildings are electricity-generating systems such as photovoltaics or wind turbines, which store any surplus produced in the building and, if there is still a surplus, feed it into the grid of the energy suppliers.

Efficiency House Plus

Create an energy-efficient building		Use renewable energy
Design a compact building	Low system temperature	Solar gains through the windows
Optimum orientation	Short pipe runs	Use daylight
Thermal zoning	Hydronic balancing	Solar collectors
Thermal insulation	Efficient operating systems	Biogenic fuels
"Super windows"	Demand-controlled systems	Geothermal or ambient heat
Avoid thermal bridging	Efficient appliances	Heat recovery
Airtightness	Efficient lighting	Photovoltaics
Screens to depict behaviour visually	Heat recovery	Wind turbines

The key energy principles of an Efficiency House Plus

Key parameter: building design

The factors that make for an energy and land-saving, ecological and economical building are set early on in the design stage. In terms of building design, the following three aspects deserve special attention:

Compactness

Given a comparable standard of insulation, detached houses have a significantly higher need for heating energy per square metre of living area than semi-detached and terraced houses, or apartment blocks. This is due to the higher surface area to volume (A/V) ratio. This ratio indicates the size of the envelope of the heated part of a building through which heat exchange occurs in proportion to the volume it encloses. Roof shapes should be kept simple to permit compactness. Dormer and bay windows should be avoided where possible since they increase surface area and usually have poorer thermal insulation.

Orientation

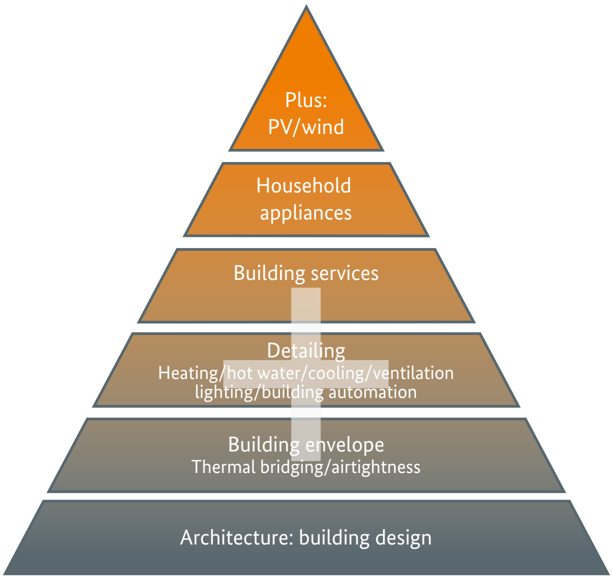
Optimal use of solar energy through windows relies on as many surfaces as possible facing south. South-facing roofs with an incline of about 30° enable optimum efficiency all year round for solar water heating collectors or photovoltaics. Even north-facing roofs can be used for photovoltaic systems if they have a shallow pitch.

Zoning of the building

Rooms that are not heated as much, such as parents' bedrooms or the kitchen, should be north-facing. A lower temperature can be set in rooms with direct sunshine than in shaded rooms. The layout should be organised in such a way to minimise the surface area of partition walls between the heated and unheated zones. Internal heat losses within a building can have a significant impact on the heat losses of the entire building. Open-plan designs over several storeys may pose a problem in terms of energy consumption.

Design factors that influence energy performance:

- compactness
- orientation
- zoning of the building
- thermal insulation measures
- ventilation design
- heating design



The design pyramid for the Efficiency House Plus

Focus on building services

The layout of the building should be such that the boiler room/plant room is in the centre of the building wherever possible so that heat losses from the heat generator and storage tank can be directly used in the heated zone and to ensure that pipe runs between solar collectors and the storage tank and for exhaust gases are as short as possible. The service shafts should also be in a central position in the heated area of the house, to keep distribution pipe runs short and heat losses low.

TIP:

A more compact building pays off twice over: a reduction in surface area to volume (A/V) ratio of 0.1 m^{-1} usually lowers heat-energy demand by up to 10 kWh/m^2a and at the same time lowers construction costs by € 50 to € 80/m^2. The use of bay and dormer windows in particular should be reconsidered.

Key parameter: building envelope

The quality of a building's thermal insulation is the main factor determining its need for heating energy. Between 50 and 75 % of heat lost from an average building is a result of transmission heat losses through the building envelope. Insulating external building components thus has huge energy saving potential and has proven to be the most reliable way of reducing the need for heating energy. Without high-quality thermal insulation it is not possible to achieve an Efficiency House Plus.

External walls

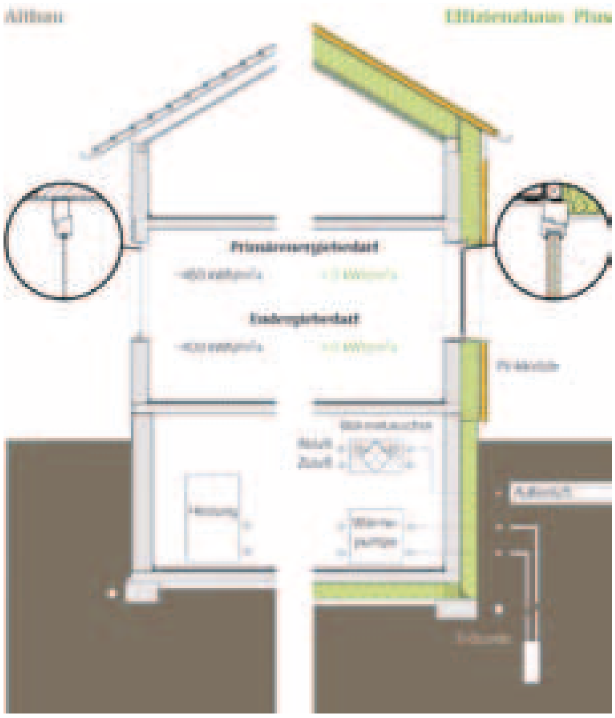
Over the decades many different ways of building external walls have developed and proved their merit. In the last 50 years, external walls of the same thickness have improved their thermal insulation quality by a factor of 10. Both innovative monolithic external walls and multi-layer building components can be used in Efficiency Houses Plus.

Windows

As a rule, it is windows that have the lowest insulation value of all external building components. However, windows can also permit significant solar gains to be achieved, so that with appropriate siting and orientation the passive solar gains from windows can completely compensate for heat losses. Modern triple glazed windows usually have U values of 0.9 W/m²K or less.

Basement ceilings/floor slabs

The average difference over a year between the temperature above a floor slab and the ground beneath it is only about half as much as the temperature difference when building components have contact with outdoor air. This means that heat insulation measures in these areas of a building are not as effective.



Schematic depiction of the structure and heating system of an Efficiency House Plus and an indication of its energy demand as compared with a 50-year-old building

TIP:
Investments in the building envelope have a long-term impact. It is therefore important that they are of a particularly high quality.

It’s all in the detail

Prevent thermal bridging

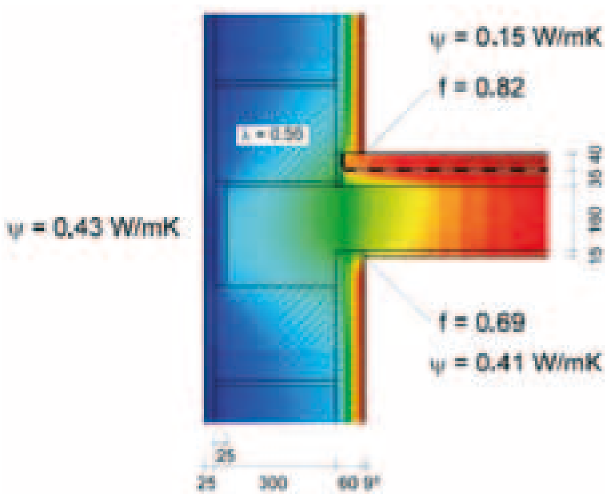
The additional energy losses from thermal bridges can be calculated as heat loss per unit length of thermal bridge [W/mK]. The influence of thermal bridges on heating energy demand is easy to calculate once the linear thermal bridge loss coefficient has been determined. Additional heat losses through thermal bridges are between 0 % in a best-case design and 25 % in a minimum-case scenario. For a detached house with 150 m^2 of heated living space this produces an additional demand for heating energy of up to 1 500 kWh/a, depending on the standard of the building. A stringent inspection of the workmanship is therefore crucial, since well-designed connection details that have been unsatisfactorily carried out can often cause weak points in terms of energy.

Connection	Coefficient for heat loss per unit length of thermal bridge ψ [W/mK]	
	Minimum	Maximum
Corner of external walls	-0.30	-0.07
Window/reveal	0.06	0.12
Window/wall beneath	0.13	0.20
Window/lintel	0.06	0.25
Floors/supports	0.00	0.15
Basement floor/supports	-0.14	0.20
Roof/eaves	-0.20	0.11
Roof/verge	-0.03	0.10

The range of heat loss per unit length of thermal bridge in common structural connections. There is significant potential for savings between a design that minimises thermal bridging and a standard design (maximum), which must be exploited when planning an Efficiency House Plus.

Make the building airtight

In addition to the air change rate at that can normally be ensured by opening windows or using mechanical ventilation systems, additional uncontrolled infiltration air change occurs at connections between building components, points where the building’s envelope is not airtight etc. They are normally between 0.1 h^{-1} in the case of very airtight buildings and over 0.3 h^{-1} in buildings that are less airtight. In terms of potential, this degree of tolerance is comparable with the influence of thermal bridges (about 10 kWh/m^2a). To achieve an airtight building envelope it is crucial to prepare an airtightness plan – if possible as early as the scheme design phase, but during the detailed design stage at the latest. The airtight envelope must enclose all surfaces of the volume to be heated and in the case of multi-storey apartment buildings should if possible enclose each separate living unit to rule out leakage through stair wells, service shafts etc. Particular care needs to be taken with converted loft spaces that have purlin and trussed rafter roofs since their structure means there are many points at which the shell of the building is pierced. During construction of a building, care must be taken to ensure that after the airtight skin has been completed no leaks are caused by subsequent work.



A detailed calculation can determine the influence of a thermal bridge on the temperature and heat flow in a structure.

TIP:
Airtightness and minimising thermal bridges have comparable energy saving potential, which can also be achieved through ventilation systems and solar energy systems (> 10 kWh/m^2a).

Key parameter: building services engineering

A range of different technologies, including for the building services engineering, can be used to achieve an Efficiency Houses Plus. The most important thing is that the systems used (to provide space heating and possibly cooling, hot water, fresh air and light) use as little energy as possible.

Heating

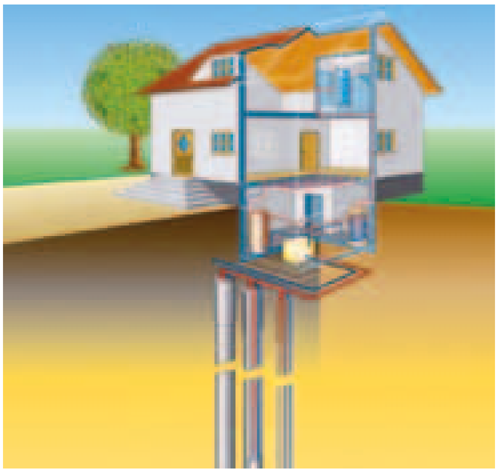
Heat losses in the heating system itself can easily be as great as the space heating demand it is meant to be covering. It is therefore important to design the heating system very carefully to keep the energy demand as low as possible. Temperatures in the distribution system should be as low as possible (< 35 °C). A common way of using ambient heat for heating purposes involves heat pumps to extract the thermal energy contained in the ground, ground water or ambient air. Thermal solar systems are sometimes used as supplementary heating, in conjunction with seasonal storage systems, to provide base load heating. Another way of incorporating renewable energy is to use biogenic fuels (biomass, bio-oil or biogas). Here particular attention should be paid to minimising the energy needed to operate the system.

Hot water

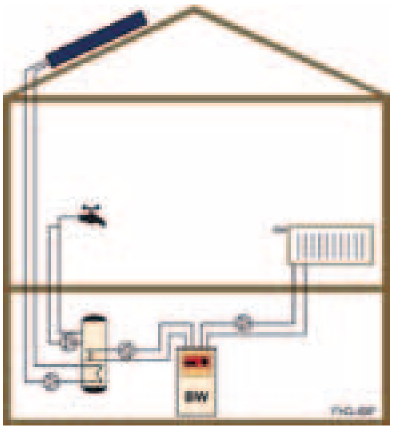
The energy demand for hot water is roughly the same as that for space heating. Circulation pipes can easily cause the energy demand to more than double. It is therefore advisable to site the water heater/tank close to the taps to avoid the need for circulation pipes or to fit a timer to the circulation system. Solar water heating is now well developed, works reliably and can save up to two thirds of the energy demand for hot water.

Cooling

A good design (appropriate to the climate) – in conjunction with shading – eliminates the need for mechanical cooling systems in residential buildings in Germany. Appropriate passive measures (e.g. nighttime ventilation, thermally activated building systems or the use of phase-change materials in attic spaces) can make summer temperatures in buildings more comfortable.



Heating system using a heat pump and geothermal probe to make use of ambient heat



Heating system with solar water heating

TIP:
Ensure that a hydraulic balance has been carried out on your heating system (savings potential > 10 % possible).

Ventilation

Controlled domestic ventilation systems with heat recovery can significantly reduce ventilation heat losses. Heat recovery rates of 80 % are not at all uncommon for today's modern systems. However, higher recovery rates usually increase electricity consumption by the fans. Mechanical ventilation systems must therefore be designed very precisely, otherwise the energy consumption of the fans, e.g. if piping is very complicated and has an unsuitable cross-section, can exceed any energy gains.

LED lighting in a living area

Follow the lead of the professionals when it comes to lighting and you will enjoy the benefit of a well-lit desk in your home.

Lighting

Compact fluorescent lamps with integrated ballasts and LED lamps are more efficient than incandescent or halogen lamps. Whereas incandescent lamps convert only 5 % of the electricity used to light and over 95 % into heat, the light yield from compact fluorescent lamps and LED lamps is four to five times higher. Bright coloured interior surfaces also result in better ambient lighting and thus in lower energy demand than dark surfaces. The design of interior surfaces can have a relatively strong influence on the energy consumption of lighting, as can the choice of luminaire. Task lighting (in kitchens or studies, for example) can also have a significant effect. This involves using powerful light only for a specific part of the room (e.g. a reading lamp) and keeping the lighting level lower in the rest of the space. It is also a good idea to consider using lighting management systems (e.g. presence detection) in hallways, basements and for outdoor lighting.

Building automation/smart metering

Smart meters can provide better information for users and give them a clearer overview of costs, which in turn raises their awareness of their household electricity consumption. They should be standard fittings in an Efficiency House Plus. Building automation systems are also beginning to establish themselves on the market. They connect household appliances in a wireless network to a central control unit and can also be used for smart heating control. However, the focus is on convenience rather than energy saving. It is imperative to check the power rating and energy demand of building automation systems and their add-on components. A power rating of more than 50 W should be avoided since their energy use will cancel out any savings!

TIP:
Check the power rating of your ventilation system. It should if possible be less than 50 W per housing unit. Every additional watt of power uses 10 kWh of electrical energy a year.

Key parameter: household appliances

The average amount of electricity used by Germany's 40 million households for household processes and lighting (not counting space and water heating) is currently 2 650 kWh per year (30 kWh/m²a), and the trend is rising slightly.[3] Of this total, 33 % is accounted for by household processes (cooking, drying laundry, ironing), 10 % by lighting and the remaining 57 % by household appliances and consumer electronics. About 13 % of households' electricity consumption is accounted for by stand-by losses, especially from consumer electronics and computer equipment.

Labelling is mandatory for the following household appliances:

- refrigerators and freezers
- washing machines
- tumble dryers
- washer dryers
- dishwashers
- electric ovens

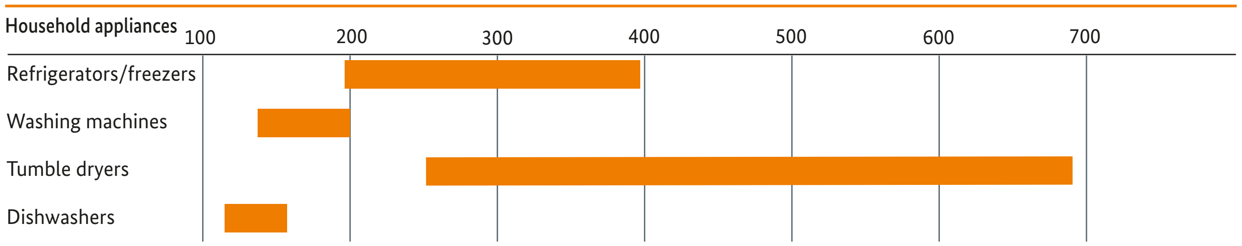
Household appliances

In addition to good performance characteristics, low energy and water consumption are important criteria when choosing an electrical appliance. Since 1996, the EU energy label (energy efficiency label) has given precise information about this. Providing this information to consumers is a statutory requirement and is regulated in Germany by the Energy Consumption Labelling Act (EnVKV). Tumble dryers have the highest level of consumption and also the greatest potential for savings, followed by refrigerators and freezers.

Stand-by consumption

This is the electricity used when an appliance is in stand-by mode. In other words, it is electricity that is consumed even when the appliance is not being used. With stand-by consumption it is important to remember the old adage that "every little counts." Each individual appliance makes hardly any difference but all appliances together definitely do. Consistently ensuring that appliances are not left in stand-by mode can save households up to 350 kWh of electricity a year.

Annual electricity consumption (kWh/a)



The range in electricity consumption of selected household appliances: top runners of 2010 compared with standard appliances in 2000

3 Federal Statistical Office, Germany; press release of 18 October 2010

TIP:
Households that are equipped with highly efficient household appliances (top runners) and lighting systems use roughly 50 % the amount of electricity needed by comparable households with standard appliances.

What gives the Efficiency House its “Plus”?

Building an Efficiency House Plus involves integrating renewable energy generation systems. They usually take the form of photovoltaics or domestic wind turbines. Alternatively, surplus heat gains from waste heat or thermal solar systems that are fed into local or district heating systems can be included as “energy credits.” Depending on what fuel they use, fuel cells and small-scale or micro CHP units may be eligible for a credit for primary energy, but in terms of delivered energy they cannot count towards a net energy gain.

Photovoltaics

The efficiency achieved with the solar cells commonly used in today’s photovoltaic systems ranges between a few percent and 25 percent. Thin-film modules based on amorphous silicon currently achieve between 5 and 13 % efficiency, polycrystalline silicon solar cells between 13 and 18 %, and cells made of monocrystalline silicon between 14 and 24 %. Crucial when ascertaining performance are the modules’ ventilation and packing density. Packing density is the ratio between the area covered by the photovoltaic cells and the overall area of the material the cells are embedded in (excluding the edging). Common products have a packing density of 0.9. The system performance factor describes the ratio between a system’s actual yield and target yield. It indicates how much of the theoretically possible electricity yield is actually available for use, including losses caused by conversion in the inverter, the length of the electricity cables, shading and possibly other factors. The system performance factor of a photovoltaic system should generally speaking be at least 70 %. Optimised systems achieve performance factors of up to 90 %. State-of-the-art systems installed in Germany deliver an annual yield of between 700 and 1 100 kWh per kW_p.

Wind turbines

In urban settings it rarely makes sense to site a wind turbine close to a building. Domestic wind turbines primarily serve to meet a user’s own electricity needs and they are economically effective only if they do that! Planning permission is usually only granted on provision of evidence that the applicants use at least 50 % of the annual yield themselves.

Domestic wind turbines can be used in windy areas to meet a user’s own needs.

TIP:
Obtain a guarantee of your photovoltaic system’s system performance factor from the installer. It is common practice to provide this to investors and banks.

Energy is not the only plus: a few facts …

A whole range of components and systems carry out the diverse functions a house has to perform and on the whole each of them is evaluated, labelled and optimised separately. This often produces solutions that are ideal in only some respects and lead to contradictory claims.

Furthermore, architecture has the greatest impact on the long-term activities of a society, since it is the buildings sector that has the highest energy consumption and largest mass flows. The products used (building materials and components and also the buildings themselves) also have an extremely long lifetime and therefore influence the environment and society for a long time. Consequently, it is essential to take an integrated view and make an evaluation that looks at all aspects. This is what a sustainability assessment does.

"Sustainability is the idea of a lasting development of the economic, environmental and social dimensions of human existence that does not jeopardise its future. These three pillars of sustainability interact with one another and in the long term need to be coordinated and balanced." This is the most common definition of sustainability, which was coined by the German Bundestag's Study Commission on the Protection of Mankind and the Environment. Sustainability thus embraces all aspects of our behaviour.

The remit of Efficiency Houses Plus is not primarily to act as "mini power stations" and generate energy. Like all buildings they should:

a) protect their users from

- intruders, both people and animals (need for safety);
- fire from their surroundings or from within their own boundaries;
- moisture in the form of precipitation, condensation and mould, frost, or swelling and shrinkage;
- cold when outdoor temperatures are low;
- heat during mid-summer conditions or high interior heat loads;
- noise from outdoors, including from neighbouring residential or commercial properties belonging to the occupants or someone else;
- electric fields and radioactivity;
- glare from direct or reflected sunlight.

b) provide a defined level of comfort with regard to

- light – with as much daylighting as possible and any artificial light that is used being extremely energy efficient;
- heating – to ensure comfort when outdoor temperatures are low;
- cooling – to avoid overheating;
- humidity – particularly to meet specific use requirements;
- fresh air – natural or from air conditioning;
- room acoustics – to ensure adequate speech intelligibility and enable occupants to listen to music at the desired level of auditory sensation.

c) enable the elimination of

- pollutants from the building materials and from using the building;
- moisture occurring during the construction and use of the building.

… on the sustainability of an Efficiency House Plus

To ensure that the Assessment System for Sustainable Building (BNB) also enjoys wide acceptance in the housing sector, the method it uses needs to be radically simplified. To do this, the resources to be protected and protection targets to be assessed are divided into sustainability's three principal dimensions: social, economic and environmental. To create incentives for building owners to ensure a smooth running construction process, the quality of the construction process is also reviewed in an additional cross-cutting category. Limiting the assessment method to three main categories and a cross-cutting category makes it easier to understand and use. By contrast with the Assessment System for Sustainable Building (BNB) for office buildings (diagram below) and the seal of quality for sustainable housing (NaWoh), an evaluation of technical quality and location quality is not included.

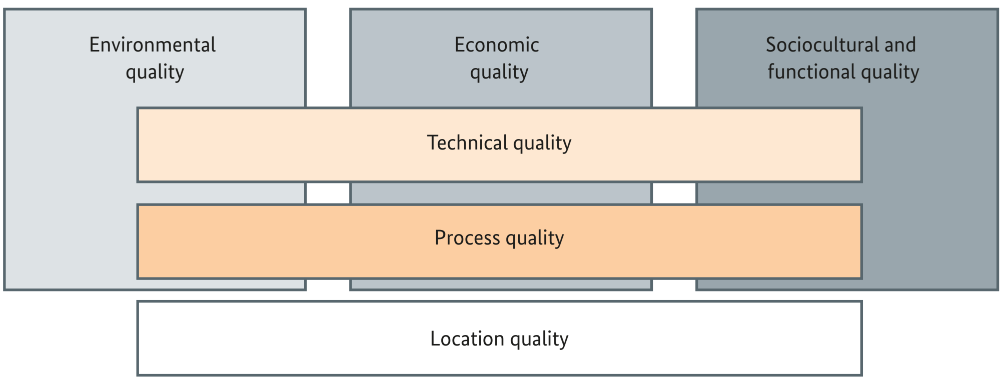
For residential buildings, the Assessment System for Sustainable Building looks at the following aspects:

Socio-cultural and functional quality
- provision of a healthy living environment
- thermal comfort
- visual comfort
- sound proofing
- comfort and user information with regard to the building services
- safety
- accessibility

Economic quality
- life cycle costs
- value retention

Environmental quality
- environmental impact
- energy
- raw materials used and volume of waste
- biodiversity
- potable water consumption
- land use

Process quality
- project preparation
- property documentation
- quality of workmanship



Structure of the German system for certifying sustainability under BNB

Typical values for a model house

Below we have taken the example of an average detached house to illustrate the wide range of options for building an Efficiency House Plus. In terms of size, the building represents the average for all detached houses built in Germany since 1990. The building form and the room layout are simply examples; in practice there is great diversity.

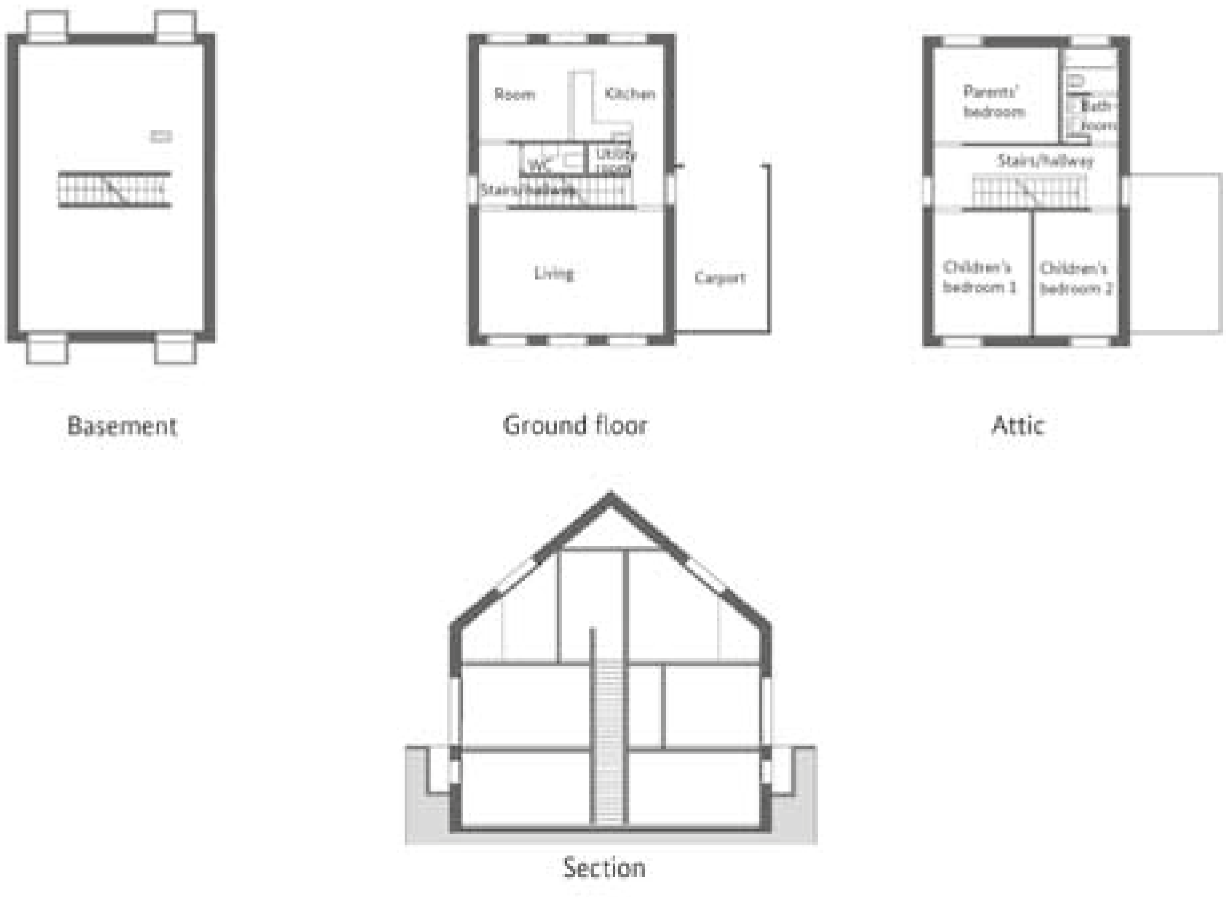
Typical values

Living space: 108 m^2
South-facing roof area: 71 m^2

U-values

- external wall: 0.11 W/m^2K
- roof: 0.11 W/m^2K
- top floor ceiling: 0.11 W/m^2K
- basement ceiling: 0.12 W/m^2K
- windows: 0.80 W/m^2K
- roof lights: 1.20 W/m^2K

Building type: detached house[4]



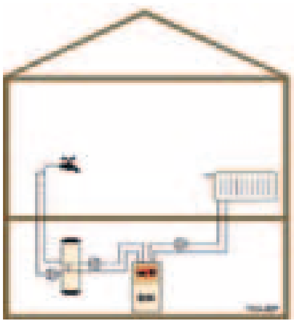
4 The floor plans are by Luis Ocanto-Arciniegas, Ourstudio, Dortmund.

Options reviewed

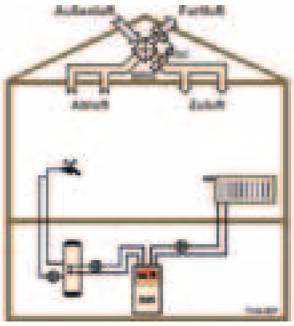
The model building studied was equipped with four different system designs. The table below shows calculations that were done to ascertain how large the photovoltaic area needs to be to make this building into an Efficiency House Plus.

Whereas the building conventionally equipped solely with a condensing boiler needs a photovoltaic area of 91 m^2 (which is larger than the available roof area), the same building with an efficient domestic ventilation system needs only a 79 m^2 photovoltaic area (for which there is almost enough space on the south-facing roof). Options 2 (condensing boiler, ventilation system and solar water heating) and 3 (air source heat pump and ventilation system) need only 60 and 42 m^2 photovoltaic area respectively, for which there is sufficient available space on the southern roof slope.

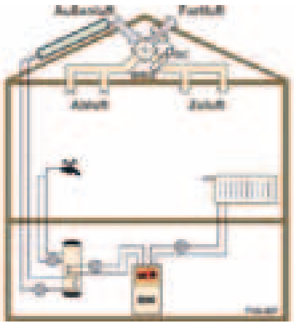
The comparative calculations illustrate that a very energy-efficient building is required, in conjunction with photovoltaic systems, to achieve an Efficiency House Plus. Neither installing a photovoltaic system alone nor an energy-efficient building alone are sufficient to achieve this goal. It is only the combination of all the different measures that produces the desired Efficiency House Plus.



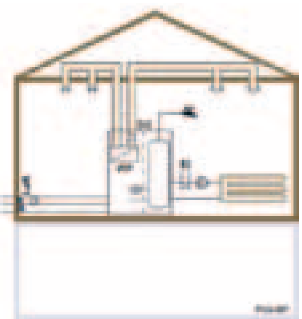
Option 0:
condensing boiler,
window ventilation



Option 1:
condensing boiler, ventilation system with an 80 % heat recovery rate



Option 2:
condensing boiler, ventilation system with an 80 % heat recovery rate, solar water heating



Option 3:
air source/exhaust air heat pump, ventilation system with an 80 % heat recovery rate

	Not including photovoltaics (PV)						**Including photovoltaics (PV)**	
	Delivered energy demand [kWh/m^2a]							
Option	Heating and hot water	Auxiliary energy	Household and lighting	Total	Primary energy demand (not including PV) [kWh/m^2a]	Photovoltaic area needed [m^2]	Final energy demand [kWh/m^2a]	Primary energy demand [kWh/m^2a]
0 Condensing boiler, window ventilation	**65.2**	**3.4**	**20.0**	**85.6**	**134.6**	**91**	**−0.1**	**−100.0**
1 as 0 plus ventilation with 80 % heat recovery rate	**48.6**	**5.7**	**20.0**	**74.3**	**122.6**	**79**	**−0.2**	**−79.4**
2 as 1 plus solar water heating	**30.2**	**6.0**	**20.0**	**56.2**	**103.2**	**60**	**−0.4**	**−48.7**
3 as 1 plus air source/ exhaust air heat pump	**12.5**	**6.9**	**20.0**	**39.4**	**104.6**	**42**	**−2.1**	**−1.6**

Efficiency House Plus: a government research initiative

In 2011, what was then the Federal Ministry of Transport, Building and Urban Development (BMVBS) had a pilot building constructed in Berlin and at the same time launched a research funding programme for demonstration houses that meet the specifications of the Efficiency House Plus standard. The programme is initially supporting 35 building owners in constructing residential buildings that produce significantly more energy than is needed to run them. A scientific programme concurrently evaluates the pilot projects with the aim of using the findings to improve energy management in modern buildings and further develop the components for energy-efficient building envelopes and renewable energy generation.

The buildings are tested and evaluated under real-life conditions, i. e. with occupants. Since early 2014, two thirds of the houses have been completed and occupied; the rest of the project will "go live" over the course of the year. Eleven projects have already completed a one-year monitoring period.

Further information (in German) on the Efficiency House Plus network can be found online under the Zukunft Bau research initiative section at www.forschungsinitiative.de. The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) will continue to run the research programme through to its conclusion.

Location of the demonstration buildings in the federal government's Efficiency House Plus funding programme

The federal government's pilot project

The objective is that from 2019 onwards it should be possible for all new builds throughout Europe to be virtually climate-neutral. This ambitious goal is one of the areas the Zukunft Bau research initiative, run by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, is working on. As well as developing strategies for climate-neutral buildings, it also creates opportunities for combining highly energy-efficient buildings with cutting-edge electromobility technology.

The Efficiency House Plus with electromobility is an example of how this idea can translate into reality. The project involves more than just building a detached house. It also acts as a micro power station, a resource store, a research project, a dialogue platform and, last but not least, a contribution to modern architectural culture.

From February 2012, the house was occupied by a test family of four who would live there for 15 months. After that the Efficiency House Plus was open to the public as part of a programme of guided tours, presentations and exhibitions. In May 2014, a new test family moved in and will live in the house for another 12 months.

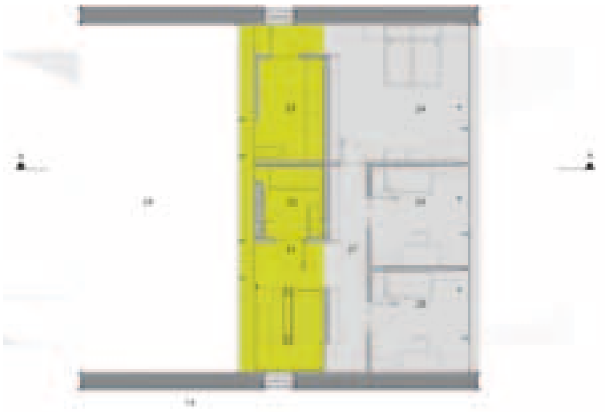
The detached house comprises 130 m² of living space over two floors and is designed for a family of four. The "glass showcase" in front of the house is designed for parking vehicles and to house the charging infrastructure needed for the electromobility aspect. The fleet of vehicles includes two electric Smart cars and two electric bikes. Between the two-storey house and the "showcase" is what is known as the building's "energy core," which houses all the building services and the wet rooms.

However, in addition to the energy aspects, the project is also meant to provide a response to sustainability issues. One of the aims, for example, was that the house should achieve complete recyclability. It is also designed to allow flexible use and provide a high level of comfort for its occupants. In the event that the house is dismantled in 2015, all the components are reusable and will go back into the economic cycle.

The building's transmission heat losses are reduced to a minimum by the low U-values of its envelope and the fact that it has been built in a way that reduces thermal bridging. The floor, external loadbearing walls and ceiling and roof have all been constructed using a timber panel construction system. The ground floor structure is 54 cm in depth. Between the moisture-resistant ground-level chipboard and the wooden flooring in the house is a void with structural timber I-beams into which a 40 cm thick layer of cellulose insulation has been injected. The underfloor heating is installed above the insulation.

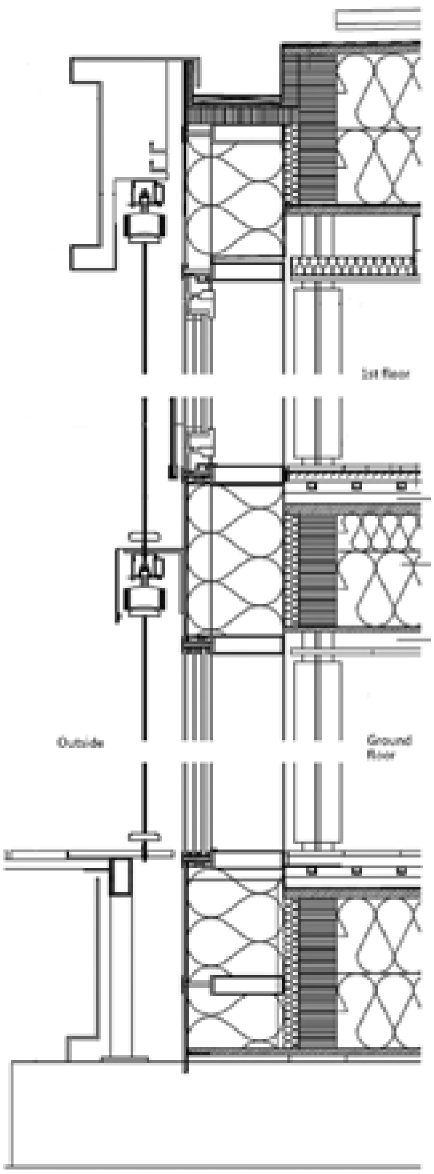
The garden view of the pilot demonstration building in Berlin

Ground floor plan of the demonstration house



1st floor plan demonstration house

Legend for the floor plans:
1 Ramp, 2 Showcase, 3 Entrance area, 4 Cloakroom, 5 WC, 6 Building services, 7 Kitchen, 8 Dining room, 9 Living room, 10 Terrace, 11 Information display and screen, 12 Conductive charging system, 13 Inductive charging system, 21 Stairs/hallway, 22 Bathroom/WC, 23 Utility room, 24 Parents' bedroom, 25 Children's bedroom 1, 26 Children's bedroom 2, 27 Hallway, 28 Double-height showcase



Section through the glass facade showing the detailing

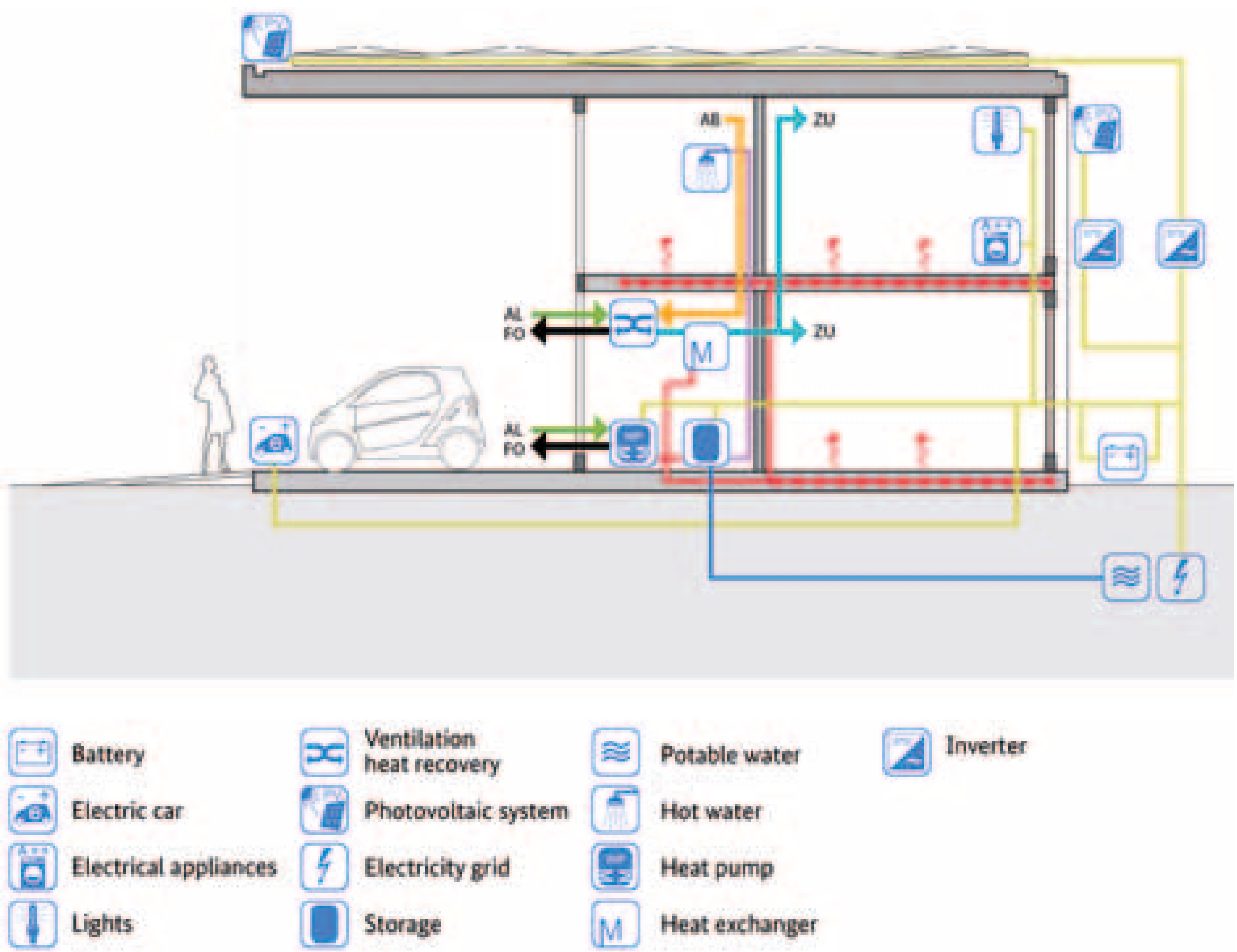
The outside walls are roughly 56 cm thick. Their special feature is the thin-film photovoltaic modules that have been mounted onto the south facade. There is a 36-cm layer of cellulose insulation in the spaces between the I-studs in the wall. There is then a 6-cm wide service void including an insulating layer of hemp mats, which not only provides additional thermal insulation but also improves the room acoustics.

The thickness of the cellulose insulation in the roof varies between 40 and 52 cm. There is then a 16-cm deep service void created by a suspended ceiling with 5 cm of hemp insulation. This gives the roof an overall depth of 74 cm.

All the components of the building envelope cited have a U-value of 0.11 W/m²K. The glass facades on the east and west sides of the building have insulated triple glazing with a U_W-value of 0.7 W/m²K. The eastern side of the building is fitted with external sun shading made of aluminium louvres, which can be controlled either automatically or manually.

An important concern was to integrate the energy-generating systems into the architectural design. The designers' simulation system calculated that the roof (98 m² of monocrystalline photovoltaic modules with 15 % efficiency) and the facade (73 m² of thin-film modules with 12 % efficiency) were likely to jointly produce an electricity yield of 16 MWh per year. It was predicted that the house would use about 10 MWh of that and the vehicles 6 MWh. The house has a central heating system that uses an air/water heat pump. The heat is transmitted to the rooms through underfloor heating. A mechanical ventilation system provides a fresh air supply to the rooms. Manual ventilation is also possible in all inhabited areas. The heat in the exhaust air is recovered and the remaining exhaust air is then discharged through the void between the ground and the suspended floor.

A building automation system that centrally processes all the measured data and transfers it to a programmable system facilitates targeted energy management. Users can communicate with the system using touchpads or smartphones. An element of the overall concept that should be particularly highlighted is a battery bank that enables the house to use the electricity it produces. It has a storage capacity of 40 kWh and is made of used battery cells that were formerly in service in electric cars. This sustainable re-use is possible because batteries in electric cars have to be replaced as soon as their storage capacity drops to 80 %, which is perfectly adequate for a "second life" in a stationary application. The prototype in the BMUB house consists of 7 250 individual used battery cells.



The building services scheme for the pilot project

The first years of operation of the Efficiency House Plus in Berlin

Data from the building, as lived in, has been recorded and evaluated in terms of energy use for two years as part of a monitoring programme conducted by the Fraunhofer Institute for Building Physics (IBP). An interim report describes the initial findings at the end of a 12-month period (March 2012 to February 2013) of monitoring the house as lived in. The measurements show that, despite unfavourable meteorological conditions, the photovoltaic systems produced more energy than was needed by the building services and the users during the monitoring period. The surplus energy met 25 % of the energy demand of the electric vehicles.

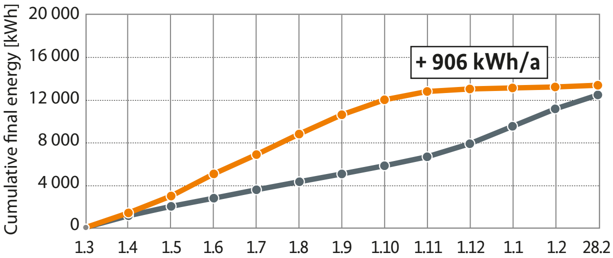
In the first year of monitoring, the photovoltaic system generated 13 306 kWh, of which 6 555 kWh were used in the house itself and 6 751 kWh were fed into the public grid. 5 800 kWh of electricity were taken from the public grid during the same period. That compares with the building's energy consumption of 12 400 kWh. The figure does not include electromobility nor project-specific energy consumption, which are accounted for by the site and the research project's public outreach budget. Thus, the photovoltaic system achieved a surplus of 906 kWh, but that was not enough to completely cancel out the energy expended for electromobility. Ongoing measurements reaffirm the results from the first year of monitoring.

In the second year of monitoring there was a 2 011 kWh surplus. It should, however, be noted that the house was mainly unoccupied in 2013 and was used for exhibitions and conferences.

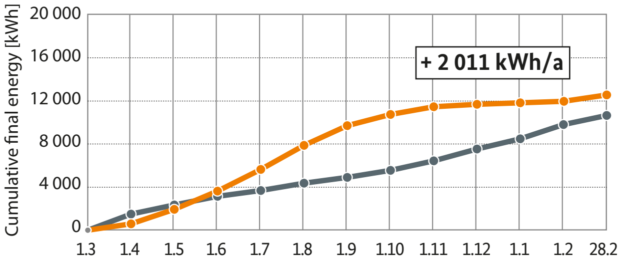
47 % of the building's energy was used for space and water heating. 4 % was used for lighting and the remaining 49 % was shared fairly equally by the auxiliary energy (such as ventilation, building automation, distribution) and electrical appliances.

The open-plan layout, combined with the wish of the users to have a lower room temperature in the first-floor bedrooms than in the other rooms, resulted in the heat pump operating inefficiently. For the third monitoring year with a new test family the floors were therefore closed off. The original uncontrolled air-to-water heat pump was replaced

Cumulative delivered energy: 1st monitoring year – 2012/13



Cumulative delivered energy: 2nd monitoring year – 2013/14



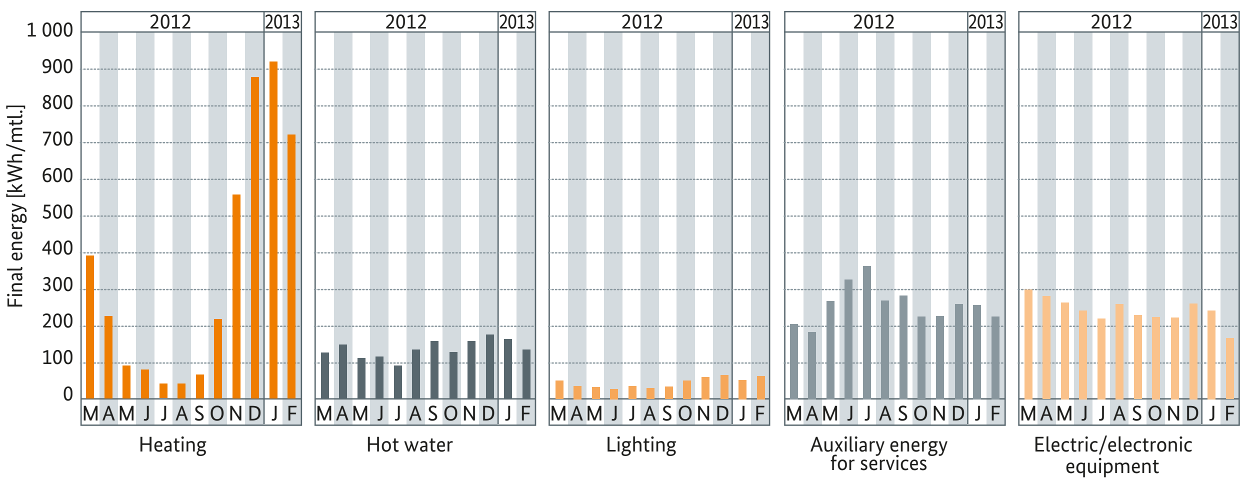
Legend for the cumulative delivered energy diagrams
- energy source – photovoltaics
- energy use – overall consumption

(not including e-mobility and project-specific consumption)

by a modulating one. It consists of one external unit that is installed next to the building and an internal unit in the energy core. Piping runs beneath the building from the external unit to the heat pump's internal unit. From there the individual rooms are supplied with heat.

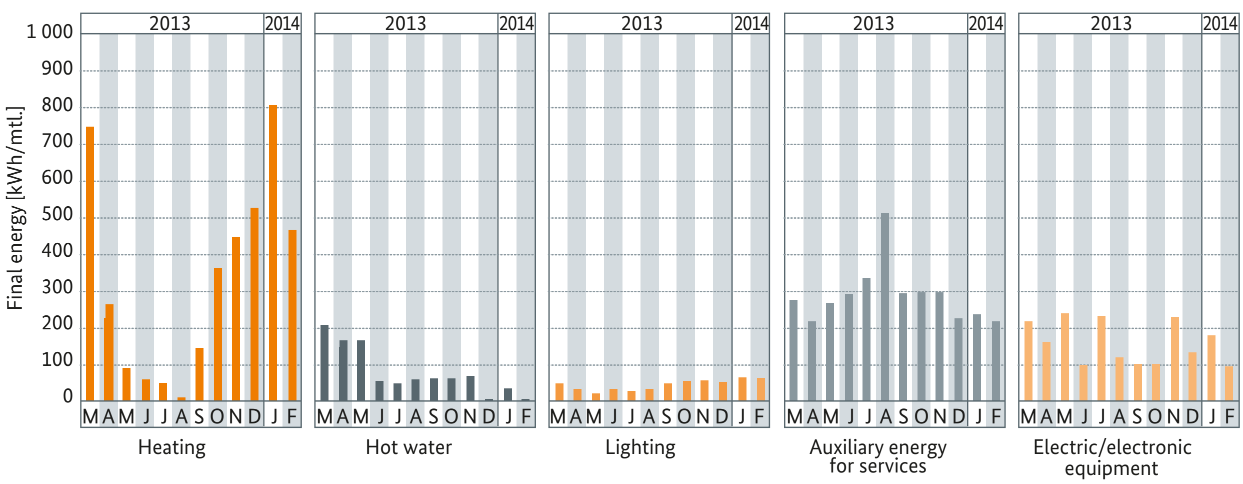
Further information on the measurements can be found online on the Zukunft Bau research initiative website. They are regularly updated.

Monthly final energy consumption - 1st monitoring year



Monthly breakdown of final energy for heating, domestic hot water, lighting, auxiliary energy and electrical appliances in the first year of monitoring 2012/2013

Monthly final energy consumption – 2nd monitoring year



Monthly breakdown of final energy for heating, domestic hot water, lighting, auxiliary energy and electrical appliances in the second year of monitoring 2013/2014

The Efficiency House Plus network

The aim of the government's research funding programme is not simply to implement one-off beacon projects but to create a network of different solutions in which to try out and optimise different technologies.

This should enable promising ideas, technologies and materials to make a faster transition into practice. The buildings can be used to gain experience and reflect on economic aspects. In the medium term, the goal is to build Efficiency Houses Plus at attractive prices. The network now consists of over 50 partners from the construction and building services industry who are successfully acting as multipliers for these building schemes in the market. The buildings are intensively scrutinized under the monitoring programme that the Fraunhofer Institute for Building Physics (IBP) is carrying out. Its aim is to record and analyse key performance data such as heating energy consumption, electricity consumption, electricity generation, the percentage of renewable energy generated used in the building, and primary energy consumption along with comfort parameters. As well as carrying out a comparison across all the projects with regard to the key performance data and compliance with the Efficiency House Plus standard, the variables used to calculate the electricity consumption of the lighting, household appliances and processes will be validated.

The research project comprises four different building groups:

Detached houses

The vast majority of the research project's demonstration buildings are detached houses. These are used as show houses as in "FertighausWelt" in Cologne/Frechen or Bremen and lived in by test families. All the other buildings have families of between two and five people living in them.

Apartment blocks

Whereas in the early years the implementation of the concept concentrated on detached houses, over the next few years the possibility of transferring the design method to apartment blocks will be trialled. To this end, large housing complexes are being built in Berlin and Frankfurt as Efficiency Houses Plus. Their ratio of roof area to facade area is different from that in a detached house. Facade areas therefore have to be increasingly used for generating renewable energy. Heat for space heating and hot water systems is provided by heat pumps, and recovered heat from waste water is also integrated into the schemes. Both centralised and decentralised ventilation systems are used.

Refurbishing existing buildings

The greatest challenge to Germany's *Energiewende*, or transition to a new energy era, is its existing building stock. The focus of the next few years in the small-house sector will therefore turn to renovation schemes. To this end, the two winning schemes in an architectural competition are currently being built in Neu-Ulm in order to try out and evaluate different approaches in practice. A special feature of the competition entry by Ruhr West University is the fact that the entire services technology has been integrated into the building envelope. This has been done by prefabricating a high-calibre heat-insulating facade system with all the necessary conduit components and mounting it on the existing external wall. This means that pipe runs do not interfere with the layout of the apartments and avoids the need for additional shafts and openings in the interior of the buildings. Darmstadt University's scheme integrates the key building services components into the roof space. Heating energy is provided from a centralised brine/water heat pump. Water is heated by decentralised exhaust air heat pumps in the individual living units.

Educational buildings built to the Efficiency House Plus standard

In addition to residential buildings, other types of buildings are also suitable to be built and run as Efficiency Houses Plus. This is particularly true of educational buildings. For that reason, schools, nurseries and higher education buildings will be incorporated into the funding programme over the next few years.

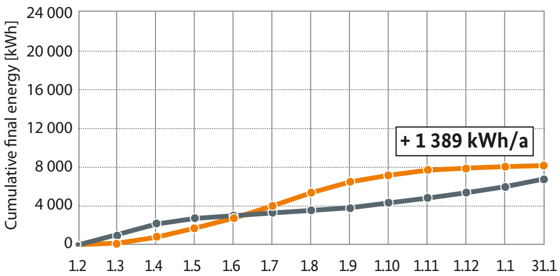
All the projects are published on the network's project website as soon as they have been built.

Built projects
(Monitored for over 12 months)

Brieselang
Elbe-Haus M1 solid building

Key data
Living space: 137 m²
U_{Wall}: 0.15 W/m²K
Air/water heat pump
PV: 9.3 kW_p
Solar thermal: 10 m²
Battery: 24.0 kWh

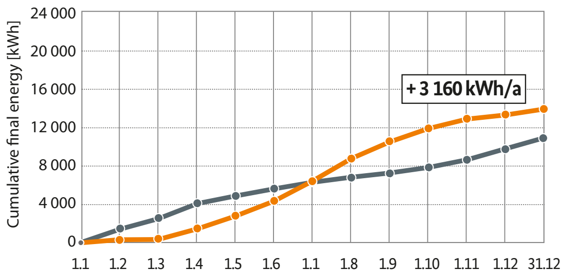
Cumulative final energy 2013–2014



Leonberg-Warmbronn
Haus Fisch

Key data
Living space: 260 m²
U_{Wall}: 0.15 W/m²K
Water/water heat pump
PV: 15.0 kW_p
Batteries: 7.0 kWh + 20.0 kWh

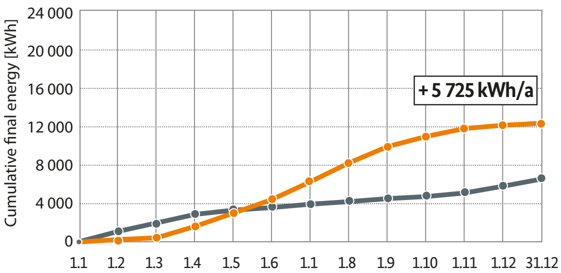
Cumulative final energy 2013



Lüneburg
Haus Molt

Key data
Living space: 129 m²
U_{Wall}: 0.12 W/m²K
Direct electric heating
PV: 12.6 kW_p

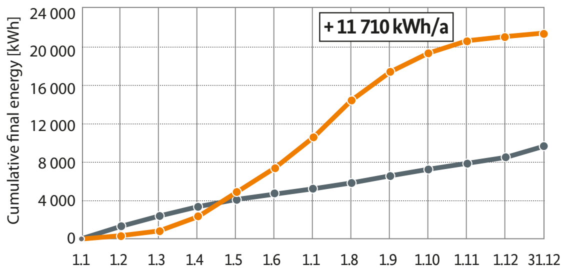
Cumulative final energy 2013



Münnerstadt
Haus Miller

Key data
Living space: 327 m²
U_{Wall}: 0.10 W/m²K
Brine/water heat pump
PV: 23.8 kW_p
Battery: 10.0 kWh

Cumulative final energy 2013



Legend:
PV – Photovoltaics

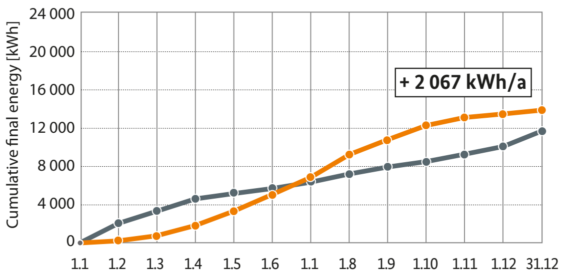
Legend for the cumulative final energy diagrams
● energy source – photovoltaics
● energy use – overall consumption
(not including e-mobility and project-specific consumption)

Cologne

Bien-Zenker Concept-M

Key data
Living space: 194 m^2
U_{Wall}: 0.12 W/m^2K
Air/air heat pump +
Brine/water heat pump
PV: 16.3 kW_p
Battery: 8.4 kWh

Cumulative final energy 2013

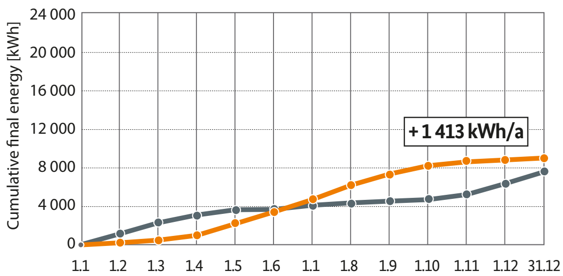


Cologne

SchwörerHaus Plan 550

Key data
Living space: 139 m^2
U_{Wall}: 0.11 W/m^2K
Air/air heat pump
PV: 11.0 kW_p
Solar thermal: 8.4 m^2

Cumulative final energy 2013

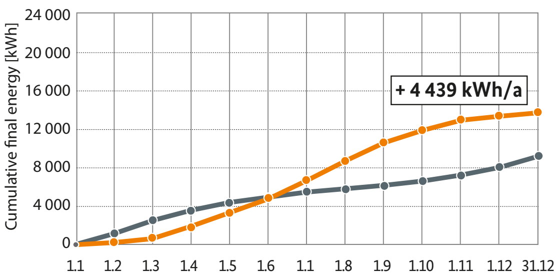


Eussenheim

Haus Höfling

Key data
Living space: 288 m^2
U_{Wall}: 0.15 W/m^2K
Brine/water heat pump
Ice storage system: 3 000 l
PV: 13.4 kW_p
Solar thermal: 11.0 m^2

Cumulative final energy 2013

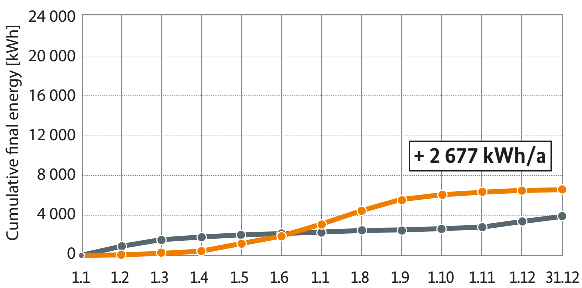


Stelzenberg

ecolodge

Key data
Living space: 113 m^2
U_{Wall}: 0.20 W/m^2K
Water/water heat pump
Ice storage system: 1 050 l
PV: 8.5 kW_p
Solar thermal: 14.0 m^2

Cumulative final energy 2013



Legend:
PV – Photovoltaics

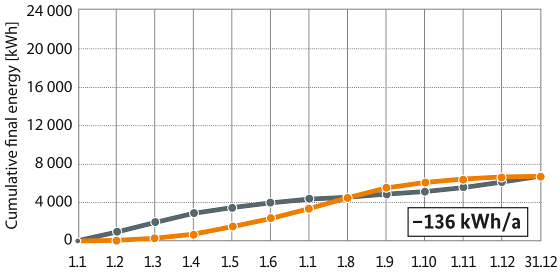
Legend for the cumulative final energy diagrams
● energy source – photovoltaics
● energy use – overall consumption
(not including e-mobility and project-specific consumption)

Bremen

HO Immobilien & Baukonzepte

Key data
Living space: 202 m²
U_{Wall}: 0.15 W/m²K
Brine/water heat pump
PV: 8.7 kW_p

Cumulative final energy 2013

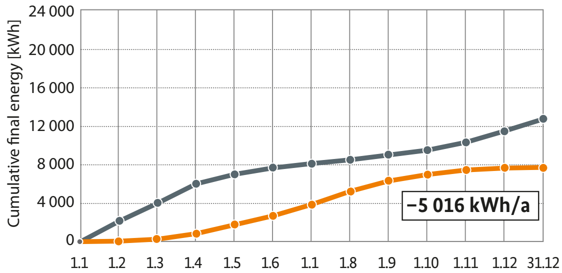


Hamburg

VELUX LichtAktiv Haus

Key data
Living space: 132 m²
U_{Wall}: 0.13 W/m²K
Air/water heat pump
Window ventilation
PV: 8.8 kW_p
Solar thermal: 19.8 m²

Cumulative final energy 2013



The cumulative graphs show the houses' total energy consumption (grey curve) and the energy generated by the photovoltaic systems (orange curve) throughout 2013. At the beginning of the year, the amount of energy consumed is greater than the energy gains from the photovoltaic panels. As a rule, energy gains begin to outstrip consumption from May onwards so that the buildings still have a net energy gain up to the end of the year. Only in the case of two projects was the target not fully achieved in the first year of operation. Adjustments to optimise operations should improve the results for the 2^{nd} year of operation.

Legend:
PV – Photovoltaics

Legend for the cumulative final energy diagrams
● energy source – photovoltaics
● energy use – overall consumption
(not including e-mobility and project-specific consumption)

VELUX LichtAktiv Haus: view into the attic mezzanine

Projects already built

(Monitoring has started)

Cologne
WeberHaus Generation 5.0

Key data
Living space: 159 m²
U_{Wall}: 0.15 W/m²K
Air/air heat pump
PV: 8.8 kW_p
Battery: 3.5 kWh

Cologne
HUF HAUS Green[r]evolution

Key data
Living space: 283 m²
U_{Wall}: 0.17 W/m²K
Brine/water heat pump
PV: 14.5 kW_p
Battery: 13.2 kWh

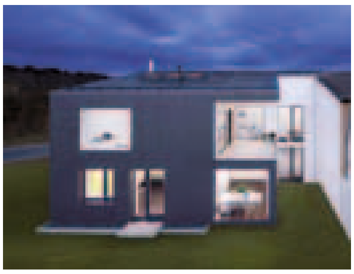
Cologne
FingerHaus VIO 400

Key data
Living space: 179 m²
U_{Wall}: 0.15 W/m²K
Air/water heat pump
PV: 8.5 kW_p

Cologne
LUXHAUS frame

Key data
Living space: 289 m²
U_{Wall}: 0.11 W/m²K
Brine/water heat pump
PV: 9.9 kW_p

Darmstadt
Energy+ Home



Key data
Living space: 185 m²
U_{Wall}: 0.15 W/m²K
Air/water heat pump
PV: 12.6 kW_p

Bad Homburg
Pro Klimahaus

Key data
Living space: 169 m²
U_{Wall}: 0.18 W/m²K
Air/water heat pump
PV: 9.4 kW_p

Schwabach
Haus Hausner

Key data
Living space: 221 m²
U_{Wall}: 0.14 W/m²K
Air/air heat pump
PV: 14.4 kW_p

Unterkirnach
Haus Neininger

Key data
Living space: 282 m²
U_{Wall}: 0.11 W/m²K
Brine/water heat pump
PV: 26.2 kW_p
Battery: 24.0 kWh

Legend:
PV – Photovoltaics

Weifa
Haus Wagner

Key data
Living space: 180 m²
U_{Wall}: 0.10 W/m²K
Air/water heat pump
PV: 30.0 kW_p
Battery: 14.4 kWh

Burghausen
Schlagmann/BayWa

Key data
Living space: 176 m²
U_{Wall}: 0.14 W/m²K
Water/water heat pump
PV: 10.5 kW_p
Battery: 10.8 kWh

Bischofswiesen
EFH-Plus in den Bergen

Key data
Living space: 628 m²
U_{Wall}: 0.10 W/m²K
Water/water heat pump
PV: 41.6 kW_p
Battery: 50.0 kWh

Buchen-Hollerbach
Haus Böhrer

Key data
Living space: 230 m²
U_{Wall}: 0.15 W/m²K
Brine/water heat pump
PV: 12.4 kW_p

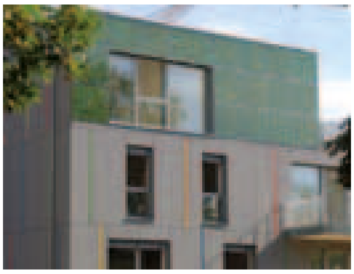
Deggendorf
Haus Bachl

Key data
Living space: 171 m²
U_{Wall}: 0.10 W/m²K
Buffer storage tank 9 200 l
PV: 7.8 kW_p
Solar thermal: 49.0 m²
Battery: 8.0 kWh

Kassel
Haus Barba/Griesel

Key data
Living space: 280 m²
U_{Wall}: 0.10 W/m²K
Brine/water heat pump
PV: 15.8 kW_p
Battery: 63.0 kWh

Tübingen
Licht + Luft



Key data
Living space: 891 m²
U_{Wall}: 0.10 W/m²K
District heating
PV: 35.0 kW_p

Frankfurt
Cordierstraße

Key data
Living space: 1 170 m²
U_{Wall}: 0.10 – 0.13 W/m²K
Micro CHP unit
PV: 49.7 kW_p
Solar thermal: 40.0 m²

Legend:
PV – Photovoltaics

Projects in the preparatory stage

(As at: June 2014)

Frankfurt
Speicherstraße

Frankfurt
Riedberg

Geisenheim
Internatsschule Hansenberg

Lüneburg
Hasenburger Weg

Berlin
LaVidaVerde

Stuttgart
Aktivhaus B10

Neu-Ulm
Pfuhler Straße

Bremen
Haus Büscher

Aktiv-Stadthaus Frankfurt

Neu-Ulm, Pfuhler Straße 4–8

Neu-Ulm, Pfuhler Straße 10–14

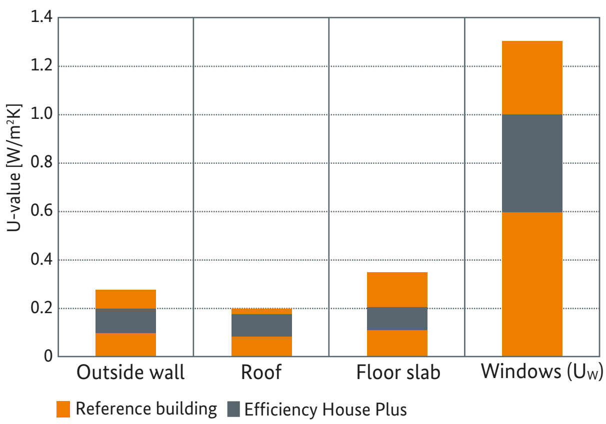
Initial results from the network

All the projects in the federal government's Efficiency House Plus research funding programme are scientifically evaluated by different teams of researchers. The results are posted as soon as possible on the project's website. In addition to this, an evaluation project being conducted by the Fraunhofer Institute for Building Physics (IBP) is looking at technical aspects and another by the Berlin Institute for Social Research Co. is looking at the social aspects of the projects. They are cross-analysed and summarised into conclusions that can be generalised. Below are a number of excerpts from their findings.

Thermal insulation

As a rule, the buildings that have been completed to date have significantly better thermal insulation than the reference buildings described in the Energy Saving Ordinance (EnEV). However, the thermal insulation is often not quite as high as in a passive house. The transmission heat loss relative to the thermal envelope area is between 0.15 and 0.36 W/m²K and thus between 10 and 60 % lower (on average 40 %) than the minimum requirements set out in the current Energy Saving Ordinance. The average energy performance of the buildings is between the two KfW standards (Efficiency House 40 and 55), tending towards the Efficiency House 55.

Heat transmission coefficients



Range of the heat transmission coefficients (U-values) of individual components of the Efficiency Houses Plus in the network (grey area) by comparison with the values specified in the reference building of the Energy Saving Ordinance (upper value of the orange columns)

Heat supply

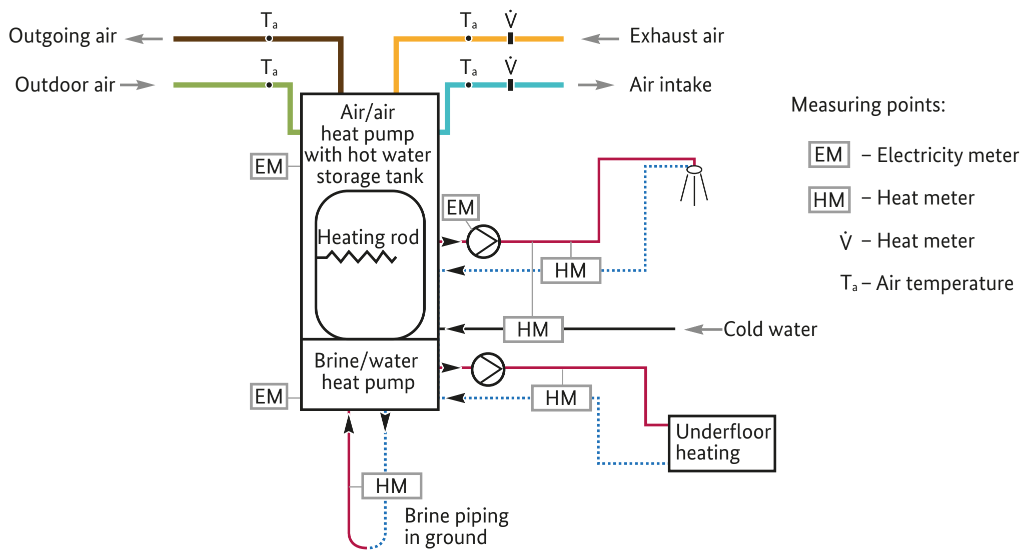
Most of the buildings completed so far have a heating supply based on electrically powered heat pumps in conjunction with panel heating systems. The systems' heat output varies between 25 and 50 W/m². In the majority of the schemes the heat is transmitted through an underfloor heating system; however, some systems also include the wall surfaces in order to be able to keep system temperatures below 35 °C as a result of large transmission areas.

The measurements recorded revealed that there is a problem with living spaces that are open-plan over more than one storey because the heat supply to spaces on different floors cannot be controlled separately, which means that some rooms had to meet higher heat loads, increasing the system temperatures and lowering the efficiency of the heat pump systems.

Due to their lower acquisition costs, an unexpectedly high number of buildings used air source heat pumps, although their typical energy efficiency values are significantly poorer than those of ground source heat pumps. Individual buildings within the network focus on thermal solar heating using seasonal storage and appropriate supplementary heating (back-up systems) such as pellet stoves. For detached houses this would mean a storage facility of between 5 and 10 m³ and an additional fuel store. This in turn means that the building volume needs to be larger than for schemes using heat pumps.

TIP:
All the components of an Efficiency House Plus do not necessarily have to be of passive house standard. Components which are about 40 % below the energy level of the reference building of the Energy Saving Ordinance are often sufficient.

Heat supply



Example of a plan showing measuring points for ascertaining energy flows in the house's heat supply system

Monitoring

It has proven to be extremely important to continually monitor the actual efficiency of the systems. Appropriate small monitoring systems are available on the market. The monitoring configuration for a building includes fitting heat and electricity meters along with temperature sensors and volumetric flow sensors. In selected rooms, air temperature, relative air humidity and CO_2 concentration are also measured. The measured data is used to continually record how much energy from the photovoltaic system and the grid is used or fed into the public electricity grid, along with the consumption of all electrical appliances and building services equipment. The data for the individual buildings is analysed and published each month on the ministry's website.

A display screen in the building automation system

TIP:

Innovative system design should include a monitoring system so that efficiency can be continually analysed and appropriate improvements made where necessary.

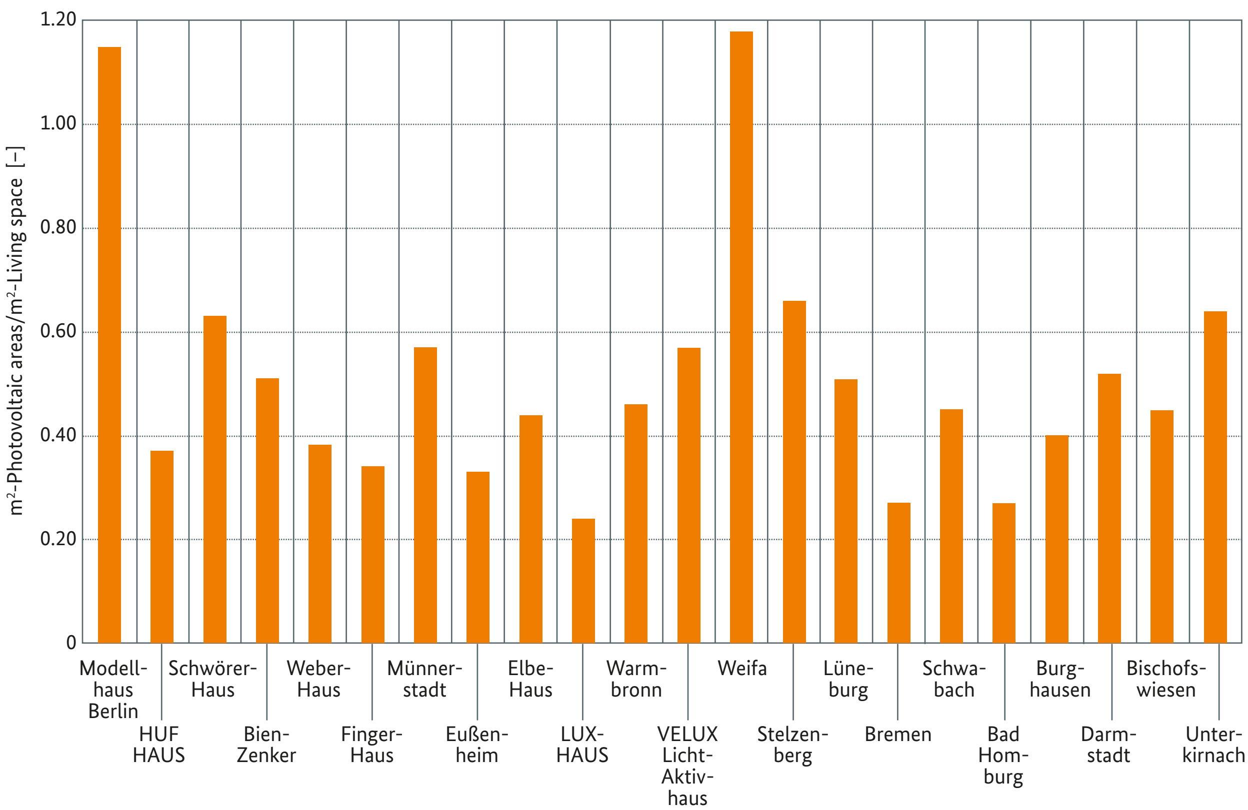
Typical values for solar electricity generation

Photovoltaic panels

To date, highly efficient houses have concentrated primarily on minimising energy demand. By contrast, Efficiency House Plus buildings call for the pros and cons to be considered between whether it is appropriate to install photovoltaic panels or increase the thermal insulation for the building envelope. For several projects the designers began by ascertaining the maximum possible surface area of collectors and on that basis calculated the thermal insulation the building needed to comply with the specifications for the Efficiency House Plus standard. An analysis of the houses completed to date shows that on average 0.50 m² of photovoltaic area per m² of living space was installed. The installed capacity of the photovoltaic systems is between 8.5 and 24.5 kW_p and averages 10 kW_p for detached houses.

On the whole, the electricity yields from the projects' photovoltaic systems that have completed one year of monitoring to date display a good fit with the yields calculated in advance.

Photovoltaic areas per m² living space



Comparison of photovoltaic areas per m² living space in the demonstration projects

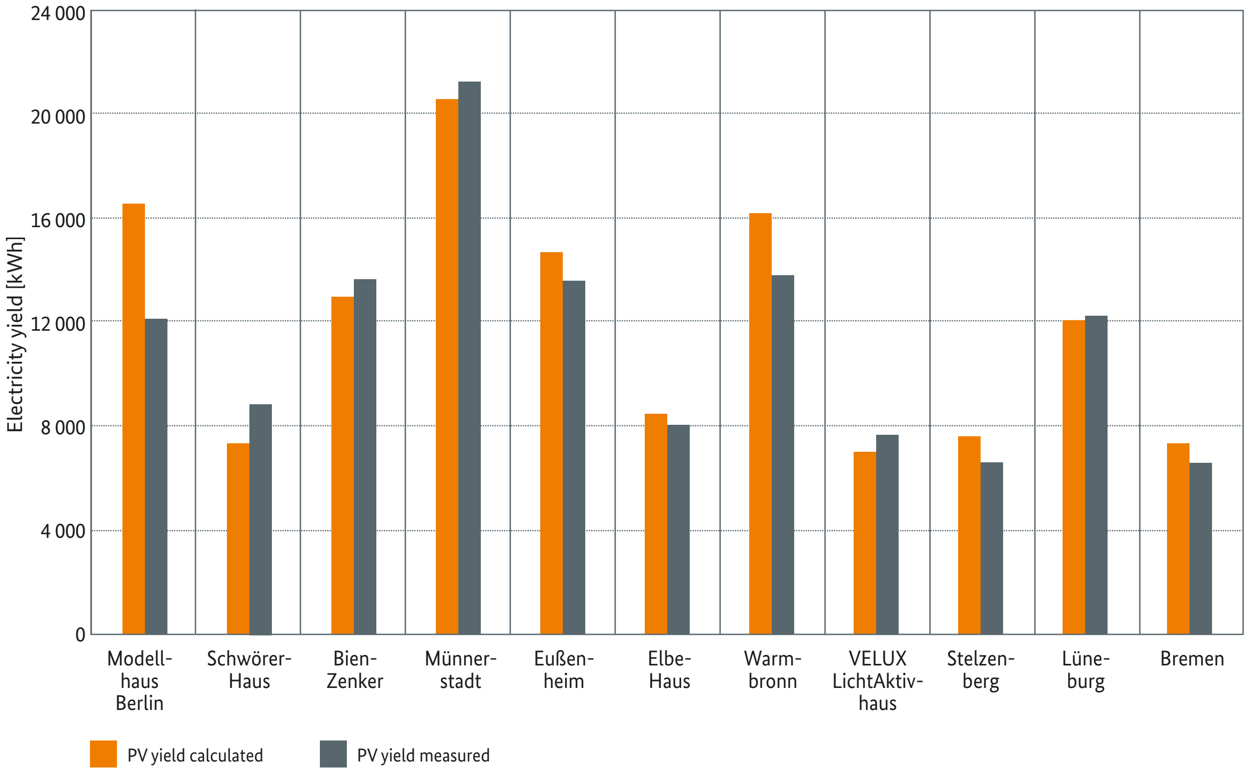
TIP:
A KfW Efficiency House 55 needs about 0.5 m² of photovoltaic area per m² of living space in order to be retrofitted to Efficiency House Plus standard.

Roof with monocrystalline photovoltaic modules

Calculations made in advance versus measurements taken

A key issue that arises when building Efficiency Houses is whether the energy yields from the photovoltaic systems can be accurately predicted, since the houses' ability to meet the targets and their economic viability depend crucially on this. The measured results of buildings completed to date show a very high degree of agreement between the calculations made in advance and the results measured. Any deviations are usually below 10 % and can be explained by particular local weather conditions or shading factors that had not been taken into account. Measurements to date reaffirm that the performance assessment method set out in DIN V 18599 can be used with sufficient accuracy as the basis for ex-ante evaluation and dimensioning of the Efficiency Houses.

Photovoltaic yield



Comparison of calculated and measured photovoltaic yield

TIP:
When calculating photovoltaic yields in advance, shading must be taken into account as much as possible to ensure a good agreement with the subsequent operating data. Trees and other vegetation that changes seasonally and over the years are particularly important in this respect.

Electrical storage systems

As a result of changes to the feed-in tariffs, companies selling Efficiency House Plus buildings responded with designs that make it possible to significantly increase the percentage of solar electricity the building could use itself. Whereas in the past it was scarcely possible for a building to use more than 30 % of the electricity produced by the photovoltaic system (without incorporating batteries), this percentage can now be doubled by integrating electrical storage into the system. The detached houses on the market today are able to use between 60 and 70 % of the electricity they produce. To do this, they use batteries with a capacity between 2 and 13 kWh. For test purposes two of the buildings have installed batteries with a storage capacity of between 20 and 40 kWh.

Battery bank consisting of used car batteries, 40 kWh

Newer battery storage, 13.2 kWh

TIP:
Using an electrical storage system (capacity between 8 and 10 kWh) can easily double the percentage of renewable electricity generated by a detached house that can be used by the house itself.

Costs

Since each of the buildings are highly individual in design and it is design elements and investments in higher standards of comfort that have the greatest impact on cost, it is difficult to make any prediction about the economic aspects or the overall costs of the buildings.

It would seem more appropriate to describe how much more or less these buildings cost by comparison with the same building of standard quality in energy terms.

Standard quality building

Currently, over half of all new builds in Germany are of a high standard in terms of energy efficiency (KfW Efficiency House 70 standard or better). Compared with the standard prescribed by the 2009 Energy Saving Ordinance (EnEV), this standard usually costs an additional € 30 to € 50 per m^2 of usable floor area to build. The Energy Saving Ordinance will prescribe roughly this standard as a minimum requirement from 2016. We have therefore taken it as a reference standard in the following considerations.

Highly energy-efficient building envelope

The Efficiency Houses Plus that have been built to date usually have a building envelope that is a 40 % improvement on the requirements of the Energy Saving Ordinance. Assuming average window sizes, this incurs extra costs of between € 50 and € 80 per m^2 of usable floor area compared with the KfW 70 standard.

Highly efficient ventilation systems for living spaces

It is essential to have a good ventilation scheme in new builds. Ventilation has already become standard in residential buildings with higher energy efficiency. However, simple systems (air extraction) are more commonly installed. Installing a system that supplies and extracts air and has heat recovery rates of > 80 % adds € 30 to € 50 per m^2 of usable floor area to the cost of a new build.

Heat pump system with buffer storage tank (5 000 l)

Heat pump systems with buffer storage tanks

In recent years, electric heat pumps have become increasingly popular in the new build market. The additional costs for heat pump systems in Efficiency Houses Plus are between 35 and € 50 per m^2 of usable floor area by comparison with a standard heating supply using a condensing boiler and hot water tank.

Highly efficient household appliances

Using highly efficient household appliances can lower the electricity consumption in an average household by about 1 000 kWh a year. This reduces the photovoltaic capacity that needs to be installed by 1 kW_p, which more than cancels out the additional costs for the appliances. The costs are simply shifted from one item to another.

Photovoltaic systems

The installation costs for photovoltaic systems have fallen dramatically in the last three years. This is largely due to mass production in Asia. Further price drops are expected soon. Currently the capital costs for medium-sized roof-mounted systems are between € 1 700 and € 2 000 per kW_p. For an installed capacity of 45 W_p per m^2 of usable floor area, which was the average for buildings to date, the average installation costs are between € 75 and € 90 per m² of usable floor area.

Electric battery systems

Electric batteries are not absolutely essential for an Efficiency House Plus but they do lower operating costs. Normal lead acid house batteries (8 kWh) cost about € 500 per kWh of capacity; more efficient lithium ion batteries cost more than double that figure.

Overall additional investment

As the analysis of the individual elements shows, an Efficiency House Plus requires an average additional investment of between € 230 and € 325 per m² of usable floor area. Installing extra photovoltaic areas to support electromobility will increase the level of investment accordingly.

Lower operating costs

The operating costs for an average detached house of KfW Efficiency House 70 standard can be estimated at € 8 per m²a of usable floor area for heating and € 10 per m²a for electricity – in other words a total of € 18 per square metre per annum. This potential can be best exploited in an Efficiency House Plus.

Even two years ago, it was still possible to reduce the operating costs of an Efficiency House Plus to less than € 0/a. Today this is in practice no longer possible for houses that produce only slightly more solar electricity than they need, unless they incorporate batteries into the system. This is because of degressive feed-in tariffs and the fact that payment for the electricity generated but used by the house itself has been abolished.

Even assuming that including a large enough battery would increase the percentage of generated electricity used by the house itself to at least 65 %, the operating costs would - despite an annual electricity surplus- still be between € 2 and 3/a per m² of usable floor area. Today, only a photovoltaic system that is about 35 % "too large" produces operating costs below € 0.

Electric vehicle charging point

Possible components of an Efficiency House Plus

Note:
Field results to date have shown that the additional capital costs for an Efficiency House Plus are reasonable by comparison with the achievable operating costs. Since the feed-in tariffs are currently being revised as part of the amendment to the Renewable Energy Sources Act, any consideration of the economic aspects must always take account of the latest regulatory framework. Generalisations are not possible here.

Personal experience with the Efficiency House Plus

"We will miss the feel good factor."

That was what the Welke/Wiechers family, who lived in the Efficiency House Plus in Berlin from March 2012 to June 2013, said after they had moved out.

"What we will miss most after moving out? We have been asked that question countless times in the last few weeks and it is difficult to find an answer. We will definitely miss feeling good about taking a bath or using our car because we knew the heat, hot water and electricity for our electric car was supplied from our building's own service technology without causing any emissions."

Commenting on tours of the Efficiency House Plus with groups of visitors, the occupants added: "Again and again, when we show people around the Efficiency House Plus they are absolutely amazed at the technology used. Fortunately, a lot of it is not brand new and has already demonstrated its merit elsewhere. All over the world, architects, researchers and engineers are working on how to take sustainable building forward."

"The additional costs compared to a conventional residential building are minimal."

Andreas Miller, architect and owner of an Efficiency House Plus in Münnerstadt

"The additional costs compared to a conventional residential building are minimal. Firstly, you save money because there are a number of conventional components, such as expensive heating systems, fireplaces etc., that you don't need. By structuring our design around Passivhaus criteria we were able to reduce the technology needed to heat the building to a minimum. We were able to fully reinvest the money we saved on that in slightly more expensive (because thicker) insulation. There is only one difference in the long term: the passive house needs significantly less heat-energy over its entire lifecycle. The cheapest form of energy is and always will be the "energy you don't need." That means it will take very little time to get payback on the extra costs.

On the other hand, we have not counted the costs for the photovoltaic system as extra, because it finances itself through the feed-in tariff."

"It surpassed all our expectations."

Jürgen Molt, owner-occupier of an Efficiency House Plus in Lüneburg

"The greatest challenge was the requirement to work out a precise and detailed strategy in the early design stage. We were not sure whether the building services scheme we had chosen – with electric heating instead of a conventional system – would actually work. If it had not been a success we would have had to add a complete heating system subsequently at considerable expense. It does work - perfectly. The heating energy demand is so low that one of the radiators has never been used. And the house always has a pleasant temperature, both in winter and summer. Also, the ventilation system works virtually silently, is reliable and low maintenance. Our expectations have been exceeded on all counts."

"So far our concept has been a total success."

Wagner family in the Efficiency House Plus in Weifa

"Our aim was to build a house that we enjoy living in and in which we don't have to worry about whether it is nice and warm or whether there is hot water. It is also wonderful not to have to compare the price of heating oil or change gas supplier to save a few cents. We no longer have to open the windows to get fresh air into the house, which was always very unpleasant in winter. We don't have to do anything other than live in the house and that is a real luxury. So far our concept has been a total success: we have created an environment that we enjoy living in and are ably to supply the majority of our electricity needs ourselves."

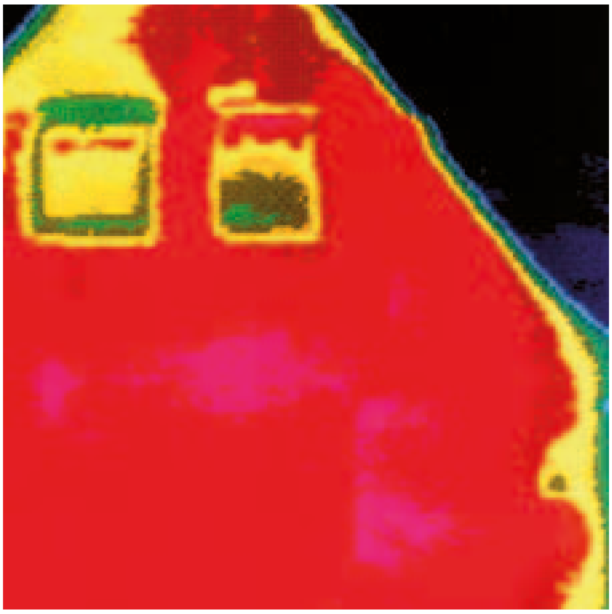
"Houses for the 'energy revolution'"

Dirk-Uwe Klaas, chief executive officer of the Association of German Premanufactured Building Manufacturers (BDF)

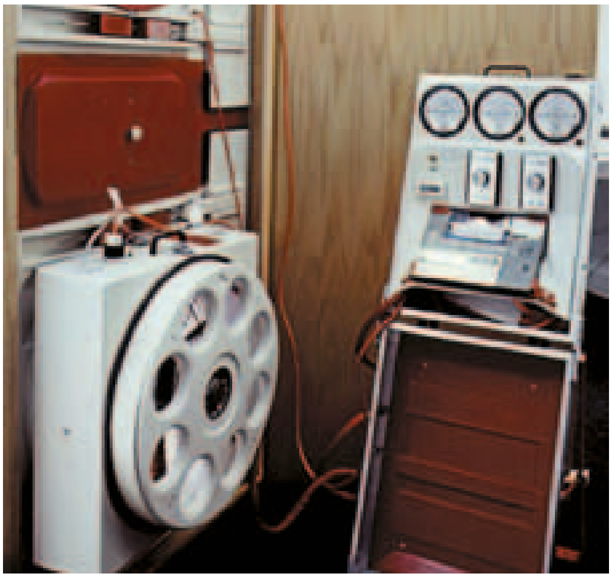
"Anyone building a house is automatically thinking of the future. That is why not only building owners but also building contractors would be well advised to take social and political issues of the future into account. Energy efficiency and sustainability make their mark on new homes for owner occupiers. With the Efficiency House Plus, German manufacturers of prefabricated buildings can supply their customers today with the right building for the new energy era of the future. The idea of independently generating electricity and using it to run your own house fascinates many building owners. If the new standard is appropriately included in public funding programmes in the future, the Efficiency House Plus has outstanding market opportunities."

What else needs to be taken into account?

Higher specifications have to be met when designing and building an Efficiency House Plus. This checklist can help to systematically address the challenges in the different phases.



Thermal imaging is a useful tool for carrying out a visual check for consistency of workmanship.



Blower door device to check the building's airtightness.

Urban design

- Site the building so that the facades with most windows are south-facing.
- Ensure there is sufficient distance from other buildings to make use of solar radiation even when the sun is low.
- Roof pitches and ridge lines should face the sun.
- Use planting to provide shade in summer and influence the microclimate.

Scheme design

- Make the building as compact as possible. If the building is not very deep, arrange rooms on one side with as broad a south-facing facade as possible and access from the north. Alternatively, if rooms are arranged on both sides of the circulation route, windows should be evenly distributed across the east and west facades. This lowers costs and saves energy.
- Site buffer spaces or parts of the building with less important functions on the northern side.
- Integrate the boiler room into the heated living area.
- Ensure the pipe runs for heating and hot water are short (site the boiler room and distribution shafts at a central location in the house).
- Site rooms that have a similar type of use (heated/unheated) together to minimise heat loss through inner surfaces.
- Prepare airtightness and thermal bridging schemes that are consistent and work together properly. Mark on the drawings places where special attention needs to be paid.
- Prepare specified tender documents with precise details of products.

Passive use of solar energy

- The percentage of window area on south-facing facades should be greater than 50 %; on all other parts of the building, windows should not be larger than is needed to provide adequate daylighting.
- Optimal orientation and pitch of surfaces to allow passive and active use of solar energy.
- Zone the building according to the temperature of the rooms.
- Place internal building components that have storage capacity to take account of the sun's path.

Thermal insulation

- Avoid thermal bridges at structural connections (floor supports, roller shutter boxes, roof flashings).
- Make sure all connection details that could impact on energy are described in the working drawings and tender documentation (as a rule 20 to 25 detail drawings are needed), specifying on the drawings all key data relating to the thermal, hygric and sealing properties of the building component. Do not let on-site work on any detail start until you have worked out the exact specification!
- Choose the highest quality roof lights possible because the heat emission from these surfaces is even greater than from walls (clear, cold atmosphere). We are familiar with these effects from iced-up car windscreens.
- Use heat insulating interior components on unheated ancillary and buffer spaces.
- Install high-quality insulation to protect jamb walls, dormer and ceiling surfaces from outside air.

Ventilation design

- If using window ventilation, ensure cross-ventilation is possible.
- It is not necessary for every window to be openable.
- In multi-storey apartment blocks, fire regulations often make the ventilation technology more expensive; decentralised schemes can be helpful here.

Heating technology

- Set the temperature of the heating system as low as possible to allow alternative energy sources to be integrated and keep distribution losses low. Take competing factors such as larger heating areas, volumetric flows and operating power into account when specifying the temperature.
- Insulate pipes to a higher standard, including when they are in building components and at penetration points.
- Ensure that valves, flanges and modules in the heating distribution system are insulated. The boiler room must not be the warmest room in the house!
- Check the possibility of thicker insulation than is already used for heating and process water tanks.
- Fit timers to circulation pumps, lighting etc.

Construction work

- Use only appropriate materials and combinations of material that are approved by building control authorities. Use the same materials throughout wherever possible to avoid mistakes on site.
- Use the highest quality glazing possible in thermally insulated window frames (especially for roof lights). Check that the glazing delivered matches the thermal insulation certificate (k BAZ >= k DIN).
- Supervise workmanship on difficult details in the building.
- Make sure all flashings are permanently airtight and windtight (rafters, dormer, interior and outside wall connections, ensure that windows have not just been fitted using expanding foam)
- Ensure thermal isolation of building components that are cantilevered and project into cold areas (balconies, canopies).
- Check the key thermal data and approvals as given on product documentation and delivery notes.
- Avoid damage to sealing layers (air and vapour barriers) when electrics, flue pipes etc. are being installed. If necessary, re-seal.
- Run a blower door test to check airtightness before the interior fit out is completed.

Monitoring operations

- Include installation of a small-scale monitoring system in the design.
- As a minimum, the efficiency of the heat generating unit should be recorded (ratio of the heat produced by the unit to its fuel intake (electricity, gas, wood)).
- The solar energy system's yields should also be monitored.

List of figures

Page	Title	Source
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	VELUX LichtAktiv Haus; Hamburg,	
	Top right, bottom right	VELUX Deutschland GmbH
32	WeberHaus Generation 5.0, Köln	WeberHaus GmbH u. Co. KG
	HUF HAUS Green[r]evolution, Köln	HUF HAUS GmbH u. Co. KG
	FingerHaus VIO 400, Köln	FingerHaus GmbH
	LUXHAUS frame, Köln	LUXHAUS GmbH u. Co. KG
	Energy+ Home, Darmstadt	TSB Ingenieurgesellschaft mbH
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	Haus Bachl, Deggendorf	Peter Kemper, DII Projektplanung/Architektur GbR
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	Cordierstrasse, Frankfurt	IWU Darmstadt
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	FRANKFURT HOLDING	
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	Hansenberg boarding school, Geisenheim	Drexler Guinand Jauslin Architekten GmbH
	Hasenburger Weg, Lüneburg	Peter Ohlms, Domizil GmbH u. Co. KG
	LaVidaVerde, Berlin	Fehlig, Assmann – newsgraphic
	Aktivhaus B10, Stuttgart	Werner Sobek, Stuttgart
	Pfuhler Strasse EH+	
	Sanierungsobjekt P 12, Neu-Ulm	BMVBS/Werner Sobek, Stuttgart
	Haus Büscher, Bremen	ARCHITYPE, Bremen
35	SpeicherstrasseAktiv Stadthaus Frankfurt	BMVBS/HHS Planer + Architekten Kassel/ABG
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	Pfuhler Strasse 4-8, Neu-Ulm	Werner Sobek, Frankfurt
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Key links for research and funding

Federal Ministry for the Environment,
Nature Conservation, Building and Nuclear Safety -
www.bmub.bund.de

The Federal Office for Building and Regional Planning –
www.bbr.bund.de

Zukunft Bau research initiative –
www.forschungsinitiative.de

Fraunhofer Institute for Building Physics (IBP), Department of Heat Technology – www.ibp.fraunhofer.de/wt

KfW Bankengruppe – www.kfw.de

German Energy Agency (dena) – www.dena.de

Efficiency House Plus calculation tool –
www.effizienzhaus-plus-rechner.de

Published by:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)
11055 Berlin

Represented by:
The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning (BBR)
53179 Bonn

Project management:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB)
Division for Civil Engineering, Sustainable Construction, Building Research
Hans-Dieter Hegner, Andrea Pfeil

Production/editorial responsibility:
The Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) within the Federal Office for Building and Regional Planning (BBR)
Division II3, Helga Kühnhenrich

Available from:
BBSR, Division II3
Email: zb@bbr.bund.de

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Nobelstrasse 12, 70569 Stuttgart
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Design
KOMBO MedienDesign Rainer Geyer, Siegburg

Printed by:
Bundesamt für Bauwesen und Raumordnung, Bonn

As at:
September 2014
3rd print run, 500 copies

Cover photo
The German government's Efficiency House Plus with electromobility on Fasanenstrasse in Berlin. It has been open to the public since 2011 as an information platform.