Bundesministerium
für Verkehr, Bau
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Energie
für Deutschland

Efficiency House Plus with Electromobility

Technical Information and Details

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FORSCHUNGSINITIATIVE Zukunft BAU

Plus Effizienzhaus

Efficiency House Plus with Electromobility

Fig.1: **A view of the Efficiency House Plus with Electromobility**

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Ministerial Foreword

Undoubtedly, dealing with resources responsibly and protecting the climate are among the most important tasks facing both politics and society. An important starting point in this regard is the topic of energy efficiency. A particular responsibility falls to buildings and transport. This is because, in Germany, approximately 70 percent of final energy consumption is divided among these two sectors, which are simultaneously responsible for nearly 40 percent of all CO_2 emissions.

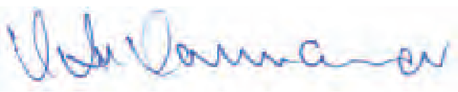
What could therefore lie nearer than to seek ways of combining these two sectors in order to generate savings? With regard to buildings, it should be possible to operate newly constructed structures in an energy-neutral manner beginning in 2019. This is but one of the ambitious objectives addressed by the Research Initiative for Future Construction ("Forschungsinitiative Zukunft Bau") of the Federal Ministry of Transport, Building and Urban Development ("Bundesministerium für Verkehr, Bau und Stadtentwicklung" (BMVBS)). Aside from developing concepts for environmentally-neutral buildings, we are also trying to create possibilities to combine highly efficient homes with the future-oriented technology of electromobility. The "Efficiency House Plus with Electromobility" is an exemplary realization of this idea. The 130 m² construction project is much more than simply a single-family home. It is also a small power plant, a resource depot, a research project, a dialog platform and, not the least, a contribution to today's construction culture.

The public is now, therefore, invited to tour this home and to gain an insight into the comfortable, environmentally-neutral and energy efficient life in the future. This model and research project by the BMVBS in the heart of the German capital city will undoubtedly gain the interest it deserves.

Aside from energy efficiency and resource protection in the living and transport areas, aspects of sustainability played a central role in the home's design. Thus, all employed materials can be recycled. In addition, the home boasts a modern and changeable design and offers exceptional user-friendliness. It is an outstanding example that highly efficient and careful energy consumption is possible without any degradation in comfort. The excess current generated by the home is stored in an house battery and also transferred to electric vehicles which act both as storage devices as well as consumers. Thus, structure and mobility are autonomous and, as far as possible, remain independent of public power networks.

From the first day, the project is subject to intense scientific support. The obtained research results are to be made available for the broad-based establishment of similar innovative structures and for the further development of technical systems. Beginning in March, 2012, a family selected from a public application process will live in the home for a period of 15 months. Aside from the scientific support to examine the interfaces between man and technology, a wide variety of research tasks will also be carried out on the home. In those periods prior to the guest family moving in and after their departure, the house also invites members of the public to tour its facilities and presents an information and presentation platform for public research dialogs.

I am curious as to what experiences will be gained from "real" life in the "Efficiency House Plus", and hope that the project will contribute to the broad introduction of this future vision in the construction and transport sectors.



Dr. Peter Ramsauer
Federal Minister of Transport, Building
and Urban Development

Efficiency House Plus with Electromobility

Energy-Saving Construction Development in Germany

The construction sector possesses one of the greatest development potentials with regard to sustainable economics and climate protection. After all, buildings represent more than one-third of energy consumption, being the largest energy consumer in the public sector and therefore one of the sectors responsible for CO_2 emissions.

It is not artificial shortages such as was the case in the oil crises during the 1970s, but rather increasing demand which makes energy more expensive than ever in Germany. Germany possesses a long tradition of reacting to these challenges. Since the first Heat Insulation Ordinance in 1977, regulative laws have been of particular significance. They are intended to enforce sustainable, ecological construction, to provide a public service and to contribute to the introduction of new techniques and technologies in the field of structural thermal insulation and facilities for building services on the construction site.

Particularly after the introduction of the EU Directive on Energy Performance of Buildings, the complete energy balance of all structures became a standard. In Germany, this directive was implemented by the Energy Saving Ordinance, which, particularly aside from structural insulation, also assesses factors such as the equipment technology and the utilization of renewable energy. Despite the ordinance having been tightened on numerous occasions, standard structures remain energy consumers for which energy particularly from fossil sources must be made available.

The updated EU directive requires that, as of 2021, only homes which utilize only as much energy as can be produced from renewable resources be constructed. The built-up area must not only exhibit higher efficiency, but, in future, must also be able to generate energy itself. This demands research into options for the long-term establishment of "efficient and environmentally-neutral buildings".

Model developments of the Research Initiative for Future Construction of the Federal Ministry of Transport, Building and Urban Development (BMVBS) present this new generation of buildings such as, for example, the "World Solar Master" of the Darmstadt Technical University in 2007 and 2009. These represent structures with a positive annual energy balance. That is, these buildings annually create more energy than is needed to operate the buildings.

At the conclusion of development work on numerous components and after the examination of the initial models, the BMVBS intends testing such a structure under actual conditions, using the "Efficiency House Plus with Electromobility"[1], while simultaneously gathering recommendations concerning energy management through to electromobility. For this, synergies between the new generation of buildings and transport (electric home and electromobility) are to be examined with respect to their sustainability, suitability for daily use and market suitability. The public architecture and university competition awarded in 2010 was won by the University of Stuttgart with the Werner Sobek Office. The Fraunhofer Society will carry out a series of scientific examinations of the home and will provide scientific support for the project as a whole.

The intention of the development is to provide demonstrative proof that energy supplied to two central living areas solely from renewable sources is already possible even today and suitable for daily use according to the motto: "My home – my filling station". Simultaneously, the Efficiency House Plus with Electromobility represents the established construction of the archetype of the new construction promotion program presented in August, 2011, by the BMVBS, and intends to support the broadest-possible introduction of this new design generation throughout Germany. The newly created network is intended to test the latest components under conditions of continuous employment, to prepare recommendations for their ongoing development and to further improve the economy of similar projects.

1 BMVBS terminology list with respect to the Efficiency House Plus, valid as of August, 2011: The efficiency house plus level has been achieved once both a negative annual primary energy requirement (SQp < 0 kWh/m²a), as well as a negative annual final energy requirement (SQe < 0 kWh/m²a) can be shown. All remaining conditions set forth in the 2009 Energy Saving Ordinance (EnEV) such as, for example, the requirement for summer insulation (refer also to the BMVBS brochure "Wege zum Effizienzhaus-Plus" (Efficiency House Plus Methodologies)) must also be achieved.

Standard House
The standard house obtains its energy from the public supply net and transfers it to the inhabitants.

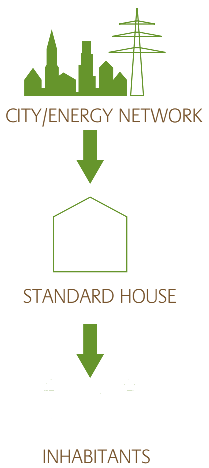


Fig. 2: **Energy flows in the standard house**

Efficiency House Plus
The Efficiency House Plus generates its own energy and makes it available to the inhabitants or feeds the excess energy back into the public grid.

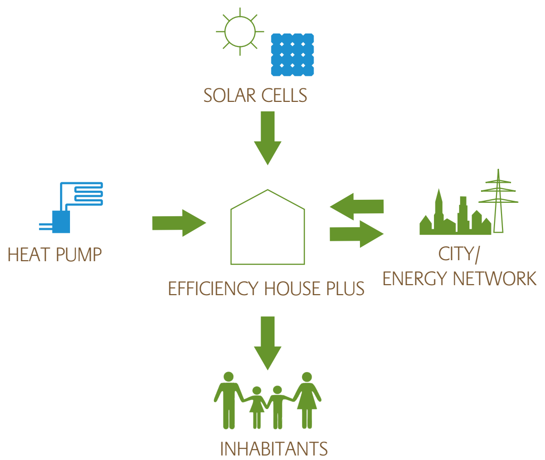


Fig. 3: **Energy flows in the Efficiency House Plus**

Efficiency House Plus with Electromobility
The Efficiency House Plus with Electromobility creates energy and makes it available to the users and their vehicles. Excess energy can either be fed back into the public grid or can be stored in an house battery.

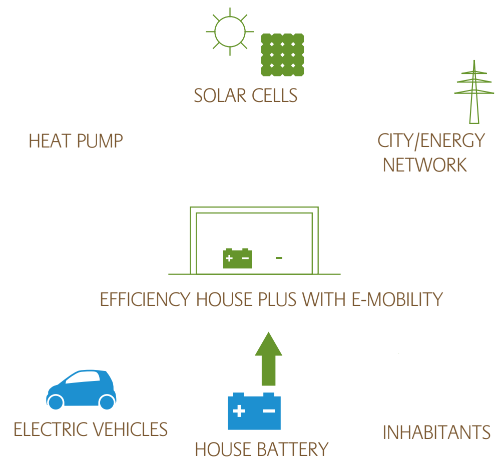


Fig. 4: **Energy flows in the Efficiency House Plus with Electromobility**

- 100 % annual average self-sufficient supply utilizing renewable resources
- All home construction materials are fully recyclable
- Support during the research phase thanks to an extensive monitoring program
- Sustainability assessment in accordance with the German Efficiency House Plus certification system

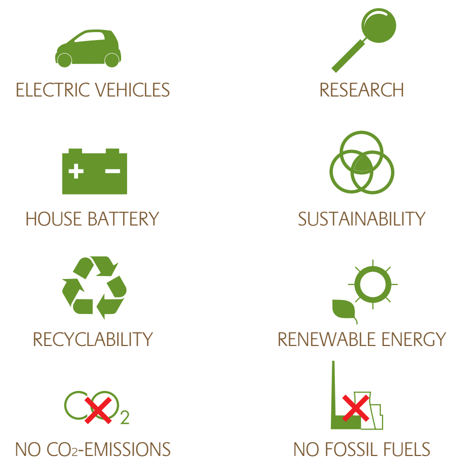


Fig. 5: **Special features of the Efficiency House Plus with Electromobility**

Research Related to the Efficiency House Plus with Electromobility

Aside from extensive validation of measuring techniques, a variety of scientific examinations will also be carried out. Chief among these are the following:

Thermal and moisture transfer through highly insulated exterior components
Using measuring sensors installed in the highly insulated, wood exterior walls, the temperature, humidity as well as the temperature flow will be measured and analyzed in real time in the home's exterior walls, its roof and its floor. In particular, this is intended to better describe the behavior of moisture in the open-pored insulation material.

Energy management
Using weather reports as a basis, the home's energy management system is designed to estimate the produced energy amounts and energy consumed by the home (for the home itself and for electromobility) and to deduce the battery storage utilization rate. This will permit improved utilization of the generated solar cell current.

Power grid stabilization
The stabilizing effect of the battery storage unit on the public power grid is to be examined. Simultaneously, a foundation of how multiple battery storage units can be combined to create a "virtual power station" will be prepared. This will allow regulating current generated from renewable sources to be made available uniformly in minutes.

Battery cell reuse/house battery sizing
Using newly employed battery management systems and the charging/alternator unit, exhausted lithium ion battery cells from the electromobility area will be examined with regard to their aging, their residual power level and their employment as house batteries. With regard to selecting the correct battery size (battery storage) for the Efficiency House Plus, a newly developed software tool will be employed for the first time to economically ensure the currently high specific expenses of house batteries.

Social-scientific family support
From March, 2012, through May, 2013, the home will be inhabited by a family of four, during which time they will be provided with social-scientific support in order to gain insights into the man/technology interfaces, the level of acceptance and the employment of new technologies, the utilization of intelligent networks to operate the home, and the use of electromobility.

Research Sponsorship Provided by the BMVBS

With its "Future Construction" research initiative, the BMVBS promotes the economy, science and society in the construction field during the energy conversion. Within the context of the BMVBS "Future Construction" research initiative, impulses are provided to the following research clusters:

- Sustainable construction, construction quality;
- Energy efficiency, renewable energy in the building area, calculation tools;
- Structural inventory modernization;
- New concepts/prototypes for energy-saving construction, zero or efficiency houses plus;
- New materials and technologies;
- Demographic change;
- Comprehensive bodies of legislation and tendering.

The research initiative comprises departmental and proposal research and the research promotion provided for Efficiency Houses Plus (a shared investment promotion provided by the Federal Government for technical innovation and its research support). The BMVBS supports the construction of buildings which produce significantly more energy than is required for their operation. The pilot projects are to be assessed within the context of a scientific support program. The results should aid in improving energy management in modern structures. In addition, the necessary components for an energy-efficient building shell and the utilization of renewable energy will undergo further development.

Additional information with regard to the research topics, research guidelines and intentions of the BMVBS are available under: www.forschungsinitiative.de

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Efficiency House Plus with Electromobility

Competition

The objective of the realization competition carried out during the second half of 2010 was: "to define the current state of development of the networking of energy-efficient, sustainable construction and living in the Federal Republic of Germany, using an actually constructed, architecturally attractive pilot research project."

First prize was won by the University of Stuttgart Working Society, the Institut für Leichtbau Entwerfen und Konstruieren (Institute for Lightweight Design and Construction), headed by Prof. Dr.-Ing. Dr.-Ing. h.c. Werner Sobek, and the Institute for Building Energetics, the Lehrstuhl für Bauphysik (Chair of Building Physics), the Institut für Arbeitswissenschaft und Technologiemanagement (Institute for Human Factors Engineering and Technology Management) Werner Sobek Stuttgart and Werner Sobek Green Technologies.

Extract from the award jury's report: "In a very convincing manner, this concept represents the combination between energy-efficient living and electromobility. The interaction between the user, the home and the vehicles is ... intelligently planned ... As a sustainable, architecturally contemporary and adaptable concept, this is an innovative contribution."

Location

The Efficiency House Plus with Electromobility is centrally located in inner city Berlin (Fasanenstraße 87a, 10623 Berlin-Charlottenburg). Thanks to its location directly near the Zoo Station, it exhibits an optimal link to public transport. Closely-spaced commuter and underground railway links, coupled with numerous bus connections provide nearly round-the-clock links across the entire city and the Berlin airports; numerous regional railways offer connections to the surrounding countryside. National and international railways are easily accessible from the main railway station, lying a mere 4 kilometers away.

Fig. 7: **Location within Berlin**

Fig. 6: **Visual representation**

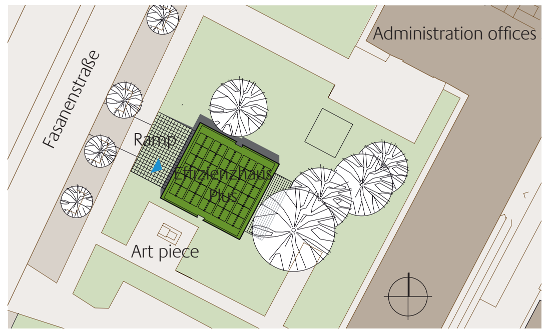


Fig. 8: **Floor plan M 1:1000**

Fig. 9: **Photo of the surrounding area**

Concept

1 Solar cell modules: integrated in the façade and on the roof

2 Energy and technical center

3 Battery

4 Information display and conductive charging system

5 Fixed slats

6 Stairs

7 Inductive charging system

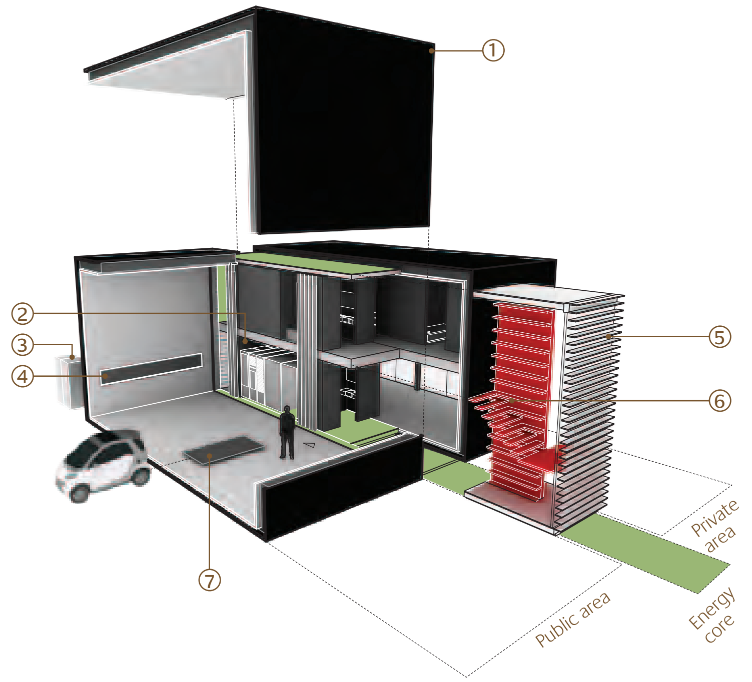


Fig. 10: **Key component designs for the Efficiency House Plus with Electromobility**

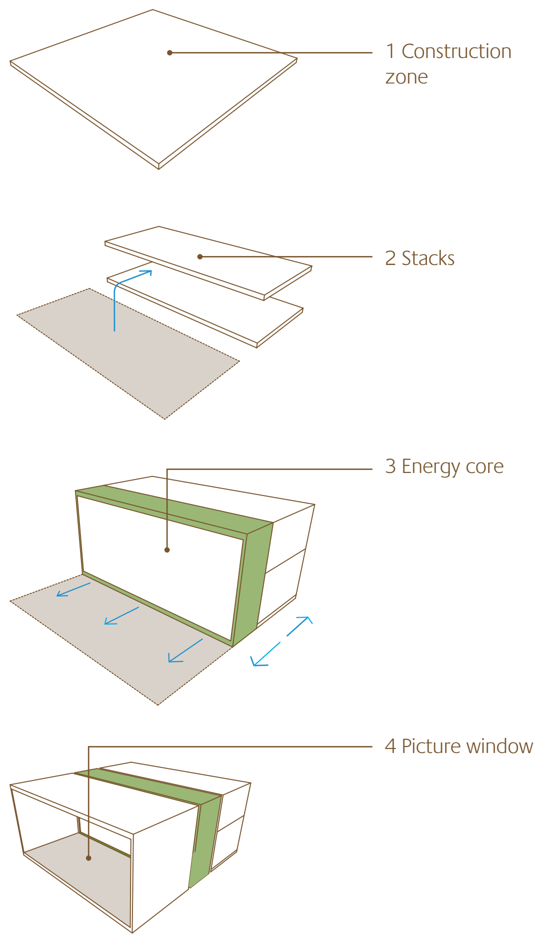


Fig. 11: **Design components**

The Efficiency House Plus with Electromobility demonstratively embodies the factors that are of the greatest significance for an energy-efficient structure:

- Optimized construction with regard to the urban location;
- The highest level of compact design;
- Maximization of energy gains and minimization of thermal loss through the building shell;
- Optimization of the structural technology without any loss of comfort to its inhabitants;
- Assurance of energy needs through renewable, locally generated energy.

The home's objective is to provide the users and inhabitants with the highest level of comfort – and to simultaneously ensure that an optimal energy balance can be achieved. To do this, the suitability and the orientation of the construction site were carefully analyzed. The Efficiency House Plus utilizes the entire available site, thus maximizing the roof surface which can be employed to generate current from a solar cell installation. The closed façade on the north side minimizes thermal losses. The south side, also equipped with a solar cell system, maximizes energy recovery. The entrance to the home lies off the Fasanenstraße – on the west side – where the picture window is and where the electric vehicles are parked and charged. A tree-covered area lies to the east of the home, faced by a private terrace.

Efficiency House Plus with Electromobility

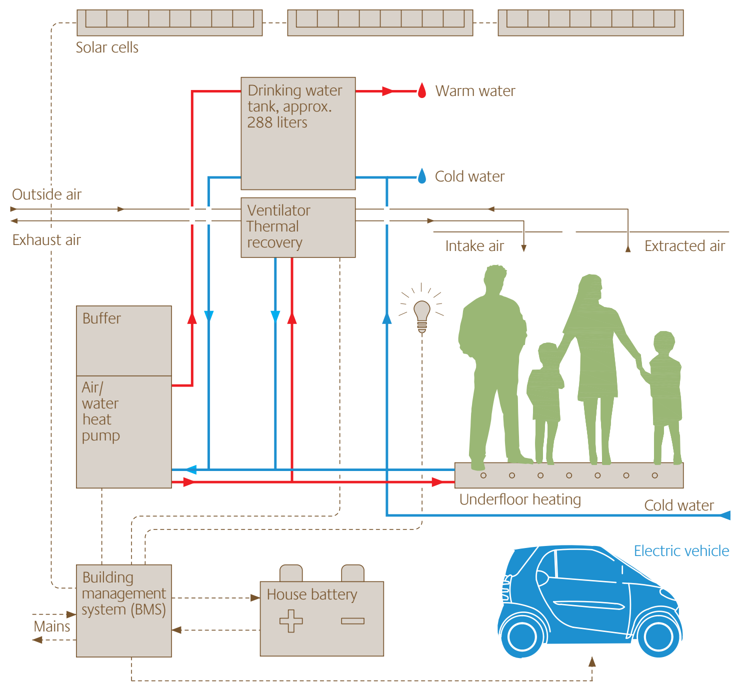


Fig. 12: **Schematic diagram of the technical concept**

The living areas cover two floors: The ground floor contains the living and dining areas; the upper floor contains the bedrooms. The "energy core", which comprises all the home's technical functions, represents the interface between the house and mobility. Behind the picture window facing the public street, the home's electric vehicles can be parked and recharged. Here, interested individuals can obtain additional information regarding the home and its characteristics.

The energy concept combines proven, familiar and innovative components. Energy is generated from two sources. An air-water-heat pump recovers the necessary heat from the ambient air in winter. The solar cells on the roof and along the southern façade generate current. This current is either available immediately or – after being briefly stored – can be utilized later or can be used to charge the electric vehicles. Any additionally generated power can be fed to the public supply grid. Innovative technology and intelligent energy management allows bi-directional battery operation – that is, both as a power consumer, as well as a power supplier to the public grid.

Gross floor area:	181 m^2
Net floor area:	147 m^2
Gross room area:	645 m^2
Heating requirement:	21.1 kWh/m^2a
Heating: Air/water heat pump Compact ventilation device Thermal output:	5.8 kW
Hot water tank:	288 litres
Ventilation:	400 m^3/h
Mechanical ventilation Heat recovery:	> 80 %
Roof solar cells:	98.2 m^2 14.10 kW_p
Façade solar cells:	73.0 m^2 8.0 kW_p
Projected energy generation:	16,625 kWh
Projected energy consumption: (incl. 30,000 kilometers annually for driving)	16,210 kWh
Projected balance:	+ 415 kWh

Fig. 13: **Technical specifications**

Architectural Implementation and Flexibility

The efficiency house is also characterized by its flexible utilization concept. Its interior can be adjusted to meet changing user requirements without the need for any major structural alterations. With the exception of the kitchen, the ground floor has been designed on an open plan. The upper floor has few barriers, that is, when needed, the entire floor, together with the entry area can be redesigned as a complete open plan without the need for any major structural alterations. The home has a modular design and, if required, can be reconfigured to meet other demands or needs, for example, as a site at which information can be exchanged.

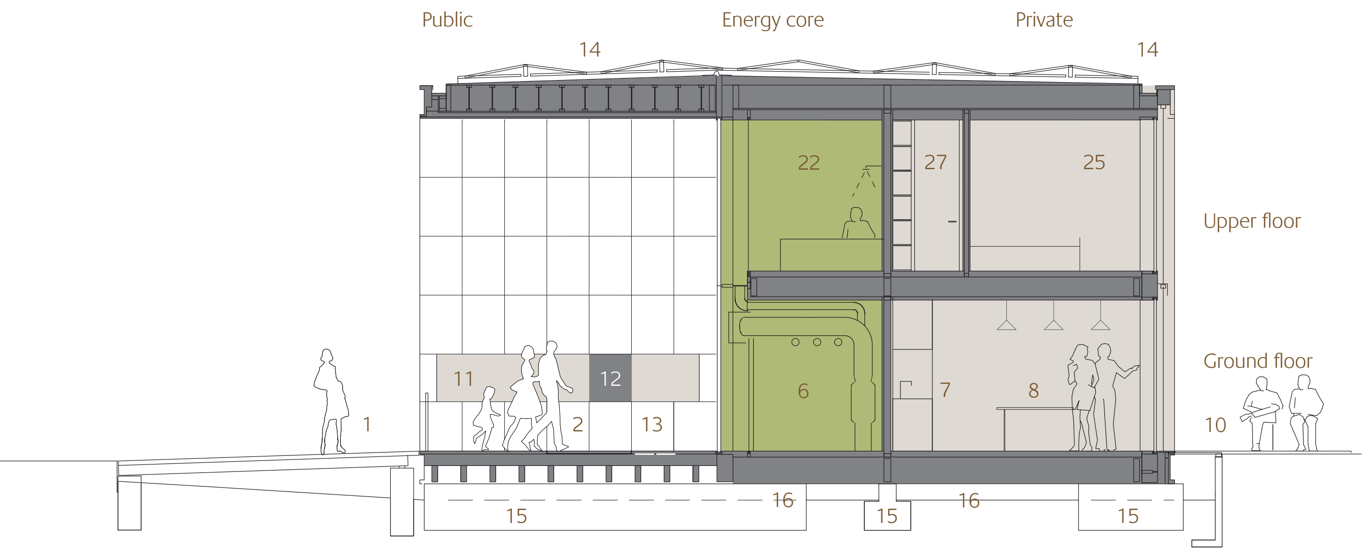


Fig. 14: **Cross-section A-A**

Fig. 16: **Floor plan of the ground floor as a living area**

Schematic key
1 Ramp
2 Picture window
6 Household technology
7 Kitchen
8 Dining area
10 Terrace
11 Information display and screen
12 Conductive charging system
13 Inductive charging system
14 Solar cells
15 Reinforced concrete foundation strip
16 Air space under the floor panel
22 Bathroom
25 Child 1
27 Hallway

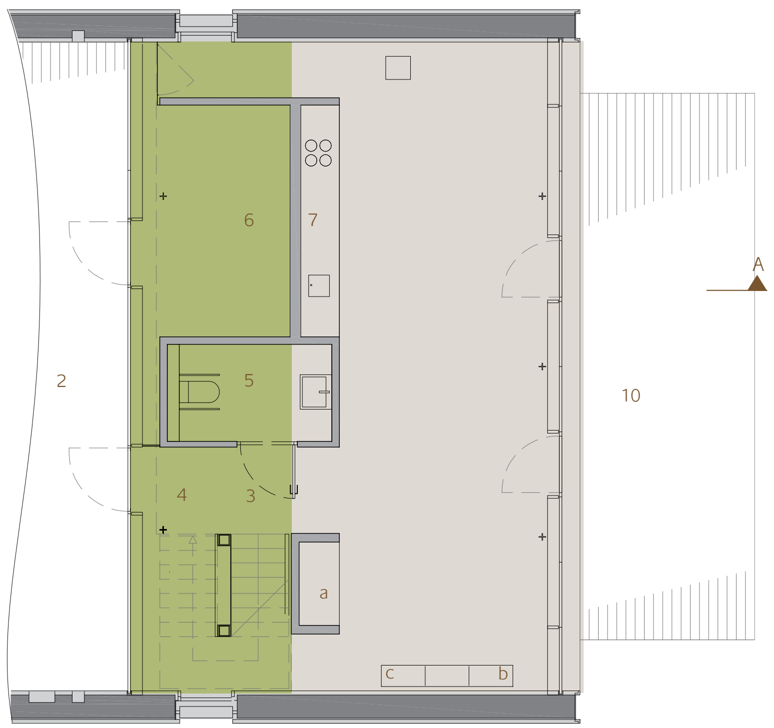


Fig. 15: **Floor plan of the ground floor for events**

Ground floor key
1 Ramp
2 Picture window
3 Entry area
4 Closet
5 Bathroom, no barriers
6 Household technology
7 Kitchen
8 Dining room
9 Living area
10 Terrace
11 Information display and screen
12 Conductive charging system
13 Inductive charging system

Key to furnishings
a Shelf with media access
b Screen/television
c Sideboard/information

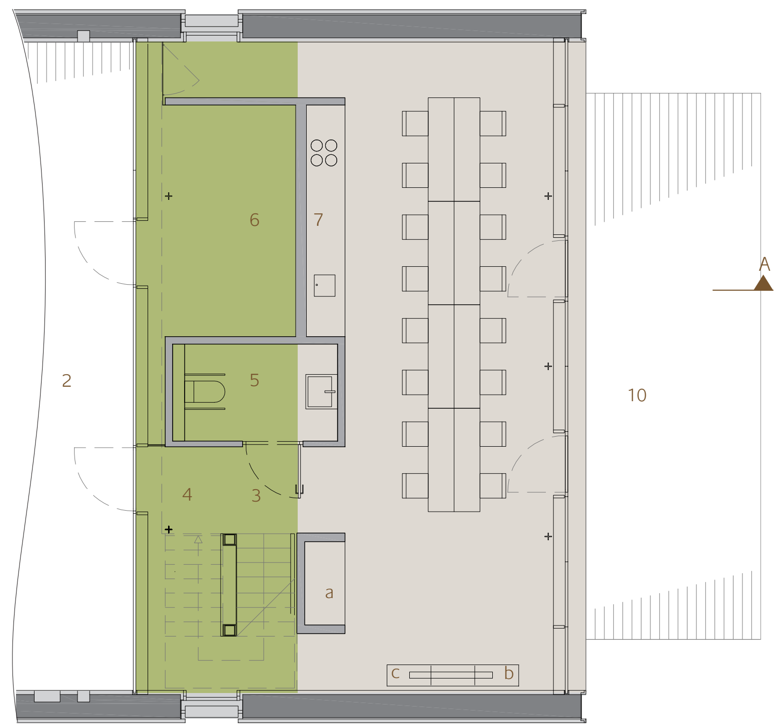


Fig. 17: **Floor plan of the ground floor for conferences**

Fig. 18: **Floor plan, upper floor when employed as a living area**

Upper floor key
21 Stairway/hallway
22 Bathroom
23 Domestic supplies area
24 Parents
25 Child 1
26 Child 2
27 Hallway
28 Open area, picture window
29 Employee rest area (if required)

0 1m 5m

Fig. 19: **Floor plan, upper floor when employed for events/research**

Ventilation

A mechanical ventilation and extraction system provides very good air quality for the interior spaces. In addition, every lived-in room within the home can also be manually ventilated. The heat contained in the extracted air is recovered prior to the exhaust air being channeled into the space between the ground and the floor panel.

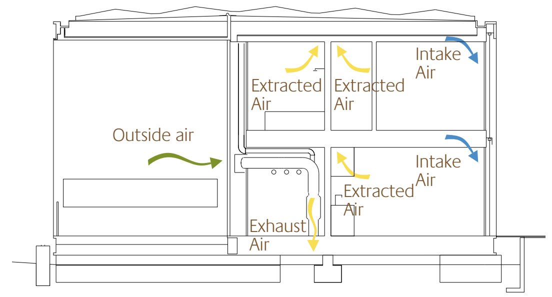


Fig. 20: **Schematic diagram of the ventilation system**

Illumination and Lighting

The completely glass-enclosed east and west faces provide a generous feeling of space and allow a great amount of daylight to enter the home. On the east side, an exterior, adjustable sun screen provides shade. The sun screen's louvers prevent the home from overheating and, if needed, can act to shield inhabitants from the rays of a low-lying sun. On the west side, this function is fulfilled by the picture window so that no exterior sun protection is required. Energy efficient LED lights are used to illuminate the home. The lighting is equipped with dimmer switches and is controlled by motion detectors.

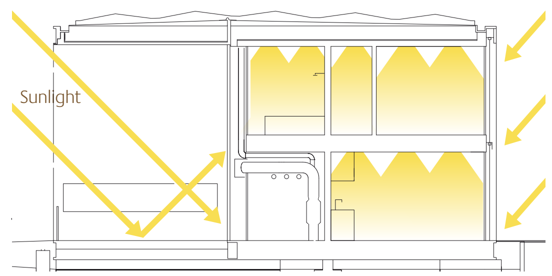


Fig. 21: **Schematic diagram of the lighting/ illumination system**

Initial Equipment

The home has been completely furnished and contains all other required fittings. Wherever possible, ecologically compatible materials and products were employed, to permit as near complete a recycling as possible. The interior fittings are esthetically sophisticated while still embodying the guiding thought driving a sustainable home down to the smallest detail. In their own way, they quite emphatically show that, even today, products which meet the needs for sustainability and recyclability are available on the market.

Fig. 22: **Spatial distribution**

Exterior view, looking in from the garden

View of one of the children's rooms (upper floor)

Open kitchen in the living and dining areas (ground floor)

View from the master bedroom into the hallway (upper floor)

Bathroom

View through the picture window from the front

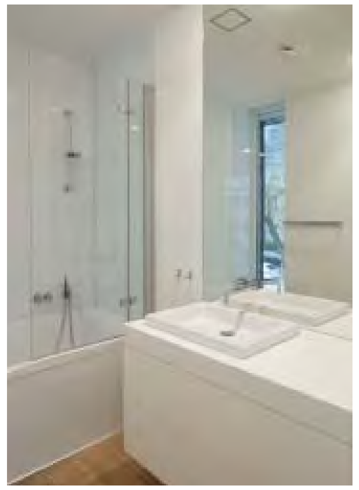


Fig. 23–28: Photographs taken after building completion

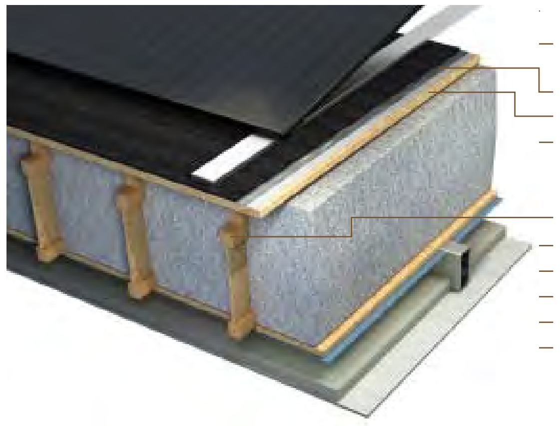


Fig. 29: **Roof structure over the living area (insulated)**

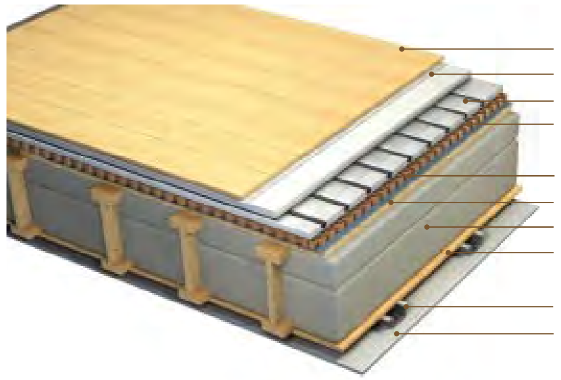


Fig. 30: **Structure of the ceiling between the ground and upper floors**

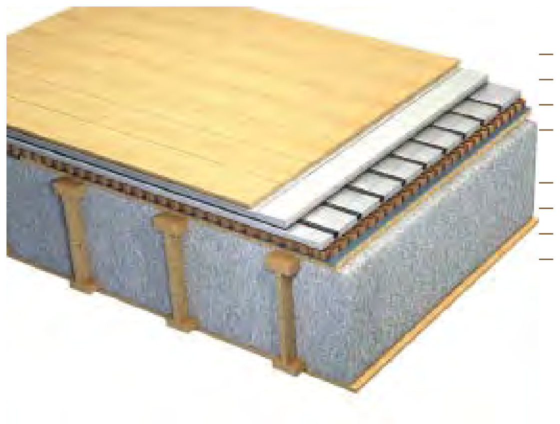


Fig. 31: **Floor panel structure**

Efficiency House Plus with Electromobility

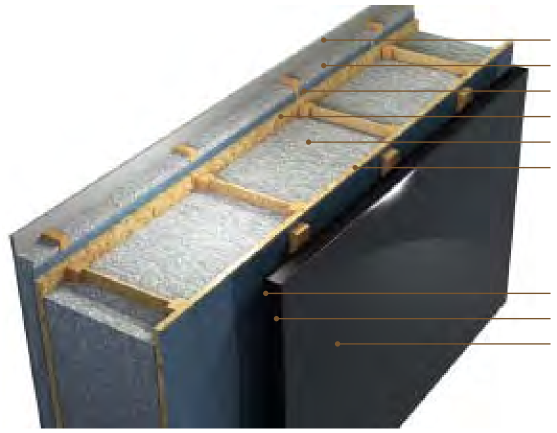


Fig. 32: **Structure of the insulated, opaque exterior wall**

Structural Shell: Frame, Construction and Superstructure

The home is constructed on a slab, made of prefabricated, reinforced concrete strip and individual foundations. These foundation elements are surrounded by the cantilever timber panel ground floor structure. The roof and ceiling construction are also made from cantilever timber panels, as are the external and internal bearing walls. Along the entire, glazed east and west façades, individual steel supports provide additional strengthening for the ceiling and roof constructions.

The timber panel components of the home's shell are highly insulated, thanks to blown-in cellulose fibers. Additional hemp insulation provides a high level of sound insulation for the interior.

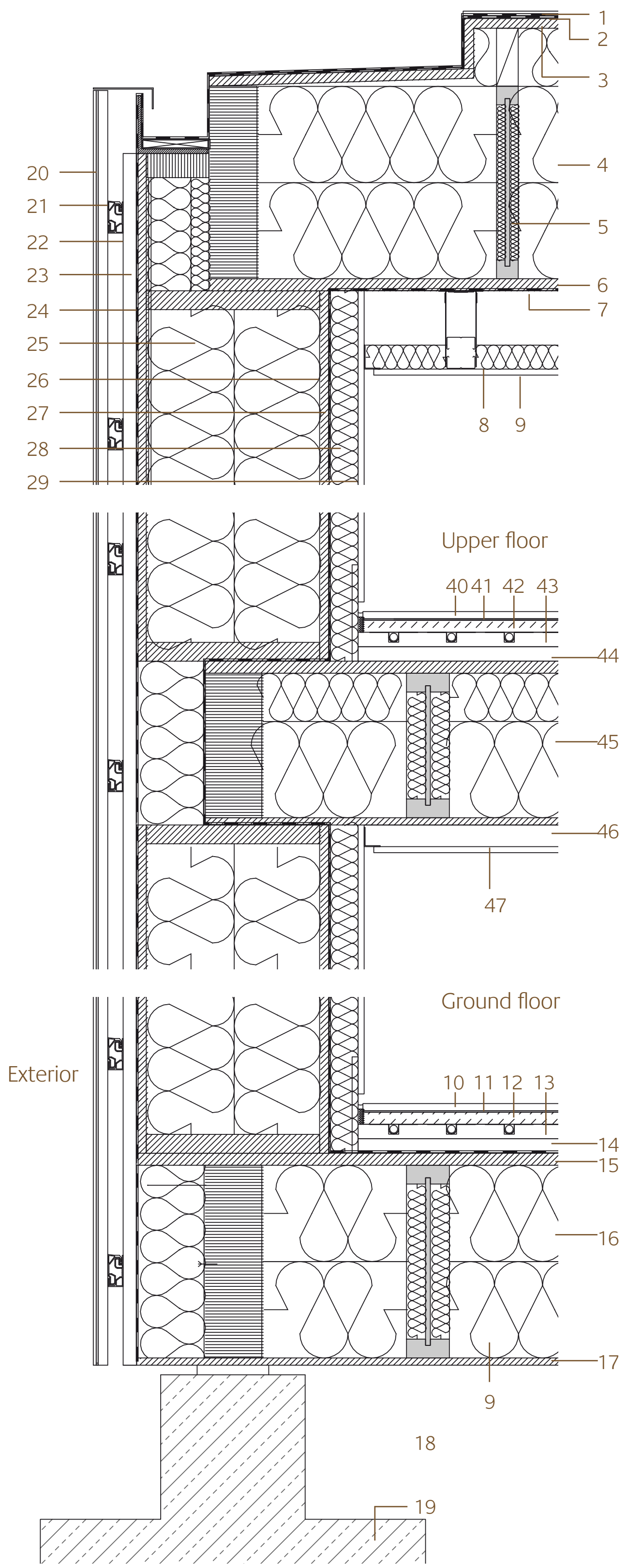
To the extent permitted by the current state of technology, no adhesives are employed to mount the wall and floor coverings so that, in case of a subsequent reconfiguration or redesign, individual types can be separated into clearly identifiable materials.

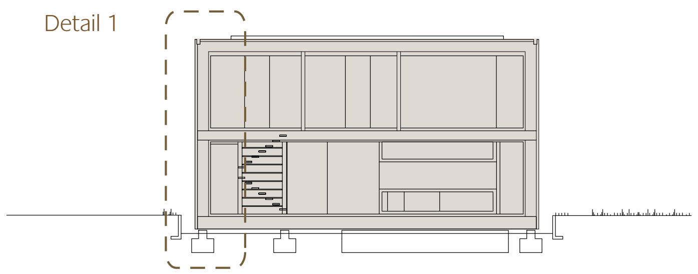
The picture window area remains uninsulated but is accessible for the electric vehicles. The wood constructions open to the effects of weather in the picture window area are constructed from larch – a very weather-resistant native wood. The floor in the picture window area is made of solid oak, so that, here too, no chemical protection is required. The construction of the terrace is similar.

The generous glass façades are equipped with triple-insulated glass, the gaps between the panes being filled with argon, a noble gas. Beyond this, the glass façade along the east side is also equipped with an exterior sun shield made of aluminum slats. This shield can be either automatically controlled, or also manually.

The closed façades are clad on the south side with back-ventilated, thin-film solar cells and on the north side with color printed glass that looks the same but does not generate power. Almost the entire roof area is covered with mono-crystalline solar cell modules.

Details





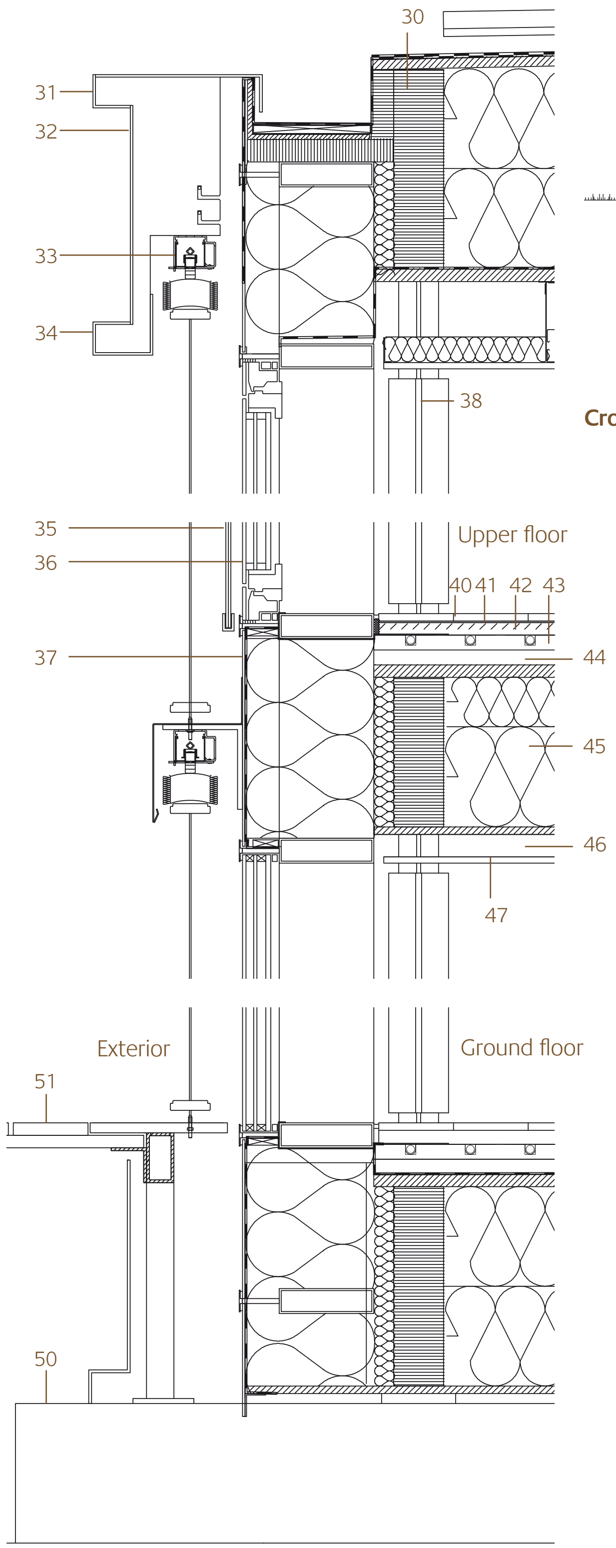
Cross-section through the opaque façade for living

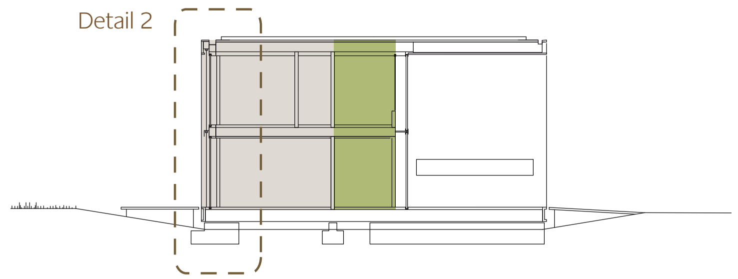
Roof structure
1 Structural protective matting
2 Plastic insulation, mechanically secured
3 OSB panel, 20 mm
4 Cellulose insulation
5 Board layer bearers or board girder bearers
6 OSB panel, 25 mm
7 Moisture adaptive vapor lock
8 Hemp matting, 50 mm
9 Particle board panels,12.5 mm

Floor structure
10 Wood paneling, floating installation, 15 mm
11 Compensation layer (cork), 3 mm
12 Dry plaster, 2 x12.5 mm
13 Wood fiber elements in aluminum casings for the installation of the underfloor heating, 30 mm
14 Honeycomb element with filling, 25 mm
15 OSB panel, 25 mm
16 Cellulose insulation, 400 mm
17 Moisture resistant particle board panel, 15 mm
18 Ventilated gap
19 Strip foundation

Wall structure
20 Thin-film solar cell modules
21 Agraffe profiles
22 Vertical panels and back ventilation
23 Moisture barrier
24 OSB panel, 20 mm
25 Cellulose insulation
26 OSB panel, 20 mm
27 Vapor barrier
28 Installation level with hemp matting, 60 mm
29 Plasterboard panels, 12.5 mm

Fig. 33: **Detail 1 Cross-section through the insulated, opaque exterior wall**





Cross-section through the transparent façade for living

Transparent façade
30 Laminated timber strips, 100 x 400
31 Aluminum slat, black
32 Aluminum slat, gray
33 Sun shield (slats)
34 Aluminum slat, white
35 Railing VSG, 10 mm
36 Triple glazing
37 Aluminum slat, gray
38 Steel cross member

Intermediate ceiling structure
40 Wood paneling, 15 mm
41 Compensation matting, 3 mm
42 Dry plaster, 2 x 12.5 mm
43 Wood fiber, underfloor heating, 30 mm
44 Paper honeycomb element with filling
45 Hemp insulation
46 Suspended substructure, 45 mm
47 Plasterboard panels, 12.5 mm

Miscellaneous
50 Strip foundation
51 Terrace, oak panels

Joints
The details indicated here illustrate how, as early as during the planning and implementation phases, the path was already set for the subsequent demolition and recycling of the employed materials.

Fig. 34: **Detail 2 Cross-section through the east-facing glass façade**

Home Technology

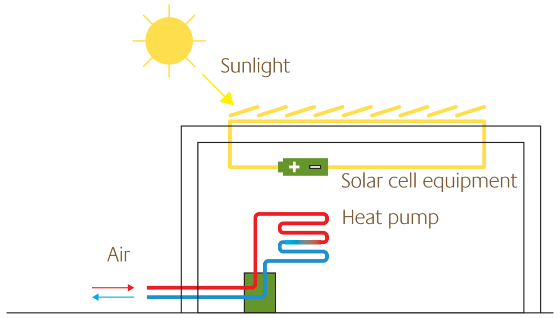


Fig. 35: **Schematic diagram of energy generation in the Efficiency House Plus with Electromobility**

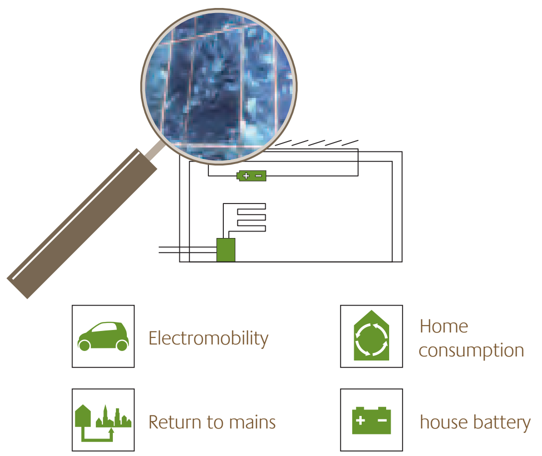


Fig. 36: **Solar cell functions**

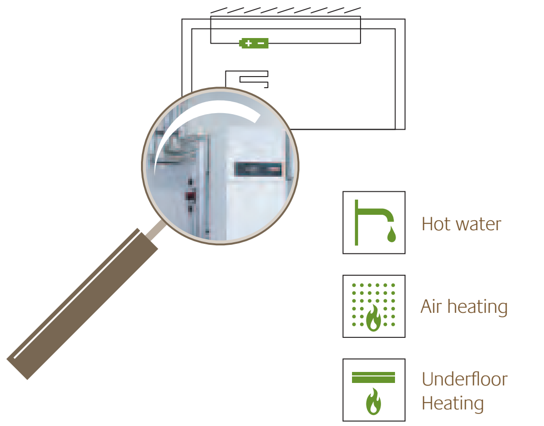


Fig. 37: **Heat pump functions**

The technical equipment is housed in the so-called “energy core”, in the glassed-in technical area. This area is an integral part of the home’s information concept. The technology is visible and comprehensible for all visitors.

The Efficiency House Plus with Electromobility utilizes the sun as its power source in two different ways: solar cell equipment generates current from the incident sunlight, while a heat pump uses the exterior air as a source for creating hot water.

On an annual average, the solar cell modules on the roof and along the south face generate sufficient energy to meet all the home’s and electric vehicles’ requirements. The home as a power plant is easily comprehensible to visitors thanks to the visible solar cell surface coverage.

The Efficiency House Plus has been designed for an operating life of two to three years. Geothermal power will not be utilized as the expenses involved in the subsequent removal of the ground probes are unreasonably high. Instead, a highly efficient air/water heat pump will be utilized to extract thermal energy from the outside air.

Heat requirements during the winter months will be met by an underfloor heating system. The greatest possible care was also taken during the installation of the heating system, to ensure that mechanical fittings could – to the greatest possible extent – be recycled. A dry screed in the floor design provides additional storage volume in the otherwise very lightweight wood construction. Because of the heater’s low inertia, the building can quickly react to different load states in the individual rooms. Examinations in Berlin have indicated that the mean air temperature is less than 18°C for 312 days, and that heating is therefore required. However, thanks to the solar profit which the home is able to achieve, the actual number of heating days is significantly less.

No cooling will be employed in the Efficiency House Plus with Electromobility. Controllable, outdoor shading elements will prevent any overheating in the summertime. By combining the home’s technology in the energy core, wiring paths can remain short. All distribution and ventilation channels are as short as possible and, beyond this are thermally insulated, so that distribution losses can be kept at the absolute minimum.

Fig. 38: **Visualization of the technical area, viewed through the picture window**

The solar cell equipment located on the roof employs high performance, mono-crystalline modules with a high level of efficiency; these modules are particularly well suited for the conversion of direct solar radiation into electric energy. Amorphous, thin-film modules are employed in the façade; these modules are particularly well-suited for handling diffuse irradiation of the kind frequently encountered in façades. A portion of the electric current obtained from solar energy is employed to operate the air/water heat pump, which converts energy collected from the outside air into heat for the home – and this even at low outside temperatures. The resulting thermal energy is distributed through the underfloor heating and the mechanical ventilation.

The employment of renewable energy in the Efficiency House Plus is highly weather-dependent. Storage systems help better balance out supply and demand. Locally generated power is stored by a 40 kWh lithium ion battery, which comprises “secondary use” vehicle batteries. Due to their loss of storage and performance of up to 20%, these batteries are no longer suitable for employment in vehicles. Initial simulations have, however, shown that there is absolutely no reason why they cannot continue to function as stationary storage batteries for many years. The cells employed in this project have been provided by BMW (Mini E).

The objective of the house battery is to serve as buffer storage in order to increase the employment of self-generated current. The current stored in the battery is available for any household task, as well as to recharge the electric vehicles.

Just as is the case with the charging technology, the entire household technology can be accessed by the home’s inhabitants via two touch screens as well as being able to be monitored and controlled via smartphones.

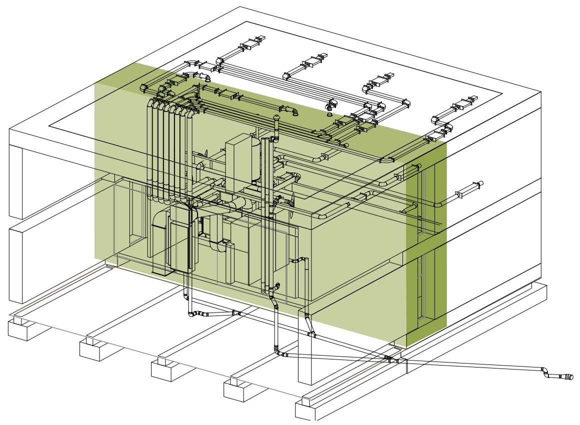


Fig. 39: **Wiring in the Efficiency House Plus with Electromobility (schematic diagram)**

Energy Efficiency at the Building/ Vehicle Interface

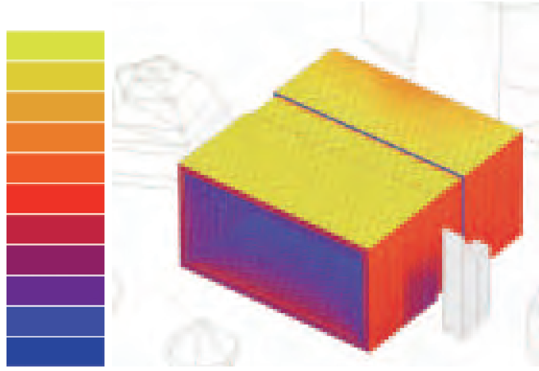


Fig. 40: **Irradiation analysis (direct and indirect irradiation), annual global irradiation**

Fig. 41: **Shading analysis: shade track on 21 June between 9.00 a.m. and 5.00 p.m.**

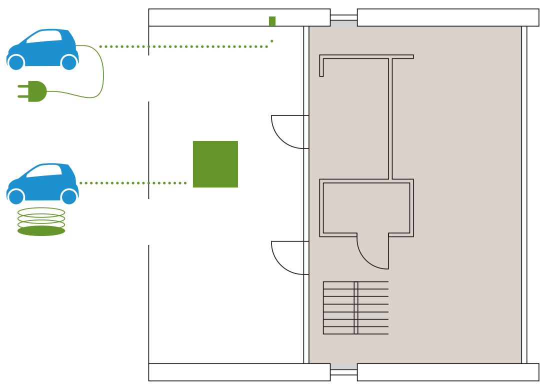


Fig. 42: **Electric vehicle recharging systems** (schematic diagram)

The efficiency of the solar cell modules and other systems in the conversion of energy continues to increase. Similar improvements can also be observed with regard to insulation and energy management. These developments allow the transition from buildings with a balanced energy footprint (zero-energy houses) to buildings that produce an energy surplus over the course of the year (plus-energy houses).

The annual energy need of the Efficiency House Plus is projected to be less than 10,000 kWh. This can be obtained by the concerted utilization of energy-efficient equipment technology coupled with intelligent control technology. With regard to the annual energy produced, more than 16,000 kWh are projected, allowing a significant energy plus to be generated for use as electromobility. The annual assumed driving performance of the electric vehicles is considered to amount to a total of 29,000 km, of which approximately 25,000 km is for the two vehicles and approximately 4,000 km for the electric bicycle. For this annual assumed driving performance of 29,000 km, an annual need of approximately 6,000 kWh is anticipated – which can be generated by the solar cell array.

The Efficiency House Plus with Electromobility is also connected to the public power mains and is able to tap electric power from it, or to feed excess power to it. With the option of storing the locally generated current in the battery and thereby making it available at a later time, the dependence on the public supply can be significantly reduced. This results in a significant contribution to the avoidance of power peaks. On an annual average, the home's energy requirements are met, while the vehicular needs are more than covered by the generated current.

The vehicles can be conductively charged via a standardized connector at a charging column, or they can be inductively recharged. With regard to inductive recharging, the charging current is transferred electromagnetically from a coil to another, making this process contact-less. The frequent plugging in and unplugging the power cables and the charging columns, which are frequently perceived as being annoying in urban surroundings are therefore avoided. This charging technology continues to operate in freezing or wet weather. Frequent recharging cycles avoid deep recharges and therefore increase the service life of today's lithium ion batteries. This comfortable recharging technique could also increase user acceptance.

Home and Equipment Simulation

A conscientious location analysis paved the way for a successful energy concept. With regard to optimizing planning with respect to comfort and energy efficiency, as well as to be able to project the energy requirements during use, the Efficiency House Plus was examined with the aid of dynamically linked equipment and home simulators. During the planning phase, the dynamic simulation process was employed as an iterative optimization tool, that is, based on the results of a simulation process, additional deductions regarding the next steps were made, which led in turn, to further simulation modifications.

In such a simulation a variety of constraints – such as the structure shell's physical properties, the intended final employment and the projected user behavior, the structural technology, as well as local climate data – all needed to be considered. Individually, this means:

Physical structural characteristics: For every simulation process during planning, the current geometries and physical structural characteristics were employed. Here, particular attention was paid to the large glass façades including their solar shield which, due to solar thermal sources on the one hand and transmission heat sinks on the other, played a major influence on the home's energy requirements and comfort. A conservative estimate was made with regard to the air infiltration – that is, the sealing ability of the shell. After completion of the home, this value will be tested in accordance with the sealing test so that it can then be adjusted in the next simulation.

Utilization: For the simulation, the home is divided into zones, each of which is assigned a specific utilization profile. This means that, for habitation, lighting, ventilation and desired temperature range, specific load factors can be applied. Depending on the intended use and the day of the week, these can differ. For the Efficiency House Plus, all profiles are based on a four-person family.

Climate: Climatic conditions greatly influence the result of a simulation. From the outset, a test reference year obtained from the German Weather Service was employed for the optimization during the planning and to examine the energy objectives.

Structural technology: The specific equipment effects were also continuously adjusted for every simulation. Thanks to ongoing feedback between the simulation and the planning, the precision of the results increased continuously.

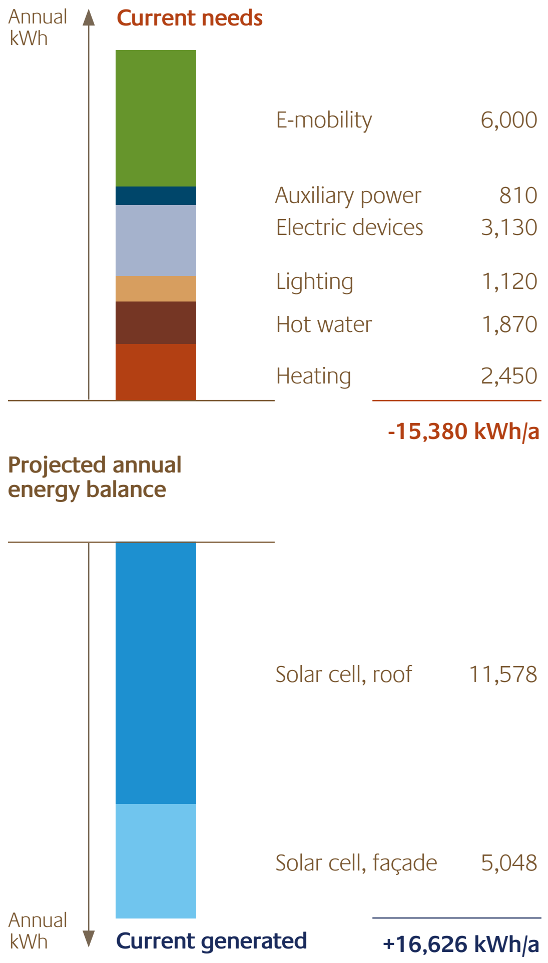


Fig. 43: **Projected annual energy generation and energy requirements, valid as of October, 2011**

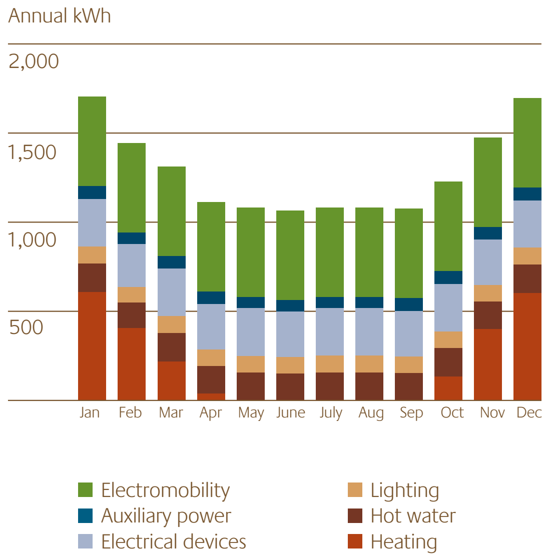


Fig. 44: **Projected energy requirements in kWh/a**

Energy Management System

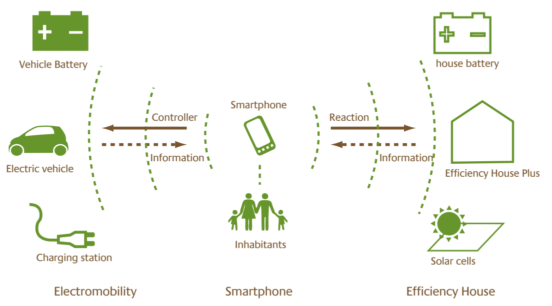


Fig. 45: **Control concept**

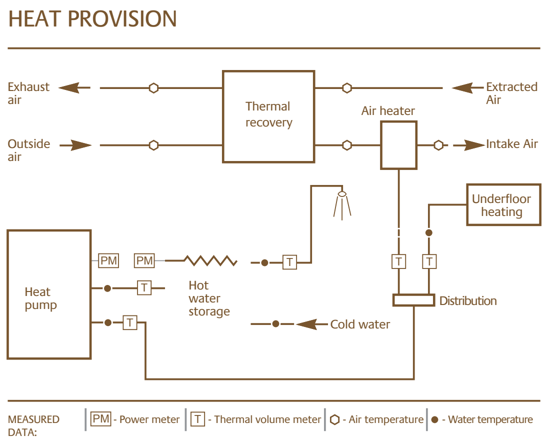


Fig. 46: **Plan depicting measuring points to determine the energy flows in the home's heat supply system**

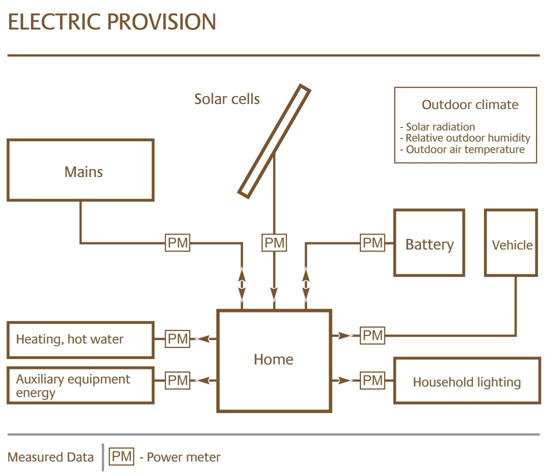


Fig. 47: **Plan depicting measuring points to determine the energy flows in the home's power supply**

While the "smart grid" controls the invisible energy flows between mobile and immobile current generators, between storage and consumption, an information and control system serves to increase user acceptance of this energy symbiosis. Smartphones are used to set up such an information and control system. Many users already use smartphones to organize their daily activities. Many automobile manufacturers are encouraging the integration of smartphones into the information and entertainment concepts of their vehicles. The next step is the application which allows the driver to access all relevant information.

The autonomous energy management system employed in this project permits the energy flows throughout the entire system to be optimized. These include the solar cells, the public power mains, the vehicles as well as the thermal and power storage devices. Aside from the objective of creating a positive energy balance, a further objective lies in a minimization of the amount of consumed mains power through the greatest possible utilization of energy generated in the home. Mains-saving operation can be achieved by avoiding consumption and supply peaks. The financial gains from mains supply is also taken into account by preferably supplying power during high rate periods.

Aside from consumption and supply from and to the thermal and current storage devices, the other options of controlling current consumption consist of, wherever possible, shifting consumption times to more beneficial rate periods. Electric vehicle recharging management will be adjusted to the anticipated power offerings so that it will primarily take place either from the house battery during excess power periods or will occur overnight from the public mains. While adhering to comfort criteria, the home's heating can also always be influenced.

A significant characteristic of the system is its ability to utilize weather forecasts to predict the current generated by the solar cells and the home's thermal requirements. Consumption of electric power by the inhabitants and their vehicles is also projected. The employed, intelligent processes are adaptive, that is, they independently adjust to changes in weather conditions and to the inhabitants' behavior patterns.

Measured Validation of the Energy Employed by the Efficiency House Plus with Electromobility

The energy flows of the demonstration structure are collected and assessed within the context of the monitoring program. The measuring configurations have been laid out in such a way that, on the one hand, complete monthly energy balances can be generated and, on the other, an assessment of the performance of the installed equipment is possible. Further, the air temperature and CO^2 concentration in representative areas undergo continuous monitoring, while the usable and excess contributions from the solar cells as well as the consumption of all devices in the home are continuously recorded.

In order to determine the heat pump's efficiency, the current amounts required to run the pump and the thermal volume fed to the heating distributor are both measured. On the consumption side, the heat volumes needed to heat the rooms as well as to heat the water used in the bathroom and kitchen are measured. Any thermal losses from the hot water storage are determined and, if required, the current required by the hot water tank's emergency heater is collected.

Parallel to the heat supply, the home's electrical supply is also assessed. For this, the operating data of all primary consumers and of the battery storage are collected separately. Aside from this, the energy required to charge the electric vehicles is also recorded. The current generated by the solar cells is compared with this value and a ratio to overall consumption is generated. Totaled over the course of the year, this should indicate that the current generated by the solar cells exceeds the total current consumption for the home and for electromobility.

Information Concept

Monitors and displays are integrated into the home's structure in the area around the so-called "picture window". Here, interested visitors can find information regarding the home's energy balance.

Motion detectors detect the presence of individuals in the outdoor area and activate the displays to initiate the transmission of information. The viewer is given information regarding the home's energy performance: for example, the current or average performance of the solar cells.

Information concerning the history and development of the Federal Government's Efficiency Houses Plus are shown on a separate screen.

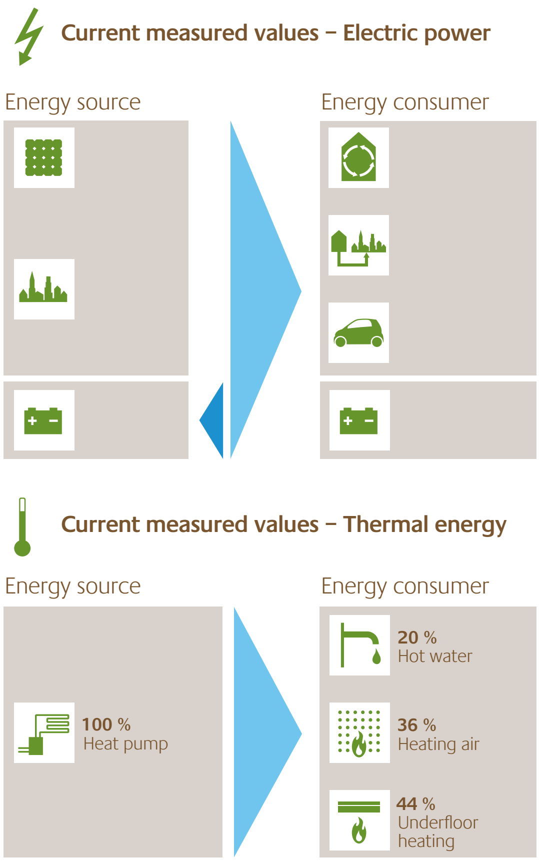


Fig. 48: **Visual information on the Efficiency House Plus with Electromobility: e.g., energy flow indication**

Material and Recycling Concept

A material and recycling concept specifically developed for the Efficiency House Plus allows the entire structure to be torn down at the conclusion of the anticipated, two to three-year project period, and to return all employed materials to the material cycle.

A portion of the building materials will be recovered by the manufacturers for immediate reemployment at other building projects (e.g., the solar cells); all remaining materials will be recycled. To accomplish this, the building materials needed to be selected so as to ensure that all products can either be biologically decomposed or that a technical process exists which allows them to be processed into new recyclable building materials. In order to be able to sort materials into separate material groups during demolition, approximately 20 application types were defined to be collected as separate fractions during demolition. Aside from the selection of the materials, the employed connection technique plays a decisive role when it comes to making the materials separable. The majority of connections are made by means of easily separable screw, click and clamp connectors.

With the aid of this recycling concept, not only can large volumes of waste be avoided, but the energy balance is also positively influenced.

With the recycling process a significant proportion of the "grey energy" used for manufacturing the primary materials can be retained and savings can therefore be made in the production of recyclable building materials.

Fig. 49: **Material selection and recyclability**

Efficiency House Plus with Electromobility

Sustainability Assessment

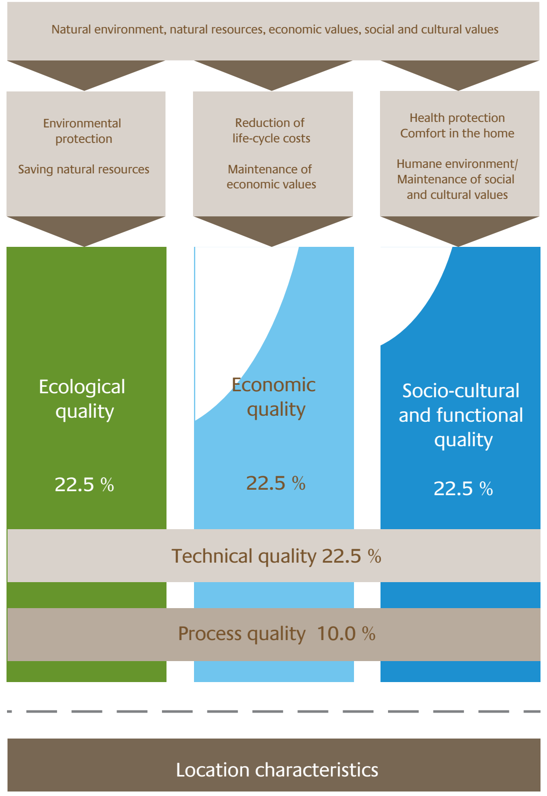


Fig. 50: **Overview of the factors influencing sustainability**

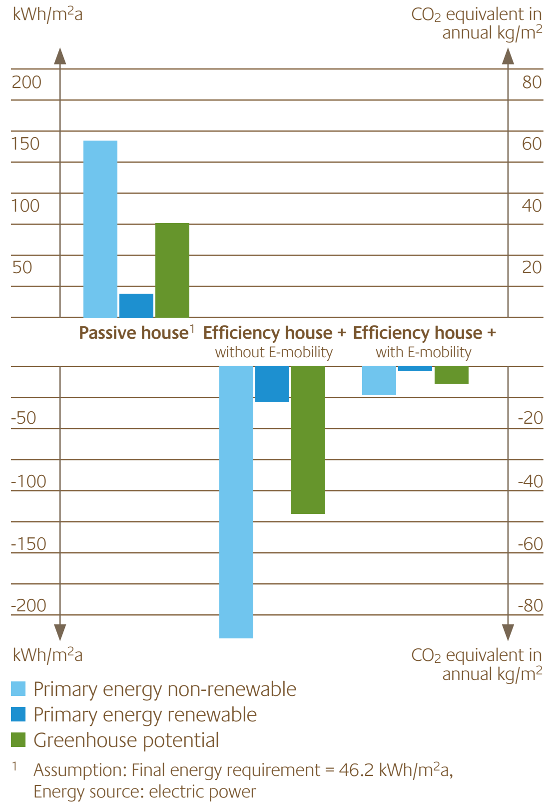


Fig. 51: **Extract from the ecological balance in accordance with the BNB, operation only, valid as of October, 2011**

The planning process was based on an integral understanding of sustainability, which went beyond mere energy efficiency. Among other items considered were the principles of existing certification systems. Using the Sustainable Construction Assessment System (Bewertungssystem Nachhaltiges Bauen (BNB)) the BMVBS has prepared a scientifically based, comprehensive evaluation instrument for office buildings. Aside from the ecological quality, the system also assesses the economic quality as well as the socio-cultural and functional quality, thus simultaneously also looking at all three pillars affecting sustainability. In addition, there is also an assessment of the so-called "cross-sectional qualities", namely the technical and process quality. When transferring these demands to residential buildings to the underlying certification system, the receipt of a "gold certificate" can be assumed. During inhabitation, an excess current is generated, resulting in low operating costs. The flexibility of the basis structure and the structure's adaptability to changing requirements should also be emphasized, as these contribute to increased value retention. Thus, future, decisive economic factors can be looked at against the background of changes in society and continually rising energy costs.

With regard to ecological quality, water-saving fittings, an extensive recycling concept and the elimination of environmentally hazardous materials protect the natural resources, without in any way leading to a reduction in comfort. The same applies to the outstanding energy balance which, thanks to systematic optimization is positive and even is significantly higher than that for a passive house. Fig. 51 illustrates the achieved ecological balance and compares it to that attainable for a passive house. In view of the limited area available, great efforts were made with regard to socio-cultural and functional quality. Among other aspects, the entire structure is free of sills and has few barriers and, by means of simple interventions, it can be made completely barrier free. The subsequent installation of a stairway elevator has been included in the planning as an option. Thermal and acoustic comfort, the quality of the air and even incidental qualities such as a place for baby buggies near the door and many other details were considered.

The Role of Electromobility

Fig. 52: **smart fortwo electric drive (ed)**

Fig. 53: **Mercedes A-Klasse E-CELL**

Fig. 54: **BMW ActiveE**

Fig. 55: **Volkswagen Golf Blue-e-Motion**

Fig. 56: **Opel Ampera**

Fig. 57: **Audi A1 e-tron**

Electromobility is a key technology for a sustainable transport system. Electric vehicles are silent and produce no hazardous materials locally. They are also capable of utilizing all renewable power sources for mobility. By 2020, one million electric vehicles are to be on the roads in Germany. However, electromobility will only make a substantial contribution to meeting the climate protection objectives once the required current is generated from renewable resources. For this reason, constructed infrastructure and buildings should also be used to generate power.

The Efficiency House Plus with Electromobility shows the synergies which exist between the subjects of living and mobility. Completely in line with the motto: "My home, my filling station", the home supplies the vehicle, right at the door. The inhabitants of the building can use the newest electric vehicles from a variety of manufacturers. The plan includes the Audi A1 e-tron, the BMW ActiveE, the Mercedes A Class E-CELL, the Opel Ampera, the smart fortwo electric drive and the Volkswagen Golf blue-e-motion. Aside from these, electric bicycles will also be available. Electromobility only functions as a complete system. For this reason, the project will also examine a variety of charging systems. A smartphone application will allow the inhabitants to choose when they wish to make use of a vehicle and the mileage they plan to travel. Based on this user information together with the home's energy state, the controller system then determines an optimal charging strategy for the vehicles. A buffer battery holding around 40 kWh of charging capacity ensures that the vehicles can also be charged at night, when the solar cells do not provide any current. A quick-charge connector with a charging capacity of 22 kW shortens the charging time by employing high current sufficient for a distance of 100 km to approx. 30 minutes.

The project is also looking into inductive charging as yet another charging technology. Here, the charging current is transferred in a safe and contact-free manner via an electromagnetic field from a primary coil mounted in the parking area to a secondary coil on the vehicle's underside. Advances in the performance electronics permit a high transfer rate of more than 90 percent. The method operates reliably under all weather conditions – even in case of freezing and rain. The Berlin project's inductive charging system possesses a transfer performance of 3.2 kW. The Efficiency House Plus, Berlin, project shows that the technologies for totally regenerative energy provision already exist today, and that they are suitable for everyday use. Electromobility and future buildings must go hand-in-hand.

Efficiency House Plus with Electromobility

Fig. 58: **Erection sequence, August, 2011, through November, 2011**

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