Hamburg ahead

INTERNATIONAL BUILDING EXHIBITION HAMBURG

Smart Material House
Soft House

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Contents

A Introduction

A. 1 Smart Material Houses

"Smart materials" are materials, material systems, and products that can be derived from them which behave not in a static but a dynamic way, in contrast to conventional building materials. In other words, because of their nature, these materials react to changing environmental conditions and adapt to them. These special characteristics result from physical or chemical influences, such as varying temperatures or sunlight falling on the building material.

The building envelope is one of the most crucial elements: the use of smart materials in the façade can enable energy and material flows to be improved and kept as small as possible, since a large proportion of these materials draw energy directly or indirectly from the surrounding environment.

Smart materials can be found in nature. Microalgae, for example, can be bred in the glass sections of façades: they then use photosynthesis to turn solar thermal energy into heat energy, biomass, and heat. The façade itself becomes part of the building services.

A "Smart Material House" is a new form of residential building in which adaptable architectural designs can be combined with intelligent technologies and construction materials. As one of the main themes of the "Building Exhibition within the Building Exhibition", these constitute an architectural pilot project, using four exemplary building types to show how new technological approaches can be translated into a forward-looking architectural language, and traditional techniques reinterpreted.

As its starting point for the "Smart Material Houses" theme, the International Building Exhibition Hamburg (IBA) presented the following basic ideas. Smart materials are active, with a transformative character. They respond to changing environmental conditions. In an intelligent interaction with "smart technologies", this process can be extended to the level of networked building services, and can monitor and optimise the energy and material maintenance.

For this purpose, the existing categories of materials must be considered afresh, because smart materials, being active, take on opposing properties and functions at different times. Material and technological innovations in architectural history were always associated with a fundamental change in what architecture could and should be. These days, it can be observed that sustainability is the background to many design decisions.

- Smart materials and smart technologies, through their adaptive functions, make it possible to control energy and material flows sustainably.
- The adaptability of smart materials endows time processes with great significance.
- A performative understanding of materials and technologies enables and fosters a new approach to the architectural design process.

A paradigm shift towards decentralised infrastructure systems is becoming apparent. By decentralisation we mean the integration of urban functions into building technology. Water systems, power generation, the use of waste heat, miniature pumps, and combined heat and power are installed and deployed locally or in the immediate vicinity. Much of the energy consumed in buildings is to be recovered in the future from existing local anergy, to reduce the proportion of high exergy.

The infrastructures of the city need to be rethought and reorganised in this context.

- Through the integration of urban functions into building technology, the house becomes an actor in a (communicative, i.e. feedback) network. Accordingly, it performs additional functions, such as being a "power plant", providing "energy storage" or comprising a "communicative place" in the urban context.

- The building envelope is the central element of the energy exchange between inside and outside. It controls inflowing and outflowing currents of energy and the circulation of material. Using smart materials and smart technologies, building envelopes can
- actively regulate energy and material flows.
- Since the beginning of the modern period, building services have been bundled away, centralised and thus often rendered invisible. With the proliferation of smart materials, the material surface can itself become a medium carrying energy and information.
- The new technologies make it possible to multiply building services and distribute them to various surfaces. Materials become dynamic infrastructures that can produce variable, partly contradictory effects.
- With the extension of multifunctional surfaces, the time factor becomes an integral part of the design and simultaneously makes it possible to use space and buildings in hybrid ways.
- Along with the increasing importance of time processes, an "open layout" can be changed into a "reconfigurable layout".
- Reconfigurable layouts are generated from the mutability of the space, the transformability of the materials, and the adaptability of the technologies, no longer solely through their (static) openness to different uses.
- There is an emphasis on the "aesthetics of the phenomena", which mainly focuses on the behaviour of materials. It is not important how the material presents itself, but when it makes its appearance.

The architectural and building services concepts behind the "Soft House" are set out in detail in this booklet. The planning process is also outlined clearly, as a large number of alterations were made between the design stage and the final execution of the project. The reasons behind these changes were technical, financial, or functional, meaning that some original targets had to be adjusted.

Model projects are particularly liable to undergo planning changes; indeed, besides presenting innovative end products, building exhibitions also seek to test out construction methods and processes. Only when the planning process is examined is it possible to ascertain whether a model building project can serve as a good example for the use of smart materials in the twenty-first century. In addition to setting out technical details for experts, this booklet is intended to provide an objective assessment of whether the "Soft House" fulfils this aim, and whether and to what extent it has ultimately succeeded in achieving the goals set out before the planning stage.

After this short introduction the "Soft House" will be presented in brief, and then explained in detail. The architectural and building services concept will be described, followed by the planning process. Finally, the model project will be assessed. The focus throughout is on the "Soft House's" energy concept, the flexible roof, and the wood construction.

A. 2 Soft House Project Outline

FEATURES

- The dynamic textile membrane façade brings together renewable energy and architecture
- A sustainable solid wood construction
- “Smart curtains” allow the space to be used in a versatile way
- Energy produced can be used directly by the building

Fig. 1: View of the south façade, May 2013

Fig. 2: View from the southwest side, June 2013

Each of the four family-friendly terraced houses has its own garden. Built to a Passive House standard, the wood building, which has been left untreated on the inside, comprises a series of well-lit three-storey homes that are interconnected across all floors. The textile membrane on the building's southern façade is an innovative architectural feature.

The dynamic façade is responsive, turning towards the sunlight similarly to a sunflower. This enables the residents to adjust the view and the amount of light entering their homes. In summer the façade affords shade, while in winter it minimises energy loss and allows light to penetrate the interior.

PROJECT PARTNERS

Architecture

- KENNEDY & VIOLICH ARCHITECTURE, Boston
- 360grad+ architekten GmbH, Hamburg

Investor

- PATRIZIA Immobilien AG, Augsburg

Technical Building Services

- Büro Happold, Berlin

Textile Façade and Roof Construction

- Textil Bau GmbH, Hamburg

Structural Design/Fire safety

- Knippers Helbig GmbH, Stuttgart
- Bauart Konstruktions GmbH & Co. KG, München

Construction Materials Partners

Global Solar® Energy, Inc, Tucson

- Svensson Markspelle, Kinna
- Phillips Color Kinetics, Burlington
- Barbizon Lighting Company, London

Other Project Partners

- Wacker Ingenieure, Birkenfeld (material tests)
- G2 Landschaft, Hamburg
- Miele & Cie. KG, Gütersloh (domestic appliances)

PROJECT DATA

Project Costs

- approx. € 2.4 million

Plot Size

- 1,050 m^2

Gross Floor Area

- 800 m^2

Size of the functional units

- 4 houses, each covering 155 m^2, over three floors

Construction Period

- February 2012 – March 2013

Energy Standard

- Passive House

Energy Supply

- Photovoltaic elements integrated into the roof and façade membrane; heat pumps using geothermal energy

B Soft House Project Details

B.1 Architectural Concept

The "Soft House" is designed as a complex composed of four terraced houses. The 160 square metre living space for each residential unit is divided over three floors. The complex has a total gross floor area of about 800 square metres. The terraced houses are 5.90 metres across. The ground floor has a greater area than the recessed upper floors, as parking spaces are integrated into the ground floor. The architectural design is very closely linked with the building services, which are based on renewable energy supply, making the "Soft House" a benchmark for the combination of architecture, energy supply, and building services.

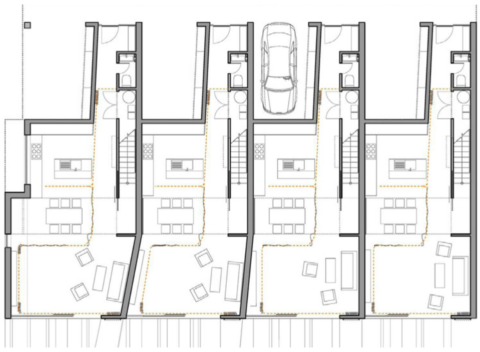

Fig. 3: Ground floor ground plan

The building's stand-out architectural feature is its moveable roof structure, which covers parts of the roof and the south façade; architecture and energy generation come together in an overarching design concept. This structure defines the look of the building, and the way in which it moves to ensure optimal power generation means that the appearance of the façade is constantly changing.

The membrane roof consists of two parts: the supporting structure and the photovoltaic units. The supporting structure in turn features two different materials: the part that covers the roof is made of fibreglass-reinforced plastic (GRP), while the part that covers the façade consists of a plastic-laminated glass fibre (PTFE) fabric. While the upper part of the structure tilts to follow the position of the sun over the course of the year, the revolvable discs in front of the façade react to diurnal variations in the sunlight. This ensures that the building is always aligned as far as possible with the sun, affording maximum energy generation efficiency. Both sides of the construction are fitted with thin-film photovoltaics that follow the movement of the roof structure.

The "Soft House" is a Passive House built of solid wood. Both of these conceptual elements are mirrored in the architectural design of the building. The south façade is defined by large glass surfaces – an unusual feature for a Passive House – while all of the other windows are kept as small as possible in order to minimise heat loss. A hybrid construction is made up of insulated plastered façades on the ground floor and a disc structure made of larch wood with a green geomembrane running behind it on the upper floors. In terms of insulation, this is applied as a soft construction.

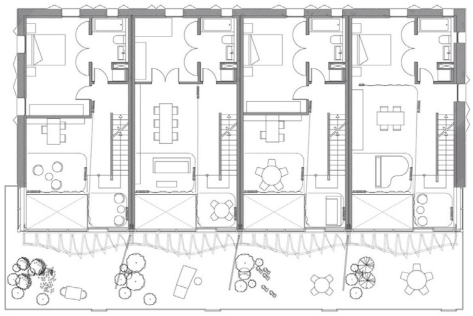

Fig. 4: First floor ground plan

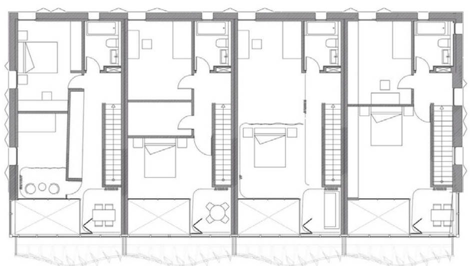

Fig. 5: Second floor ground plan

Fig. 6: Interior view on third floor

A basic theme runs through the design and material concept devised by the firm of architects Kennedy Violich – the search for soft types of expression in architecture. This is also reflected in the interior of the building in the form of "smart curtains", which run through the rooms on curved rails, allowing the space to be altered according to individual taste. To a certain extent, this concept marks a return to traditional notions of space that pre-date modern architecture. Swathes of cloth were once hung on the walls, or fabric fastened around the bed in order to keep in warmth. These curtains thus allow different temperature zones and spatial configurations to be created within the room, while also protecting against excessive sunlight. The curtains also serve as another kind of domestic technology, as the electricity generated by the photovoltaic units is fed into LED lights that are embedded in multi-layered materials and used to light the rooms (see Chapter B.2, page 10). The building's outward form is given its soft appearance by the constantly changing textile membrane structure.

The three-storey residential units can contain up to four bedrooms, thus offering large families enough space for living and working. The southern side of the building has a two-storey air space, which allows light to penetrate into the middle of the lower-lying ground floor. Moreover, the ground plans are configured in such a way that the ground floor can be converted into a granny flat if desired. The building's living concept can therefore be adapted to suit intergenerational changes and requirements.

Fig. 7: North-south section through the model

B.2 Smart Material Concept

The smart materials used in the "Soft House" – hence the name – mostly come in the form of versatile, high-tech materials: membranes, fibreglass-reinforced plastic, thin-film photovoltaics, and the smart curtains, all connected to one another via a complex building management system (BMS), and focused on energy generation and usage. Conversely, the building also takes a low-tech approach in the sense that it features traditional and simple yet efficient materials: its structure is completely timber – essentially a solid wood construction – in the form of stacked board elements.

Solid Wood Construction

As a building material wood absorbs carbon dioxide, and uses significantly less energy in production than conventional construction materials, as well as being renewable. BSH spruce uses -1.2027 kilograms carbon dioxide equivalent, whereas reinforced concrete uses +1.20 kilograms carbon dioxide equivalent. Moreover, renaturation is also possible at a later stage, as most of the waste can be recycled or used for thermal energy. Timber construction is the third pillar of the building's sustainability concept, after the Passive House theme and the use of renewable forms of energy, as it means lower carbon dioxide consumption during the primary construction, the possibility of recycling, and the use of fewer materials.

The project was made entirely from stacked board elements. The building does not have an underground level, and everything above the bed plate is constructed from timber. The walls consist primarily of dowelled stacked board elements based on traditional wooden construction methods and could, in principle, be installed by any firm accustomed to working with timber. The elements are easy to produce and, unlike those used in cross-laminated timber construction, are completely free of adhesives and can be built using traditional techniques.

Stacked board elements have been used for the

Fig. 8: Stacked board design

floors and ceilings, reinforced in a few places with steel sections integrated into the ceilings. The stacked board elements for the ceilings were braced on their upper sides and on the outside of the walls with oriented strand board cladding. The individual houses are cross-braced by isolated plywood board elements integrated into the structure. In the living rooms the stacked board elements covering the surfaces of the walls have been left bare, as they have on the undersides of large parts of the floor and ceiling structure. The boards in the ceiling elements have a rebate in order to optimise the room acoustics, giving them an acoustic profile.

Despite the fact that the terraced houses have been classified as building class 2 by the construction supervision agency, the lining of the interior walls around the stairs features non-combustible materials as a measure to compensate for the installation of the stairs over the three floors without giving them their own stairwell and landing. The stacked board construction has been rated as having a fire resistance rating of F 30-B. Plaster fibre plates have been applied to the insulated cavity of the building's outer walls, with the result that the walls have been classified as resistant to fire from the outside. As part of the fire prevention construction measures applied when building the façades, vertically placed sheets were integrated into the outer walls, preventing fire from spreading along the cladding from unit to unit.

Unlike conventional wood construction methods, using stacked board elements has the advantage that a large proportion of the elements are prefabricated and can bear heavier loads than is possible with timber frame construction, and this also reduces the construction time and thus the cost. The basic framework of the "Soft House" was erected in only two weeks. There are therefore no obstacles to implementing this concept on other sites. Another benefit of using stacked board elements is that it allows better sound insulation and fire protection, as well as a greater resistance to moisture, improving both the indoor climate and the overall level of comfort for the residents. Timber frame constructions are, admittedly, easier to insulate, but solid wood constructions have more stable thermal properties, as they cool down more slowly, hold in heat much longer due to their greater mass, and thus offer a better indoor climate.

Another innovative aspect of the "Soft House" is the way in which the installation levels are integrated into the element itself or into the construction levels, so that wood has an important role as a surface (see Figure 6). This is groundbreaking not only in terms of reducing the material and

Fig. 9: Dynamic membrane roof

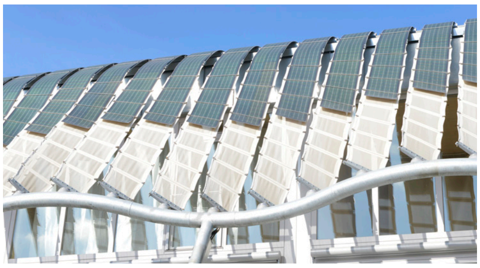

Fig. 10: Roof membrane with photovoltaic elements

energy used for building, but also allows sustainable upkeep of the surfaces by sanding and resealing. The stacked element method used in the "Soft House" can be seen as a key design method for reinforcing walls of multi-storey buildings, as all of the structural and acoustic insulation was considered in detail in the first place. Up until now, the integration of the building services into the construction, thus ensuring a high level of living comfort, has been a rarity in multi-storey timber buildings.

Dynamic Membrane Roof

The building's flat roof serves to protect it against weather and cold, and is also the installation level for the membrane roof. The membrane roof consists of two structural components. Fibreglass-reinforced plastic boards are fixed to the top of the building. These act as the flexible support material for the thin-film photovoltaics that follow the annual course of the sun, enabled by the bending of the boards. At the same time, the boards overhang the edge of the roof and act as springs for the textile membrane strips (or twisters) in front of the façade. The whole construction is supported by a steel framework that is anchored to the flat roof and the ground, and absorbs the considerable force of the wind. The curved girders also conceal the motors and hydraulic conduits for the twisters.

Flexible thin-film photovoltaic modules in the form of 6 metre lengths are fixed to the 50 centimetre thick membrane strips, which can bear a total weight of about 5 tonnes. The thin-film photovoltaic plastics use the PowerFLEX™ BIPV - 300W product manufactured by the firm Global Solar® Energy Inc., which has its headquarters in the USA. These modules are only 3 millimetres thick. The photovoltaic modules are held in place mechanically: they are clamped at the upper end, and pinned and smoothly mounted along the rest of their length by welded brackets. It was not possible to fix the boards firmly to the twisters due to the torsion when the twisters turn, as the modules cannot withstand the strain when the materials move simultaneously in two directions.

The bending and twisting of these strips control the degree to which the building's outer shell is opened, and the photovoltaic modules track the position of the sun, thus combining the building's shading and energy generation functions. At the same time, the use of daylight and heat protection in summer is optimised by the diffuse yet transparent properties of the textile and the high reflectivity of the rotating strips. The innovation of this system lies in the way in which it brings together shading, energy production, and daylight.

The part of the membrane that covers the roof can be adjusted to make the most of the changing position of the sun over the course of the year, thanks to the possibility of altering the tilt angle. The system has a hydraulic drive that propels eight ligaments at the same time for each unit. The ligaments could not be controlled individually as this would result in a massive increase in maintenance costs. The controls for the hydraulics are housed in a curved steel pipe at the lower end of the membrane roof. The residents can use the sails of their units to override the automatic system that aligns the sails with the sun, thus enabling them to alter the view into or out of their home at any time.

Individual approval had to be sought for the structures made of the fibreglass-reinforced plastic (GRP) and the membrane made of plastic-coated glass fibre (PTFE). No new materials were developed, but materials approved for use in buildings were used in a new context – as a roof and sun screen structure – as part of the "Soft House" project. The membrane, in particular, was subjected to numerous material tests (see Chapter B.4, page 17).

Flexible thin-film photovoltaic cells are becoming increasingly important in all types of buildings, and are beginning to replace the traditional silicon cells. These flexible photovoltaic cells are characterised by simpler production methods that are also set to be cost-effective in the future, as well as a reduction in the carbon dioxide equivalent of over 50 per cent, and the reclamation of the energy involved in around a quarter of cases, unlike conventional silicon photovoltaic modules.

The membrane support structure consists of

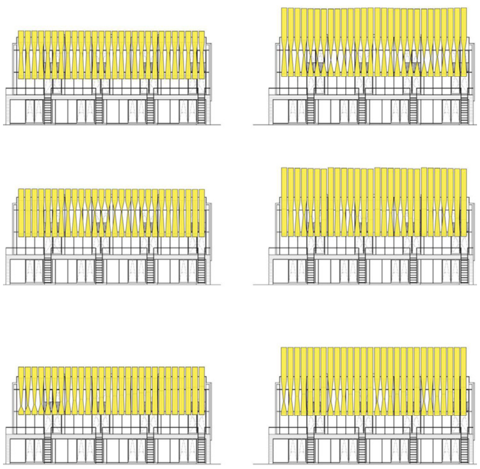

Fig. 11: How the roof membrane works

Fig. 12: Wind tunnel tests

a steel structure with minimised profile measurements. The glass fibre reinforced plastic boards are mounted on a steel structure that can be altered, or made to bulge outwards, by the hydraulic drive. These boards overhang the edge of the roof, and serve as a support for the PTFE membranes. The membranes are fixed firmly to the GRP boards, and the flexibility of the latter provides the pre-tension required by the membranes – it acts like a rigid feather. The PTFE membranes are also fastened to the curved steel girders in front of the façade, which contain the hydraulic system and its motors. The PTFE membranes are in turn reinforced by wire cables and cross-braces made of slender steel rods, which make them better able to withstand strong winds.

Special wind tunnel tests had to be carried out to assess the structure. During testing the fastenings of the thin-film photovoltaic modules were also assessed. These are loosely set on the GRP boards so that they are still able to slide, and are only fastened in places. The photovoltaic modules are fixed to the membranes by steel clasps. The membrane strips have a capacity of 300 watts. The material that makes up the PTFE membranes is characterised by its optical quality, a translucency of 35 per cent, flexibility, great fire protection properties (EN 13 50), strength, and a long service life of over 30 years. Moreover, the bendable, malleable structure is based on those found in nature.

Low Voltage System / Smart Curtains

The low voltage system is intended to avoid conversion losses in two different ways: by generating electricity through photovoltaics in the low voltage range, and by using modern low-voltage lighting systems. It thereby increases the effectiveness of the photovoltaic system by about 19 per cent. At the same time, the proportion of low voltage appliances (around 30 per cent per household in 2010) is rising, so the building addresses this trend in its own power supply. Electricity is generated during the day by the roof and façade, cached in a battery, and used in the evening for room lighting.

The smart curtains are part of this system, and

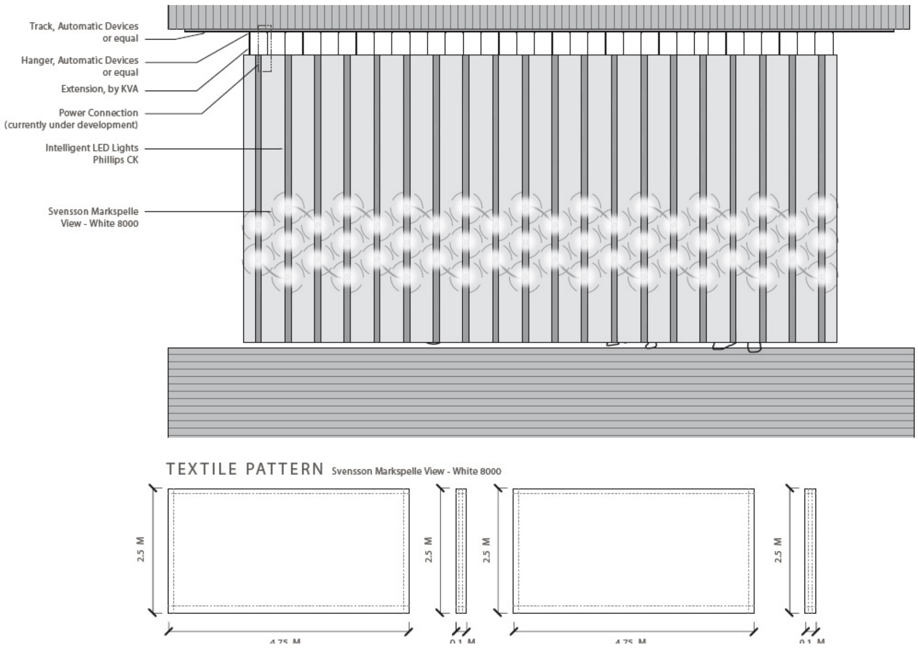

Fig. 13: Construction of the smart curtains

Fig. 14: Smart curtain with LEDs

represent the innovative features of the "Soft House's" architectural, electricity, and climate concept. They enable the same area to be used in a convertible, customised way, with minimum energy or material input. A lighting component using LEDs and a low-voltage terminal was designed for the smart curtains. There are exactly 50 LEDs integrated into them. They can be controlled separately and are able to respond to natural wind conditions. At the same time, the curtains act as soft elements that define the space. This allows the residents to enlarge or separate the rooms according to their needs.

The pioneering wiring design brings system elements together with the interior look of the house. With its low voltage electricity supply, a creative and space-defining element within the "Soft House" – the curtain – is given a technological function.

Building Management System (BMS)

The smart building management system (BMS) installed in each of the "Soft House's" units regulates the domestic facilities and is used to interconnect and control the excellence measures described earlier, in particular the energy harnessed through the dynamic textile shell, the caching of the photovoltaic electricity in a battery system, the direct use of the low voltage electricity by the building itself, the heat supplied by the heat pump, and the geothermal cooling system that comes into operation during the summer. The BMS promotes the greatest possible level of synergies within the building by joining up its energy-related components, including the resident's behaviour. The system's visualisation and mobile components allow the occupant to determine and act upon the best way of generating and using energy. It therefore makes the building services transparent for the residents, and by involving them in the process through such interactive features encourages a greater awareness of energy production and consumption.

Another innovative aspect of the design is the way in which it has been set up to conform to the load-dependent electricity tariffs (Smart-Metering), established by the Federal Ministry of Transport, Building, and Urban Development, which have been mandatory since 2011, with active and passive load management. The automation points have been chosen in such a way that bus systems with considerable potential are integrated into the activation mechanisms of household appliances. The system activated load management to control household devices (pumps, ventilation units, lighting, etc.), and make the corresponding household appliances switch on and off at particular times, or give certain appliances priority, via a bus system, so that a maximum number is not exceeded. Appliances manufactured by the firm Miele, which have this facility, have been installed within the building.

The design of the overall system is therefore an integral part of the technical building management, and a visualisation concept with stationary and mobile surfaces has been developed to this end, in order to enable innovative load management and user participation.

B.3 Building Services Concept

The "Soft House" is a Passive House designed after the PHPP certificate. The building is supplied with warm water by a heat pump, and heated by geothermal energy from 80 metre deep drills and a heat pump. In summer the system is also used to cool the building. Geothermal probes were chosen for thermal energy storage, as three quarters of the year-round heat requirements are attributable to water heating, and only a quarter to space heating, on a seasonal basis.

No additional primary energy is required to operate the heat exchanger, as the pumps are powered by the yield of the photovoltaic units. The pumps are linked to the underfloor heating system via heat exchangers, and to the climate control systems, allowing the building to be cooled by a simple, free, carbon-neutral system in summer.

The low voltage electricity generated by the photovoltaic units is fed into the building's low voltage network and can be used directly by each household. The electrical system buffers through batteries, which enable it to use the electricity as directly as possible, without the need to transform it and therefore bring in power from outside sources via the grid, which would have to be stepped down again in order to be used by the system.

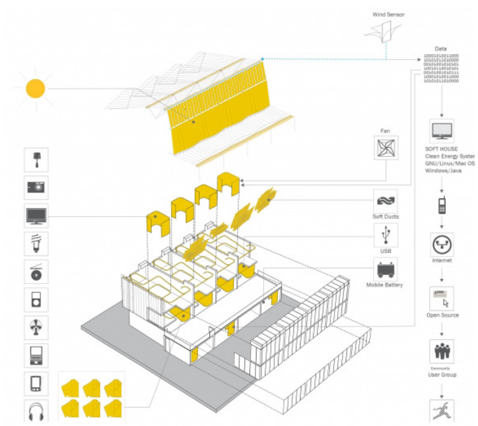

Fig. 15: View of the energy generation and distribution elements

Four photovoltaic hybrid systems created by Bauer Elektroanlagen GmbH Halle have been installed in the "Soft House". The system carries out the following functions within each unit: optimising the performance of the eight built-in photovoltaic modules using maximum power point tracking; storing and supplying the electricity generated from solar power at all times of the day; providing a maximum of 1 kilowatt of direct current for DC appliances; and providing a maximum of 3 kilowatts of alternating current for AC appliances. In addition, tariff-optimised solar electricity is fed into the grid, and if necessary alternating current from the grid is transformed in order to supply AC appliances if a battery has been completely discharged.

The status of all of these processes is outlined by the process monitoring system, which is installed on a panel in a well-ventilated space underneath the stairs, and is accessible to the residents along with all of the other system components. Remote monitoring by mobile phone is possible with the built-in server.

Solar electricity for each house is stored in 24 maintenance-free 2V lead gel batteries, which do not contain any liquid acid. Each of the batteries has a capacity of 440 Ah, giving each house a storage capacity of 21.12 kilowatt-hours in total.

Fig. 16: Lead gel battery

The "Soft House" is thus able to supply the appliances required by the houses and their residents entirely with electricity from the photovoltaic units. The battery stores enough for two days' use, increasing the efficiency of the photovoltaic units by 200 per cent. The DC to AC inverters have an efficiency rating of 97 per cent. The photovoltaic elements have a lower efficiency rating, but together they have a more diffuse emission. This makes the residents' lives more comfortable in bad weather.

The building's electrical distribution is structured in such a way that it can be made available to all points of consumption for room lighting via the power grid by simply modifying the sub-distribution of the low voltage electricity. Currently there is no single standard for LED bulbs, so these are usually normal bulbs with direct transformation from 240V to 12V, 24V, or 42V within the bulb.

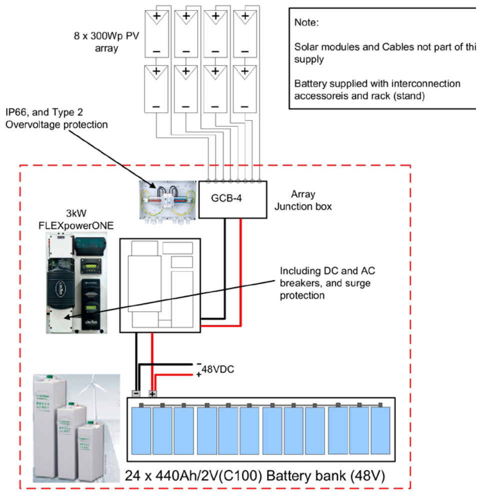

Fig. 18: Safety measures for the energy system

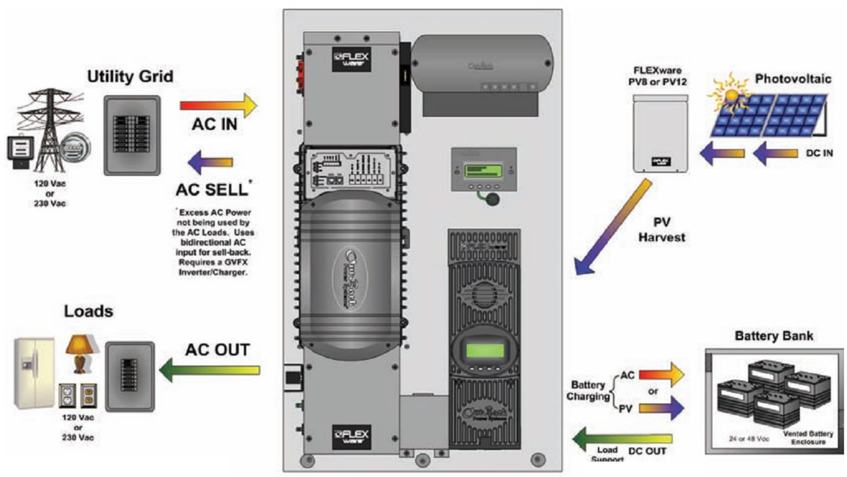

Fig. 17: Functions of the photovoltaic hybrid system

B.4 Planning Process

In the first part of the two-stage competition launched in late 2009, an idea was developed by a planning team made up of architects and building engineers, setting out a complex energy concept with textiles used as the support mechanism for thin-film photovoltaic elements on the roof and façade. Despite their praise for the idea, the competition jury noted that it was unclear how a number of structural and control engineering details (e.g. response of wind load, control of the photovoltaic system) would work in reality. These points presented certain challenges during the planning process, and a number of changes were made to the concept as a result.

Fig. 19: Elevation from the competition design

The key aspects of the concept were the following:

- Construction to passive house standard
- The use of wood as a sustainable building material
- Thermal and electrical energy self-sufficiency
- Use of a flexible photovoltaic unit
- Interactive space concept with modifiable rooms and overview of the domestic technology processes inside the building

The aim of making the building a passive house led to a more compact design concept for the structural shell. Whereas the design submitted for the competition has envisioned that the southern side of the building would be completely made of glass, in the final planning stage this was scaled down in order to ensure heat protection in summer.

Fig. 20: Interior fittings, December 2012

The combination of timber construction and the structural requirements of the building, as a result of the forces now introduced to the roof structure, also led to a more compact design for the ground plans, as terraced houses. This allowed the sound insulation and fire protection requirements to be simplified to a significant extent. The versatile living theme was retained, with a large degree of flexibility afforded by the ground plan design, and the possibility of changing the space by using the smart curtains as room dividers.

According to the original idea, the wooden surfaces inside the building would be completely open-plan. However, this could not be implemented due to fire safety measures imposed by the authorities, and also due to the high energy requirements of the garages integrated into the building. Instead, the four separate terraced houses are separated from one another by GRP panels, and are thus protected against fire.

The biggest challenge was presented by the additional roof with its thin-film photovoltaic units. The intention was to construct a simple textile roof on a lightweight metal structure, with small-scale thin-film PV modules applied to the textile. However, crisis within the photovoltaic industry meant that the product line proposed for use in the design ceased to be manufactured, so another system would have to be used. The original small-scale and therefore flexible design could not be fully implemented; instead, 6 metre-long panels had to be fitted. This prevented the

Fig. 21: Junction of the GRP boards and the textile membrane

twisters from carrying out the necessary rotating motion, and the conflict could only be resolved by fastening the PV to the twisters along only part of their length, and using an alternative Velcro fastening system for the rest.

According to the original plan, there was to have been a membrane roof on both the north and south sides of the building. The membrane roof had formed an even more prominent part of the design submitted for the competition, but when the design was revised the structure was interpreted in a more technical and functional way, and was only implemented on the southern side. The membrane concept was also further developed in terms of its technology and function: on the roof, the membrane was only partially suitable as a support material. The GRP allowed it to act as a good mounting surface for the thin-film photovoltaic units and as a support for the twister membranes. The key features of the membrane are the way in which it supports the PV and provides translucency for light control.

The concept of using the low-voltage electricity generated by the PV directly, without transforming it through building's appliances or smart curtains, is a key aspect of the project's focus on renewable forms of energy. In order to avoid transformation losses, the generated energy was set to be stored and used directly by the building itself. Reducing and preventing transformation losses alone would have resulted in savings of 19 per cent. In the meantime, however, transformation efficiency saw a marked improvement, resulting in losses of only 3 per cent. Yet this has no bearing on the theme of direct electricity use, as now the reduced feed-in compensation makes feeding energy into the public grid much less profitable than using it directly and eschewing the supply of expensive external power from the national grid.

Uniform technical standards for the use of PV electricity are not currently in place. The main manufacturers tend instead to use different voltages for powering LED bulbs. This means that everything relating to the grid and the corresponding mains voltage of 240 V remains the same, and the different potentials for the LEDs are only stepped down when they reach the bulb itself. The houses are therefore equipped to use low-voltage current for lighting throughout, but the individual users must make a decision further down the line. A buffer storage system using batteries could be set up just before the completion of the houses. Besides the system current, the only element relating to the direct use of the building's own energy that is the same in all of the houses is the smart curtains, which showcase the possibilities of direct use by consumers.

The architects' original idea for a moveable roof structure that would harness optimal energy yields was long in question. Final technical clearance and legal approval was only granted in early 2013.

Fig. 22: PV modules on the GRP boards

Fig. 23: Erection of the GRP boards

Fig. 24: Elevation of the GRP boards

As wind load and torsion forces not only had a direct bearing on the material concept, but also influenced aspects within the building, the plans had to be adjusted. The foundations, deflection of forces within the building, and the dimensions of the steel parts had to form an interplay that was very much underestimated in the design stage, thus necessitating greater expenditure on material tests and planning.

The following tests were required:

- Bending and breaking material tests for the GRP
- Checking of computationally static models in a wind tunnel, as the behaviour of the twisters in the wind could not be completely simulated by a computer.

B.5 Assessment

As a model for a smart material-focused approach, the Soft House addresses the following pertinent key issues:

- A simple, sustainable basic concept (wood used as a low-tech material with high-tech features)
- High energy efficiency (constructed to passive house standard)
- Self-sufficiency in terms of energy, through the direct use of energy generated by the building

This smart material-focused approach brings the idea of a light supporting framework together with the use of light thin-film photovoltaic plastics. This is another of the key issues to be addressed in the construction of the building. Fewer materials were used in order to save resources, while ensuring maximum efficiency. This required the system to be flexible.

The smart technology-focused approach also addresses a number of important issues:

- The effective direct use and caching of energy
- Systemic interconnection between all of the building services parameters
- Users are able to oversee the technical processes, and are integrated into the concept as a key variable, in order to achieve optimal use of the energy required within the building

Fig. 25: Interior view, 1st floor

Fig. 26: North view, June 2013

The building also clearly addresses a number of pertinent architectural issues: the energy production process is an integral part of its architectural design, and is the reason behind its constantly changing appearance. This production process, which seeks to make the building self-sufficient in terms of energy, has a bearing on its outward appearance. Complex technical processes are not hidden away, but are rather part of the everyday operation of the building. TU Braunschweig is monitoring the building's consumption data, and this will reveal whether the project's goals can be achieved.

With regard to the materials used, the thin-film photovoltaics installed have been a particular disappointment. The project team based their concept on the minimal use of materials, but with a high level of efficiency. The industry was working on solutions to fit, but as the crisis in the photovoltaics industry escalated it was no longer possible to develop new solutions for applying PV elements to the membranes in tandem with industry partners. It was therefore necessary to fall back on a standardised panel product.

Unfortunately the idea that the PV electricity would simply be able to be used directly for lighting within the building foundered due to inadequate industry solutions. There were a wide range of solutions for LED bulbs, but not for the systematic use of LEDs in combination with a low voltage grid supplied by photovoltaics, which could open up possibilities for new constructions.


Fig. 27: Smart curtains


Fig. 28: South view, May 2013

Nevertheless, this pilot project ably demonstrates the way in which the choice of materials, the energy concept, the living concept, and architectural expression are interwoven, not only in the breadth of issues addressed, but especially in the degree to which they are profoundly interconnected and dependent on one another.

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