Hamburg ahead

INTERNATIONAL BUILDING EXHIBITION HAMBURG

Smart Material House
Smart is Green

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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 underlying the "Smart is Green" will be set out in detail in this booklet. The planning process will also be explained precisely, as various changes were made between the design stage and the implementation of the model project. The reasons behind these changes were technical, financial, or functional, meaning that some of the original targets had to be adjusted.

Model projects are particularly liable to undergo planning changes; indeed, besides presenting innovative end products, building exhibitions seek to test 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 of the use of "smart" materials in the twenty-first century, or if the concept needs to be reworked. In addition to setting out technical details for experts, this booklet is intended to provide an objective assessment of whether the model project "Smart is Green" 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 "Smart is Green" apartment block will be presented in brief, and then explained in detail. The architectural and building services concepts will be introduced first, followed by a description of the planning process, and then the evaluation of the model project. The presentation will focus in particular on the energy concept and the materials used for storing energy.

A. 2 Smart is Green Project Outline

FEATURES

- Energy generation units on the roof and façades as part of the architectural concept
- Use of phase-change materials (PCMs) to store energy
- Flexible layout configurations that are adaptable to the needs of the residents

Fig. 1: View from the southeast, June 2013

Fig. 2: View from the southwest, May 2013

Each of the four family-friendly terraced houses "The aim of the building is to make the aesthetics of energy transformation visible, and to create flexible building structures that can be used by people of all ages." Michael Ziller, architect

The façades and roof of the "Smart is Green" structure are an active part of the innovative building services concept. They use different technologies to generate energy that can be used directly by the building, or even fed into the Wilhelmsburg energy grid. The focus here is on the use and storage of thermal energy to supply heat to the block.

In addition, the development and ground plans are designed to be flexible, and can be adapted to the individual requirements of the residents. Structure follows function to suit everyday needs. The building can be adapted to follow changing technological needs and the residents' requests, as the demand arises.

PROJECT PARTNERS

Architecture

- zillerplus Architekten und Stadtplaner, Michael Ziller Architekt BDA, München

Investor

- Behrendt Wohnungsbau KG, Hamburg
- Sparda Immobilien GmbH, Hamburg

Technical Building Services

- PINCK Ingenieure Consulting GmbH, Hamburg
- Ingenieurbüro Hausladen GmbH, Kirchheim

Structural Design/Fire safety

- Wetzel & von Seht Ingenieurbüro für Bauwesen VBI, Hamburg

Construction Materials Partners

- Christian Fischbacher GmbH, St. Gallen
- Outlast Europe GmbH, Dörken
- Oliver Wagner Inneneinrichtung GmbH, Hamburg

Other Project Partners

- Hamburg Energie GmbH, Hamburg
- Realisation: Andresen Garten und Landschaftsplanung, Hamburg
- Competition: Burger Landschaftsarchitekten, München

PROJECT DATA

Project Costs

- approx. € 4.4 million

Plot Size

- 1,250 m^2

Gross Floor Area

- 1,990 m^2

Size of the functional units

- 86 - 127 m^2

Construction Period

- December 2011 - March 2013

Energy Standard

- Efficiency House Plus, built to a Passive House standard

Energy Supply

- Solar thermal energy, PCM energy storage, and photovoltaic system, "Wilhelmsburg Central Energy Network" district heating

B Smart is Green Project Details

B.1 Architectural Concept

The "Smart Material House" by zillerplus Architekten grapples with a wholly modern theme – the systematic separation between the supporting framework, shell, and fitout elements – in a new way.

The compact structure, a solid construction, has long-span ceilings in order to ensure that the apartments are separated as flexibly as possible. On the southern side is a continuous balcony area, which forms its own layer, like a multi-storey veranda. The south façade has a large proportion of glass surfaces for a passive house, endowing the building with high residential value. The east and west façades have an open appearance, while the north façade appears more closed, with the surface broken up by coloured sheet metal panels. Features of the design are the vertical gardens on the south façade (climbing hydrangea on trellises), which are echoed by the sheet metal panels of the same size on the other sides, so that all four façades are brought together by these rectangular elements.

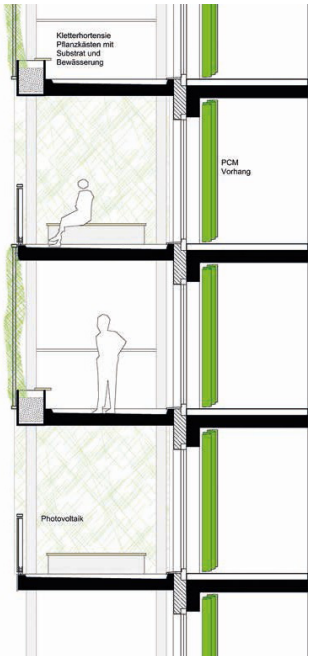


Fig. 3: Section of a horizontal garden, south façade

The south side is arranged in three layers from the outside to the inside: a planted façade element serves as protection against the heat in summer, insulated glazing protects against heat and cold, and a PCM curtain acts as a short-term heat reservoir. Central to the architectural concept here are the way in which the roof and façade have been upgraded into sources of energy for the building, as well as the opening up of the interior space to provide versatile ground plans.

The shell of the building thus not only provides heat protection, but also supplies it with energy via its "harvesting" function. The highly insulated façade consists of two levels. The first, the basic level ensuring heat protection, is formed by a thermal insulating system with integrated mineral plaster. The second level, which has a 3D design and indicates its location with its colour and a stacked appearance, like a container, is formed of green curtain façade elements made of aluminium. This allows the north façade on Neuenfelder Strasse – which, unlike most developments adjoining the street, does not have its entrance on the street side, and is not used for harvesting energy – to be incorporated into the overall design.

Fig. 4: South façade, April 2013

The curtain elements are attached to the masonry using special high load-bearing plastic fasteners, in order to prevent heat bridges. The space between the planted second layer and the first layer of the façade on the southern side is used as a "garden for each floor" in the form of balconies. These thermally decoupled balcony areas in front of the building thus create their own separate layers of space. The balconies are clad on the outside with vertical garden elements. Parts of the entrance area are designed as community and meeting space.

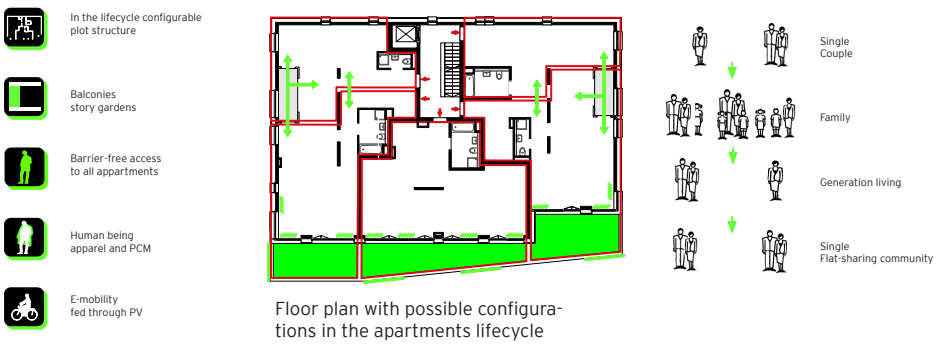
The base plate rests on auger piles. In order to prevent the auger piles from acting as thermal bridges, interior thermal insulation has been added between the base plate and the floor fill (2 × 10 centimetres). There is an additional 16 centimetres of thermal insulation between the auger piles. The roof has been constructed as a warm roof with sloping screed and 35 centimetres of thermal insulation.

The outer walls have been built as pure solid construction. The gaps are insulated with 16 centimetre thick thermal insulating material, with an additional 12 centimetre thick exterior insulation. Rockwool Aerowolle is built into the walls to provide exterior insulation, permitting extremely low U-values for parts of the building with normal thickness. Thermally insulating triple glazing with an argon filling was inserted into the window frames.

The upper floors of the solid concrete and masonry construction are designed to have three apartments each. Access is from the northern side, via a staircase and a lift. In addition to the extra rooms, the ground floor contains a community area for the residents alongside the entrance. The two ground-floor apartments and the twelve on the four upper floors have been sold owner-occupiers apartments. The interior finishes of the apartments are therefore applied according to individual taste.

The access areas and ground plans have been conceived in such a way that the apartments have versatile layouts that can be adapted to suit the residents' requirements. Structure follows function in order to meet everyday needs. This allows the building to be "readjusted" to fit with changes in use and technological developments. The building has a gross floor area of 1,900 square metres and has been built to a Passive House standard, according to the Passive House Planning Package. The apartments vary between 86 and 127 square metres, and are heated by panels in the flooring.

The 127 square metre apartments can be divided up, so that it is possible to set up a granny flat. The apartments are devised and arranged in such a way that they allow a plethora of spatial configurations which are also adaptable and can therefore meet any new demands placed on the residents' lives. The lifestyle and living needs



Floor plan with possible configurations in the apartments lifecycle

Fig. 5: Smart living – versatile spatial configurations inside the building

Fig. 6: South façade, April 2013

of young singles or couples are fundamentally different from those of a family, elderly couples, or single senior citizens.

The versatile configuration of spaces or purposes is taken into account here: while single people or couples without children often need only one bedroom, while the rest of the apartment can be an open space that fulfils different purposes, families with children generally need several bedrooms that are separated from one another. The 127 square metre apartments can therefore house up to three bedrooms. Senior citizens in turn have different requirements, and issues such as accessibility may play a more important role. The positioning of staircases, baths, and doorways can be changed in apartments to make them suitable as retirement housing, while the larger units can house people of several generations thanks to the possibility of creating a granny flat. Due to the way in which the space can be divided up, such changes are easy to make, allowing residents to adapt the apartments to their current lifestyles.

This flexibility is wholly due to the construction method behind "Smart is Green". While the load-bearing outer walls of the building and the apartments are brick-built, and the ceilings are solid constructions, the walls within the apartments are installed as components in a lightweight design.

B.2 Smart Material Concept

The most important feature of the smart materials used in "Smart is Green" is the phase-change material (PCM) used as an energy storage medium. This includes the PCM heat storage unit and the PCM curtains. In addition, photovoltaic elements are incorporated into the façade, while there is a solar thermal system on the parapet wall, and green elements in the façade. The building's automated features are also innovative – its prime focus is its "smart technology" approach to the building services concept and the overall energy supply and control. This is explained in detail in the following section.

Use of PCM as a Storage Medium to Cover the Building's Heat Requirement

The latent energy stored during the phase transition between solid and liquid aggregate states is used for managing heat in the surrounding environment. Essentially, heat can be stored as sensitive or latent heat. If a material is heated, it absorbs the heat and its temperature rises. We call this sensitive heat. During phase transition, latent heat storage materials absorb heat without undergoing a corresponding increase in temperature. The amount of heat stored during phase transition is described as latent heat.

Storing energy in the form of latent rather than sensitive heat has a number of advantages. As heat storage is not associated with a temperature increase, the downtime losses are lower than those with a sensitive storage method, which always loses heat to its surroundings due to its increased temperature. It is possible to mitigate temperature peaks, whereby the amount of energy absorbed during the heating phase is stored without causing an increase in temperature and can be discharged to the surrounding area with a time delay. Modern architectural concepts attempt to streamline the amount of building components, so as to offer versatile and cost-effective options for design. With the aim of preventing overheating in summer, PCMs can be used in two different ways:

Firstly, the passive use of PCMs increases the thermal performance of buildings, and allows temperature peaks to be mitigated, especially in lightweight constructions. In the solid-liquid phase transition about 100-600 kilojoules per kilogram can be stored within a small temperature interval, depending on the material. The specific heat capacity in sensitive storage media (masonry, concrete) is approximately 0.5-4 kilojoules per kilogram kelvin). If there is a temperature gap

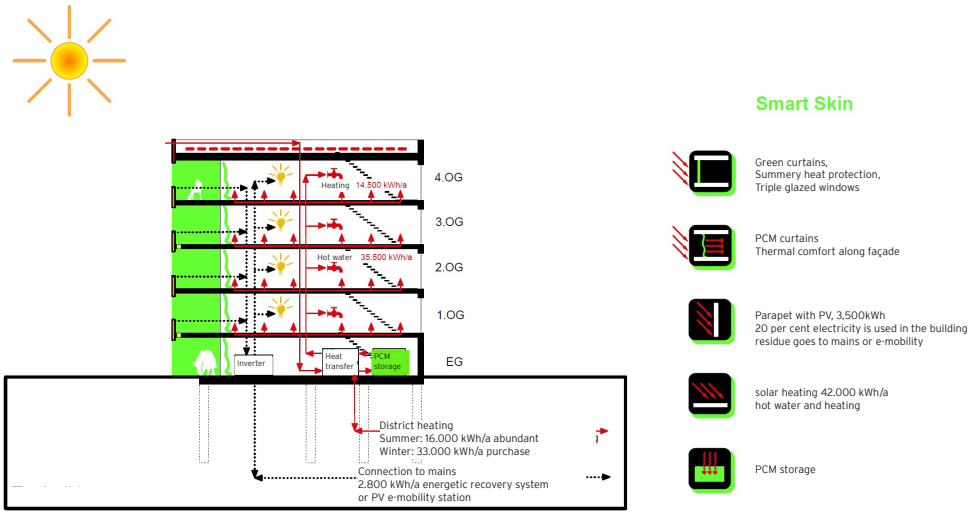


Fig. 7: Building services concept

of 10°C, this corresponds to 5-40 kilojoules per kilogram of stored heat, which is markedly below the storage capacity of a latent heat storage material. The amount of heat absorbed per millimetre of PCM layer thickness corresponds to the heat absorbed by the equivalent of 10-40 millimetres of concrete.

Secondly, heat and cold storage can also be connected with active systems. Load peaks can be deferred using the storage, enabling climate control systems in buildings to be scaled down, or a cap to be placed on load peaks in the power supply.

PCM storage elements are set to account for a considerable amount of the heat supply in the "Smart is Green" building. Such elements are undergoing tests, and are not yet mass-produced. While they are being used, their effectiveness is being evaluated. Energy storage at low temperatures is crucial for supplying energy efficient buildings with heat, and the effective use of space because less room is required by such storage has tipped the balance in favour of this option, as when more space is required by the building services the storage facilities take up increasing room, so that some other means of storing energy must be found. Three storage elements with different building units and technical components are to be coordinated with one another as part of the project, and are explained in greater detail below.

1. Short-term Storage: Improving Residential Comfort (3-6 hours)

Curtains with a PCM filling act as protection against the sun in summer, and serve as a short-term store by discharging the absorbed heat at night, when the air is cooler. Temperature peaks can be calculated and balanced in summer and winter alike. The curtain acts in the same way as a "heavy" building component.

Coated with paraffin-encapsulated PCM, this acts as solar protection and can absorb some of the sun's energy, before discharging it again at times when there is no sunlight.

As the curtain is positioned next to the façade and windows, and in modern buildings and passive houses there are no static heaters near the façade, the PCM curtain supports a pleasant climate in this area. Together with an external sunscreen built according to energy conservation regulations (EnEV) ✣ balcony overhang, exterior blinds, etc. ✣ the curtain is intended primarily to contribute towards additional comfort during the transitional period in spring, when the sun hangs low in the sky and does not shine much on the façade or the windows. Glass has a lower storage capacity than a solid wall. The curtain allows this capacity to be increased, while retaining a certain level of transparency.

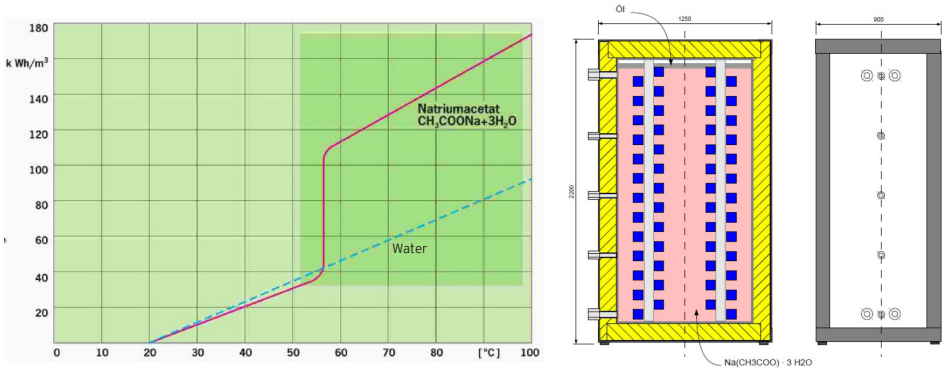


Fig. 8: Structure and efficiency comparison of PCM storage

Another advantage of PCM curtains over PCM walls is that they can hang freely, without being cluttered up by furniture. The mass of the PCM material applied to the curtain is very small compared to solid or filled construction materials, so it can be applied on both sides of the curtain or corrugated (allowing approximately 1.5-2 times the window surface). This can be covered directly by the sun or the controlled ventilation, and thus be fully charged and discharged. Temperature peaks can be balanced in this way, while there is an increased feeling of comfort near the windows.

The amount of PCM required for the curtains was determined in laboratory tests carried out by the company Outlast. The custom-built curtains were imprinted on both sides with PCM. The white base material, made of 100 per cent PES Trevira CS (tested for harmful substances according to Oeko-Tex Standard 100, weight approx. 200 grams per square metre), is printed in green on one side, and then printed and surface-coated on both sides in a dot pattern with a total of at least 130 grams per square metre of paraffin-bound PCM.

During a two-year monitoring phase, the Technical University of Braunschweig will take measurements near the curtains in order to assess the results of their use. The impact of the users' behaviour on the curtains' efficiency and their acceptance are to be reviewed.

The latent heat temporarily stored in the curtains in the area surrounding the glass façades on the south, east, and west sides of the building enables higher levels of comfort to be achieved around large window surfaces, while also reducing radiative cooling. The larger window surfaces on the south side, which have a greater thermal intensity, allow more heat to be absorbed over the course of the year. It should therefore be possible to ensure both highly transparent façades in residential buildings, and their acceptance by the users.

2. Medium-Term Storage: PCMs as Central Storage for Heat Supply

Excess solar thermal energy is stored in a buffer tank (PCM tank). Using PCMs allows the volumes handled by the tank to be halved in comparison with conventional storage (see Figure 8). Energy

Fig. 9: PCM curtains on the ground floor

is stored at the temperature required for use in underfloor heating; it is not necessary to mix sources in order to achieve the desired flow temperature. Further research should lead to increased efficiency, with the aim of more efficient heat transfer.

The solar thermal module is installed on the parapet wall and the flat roof in the form of vacuum tube collectors. The collectors on the roof are mounted at an angle of 15°. The collectors in the parapet wall facility are mounted at 90° to the parapet wall railings. This system generates an output of approximately 75 kilowatts.

This produces a large amount of heat in the summer months, which is stored in three hot water tanks. Due to the high input temperature generated by the solar thermal energy, the PCM storage unit needs to be designed to cope with such high temperatures. This prevents the solar thermal system from coming to a standstill and causing yield losses. The storage tank, manufactured by the company FSAVE, is designed to withstand these high temperatures from the solar thermal system, and can be adjusted to suit the installation. The storage system – two hydraulically connected storage tanks, each holding a cubic metre – consists of reinforcing and highly insulated plastic containers. The highly corrosive storage medium – a salt hydrate – precluded metal from being used as the receptacle. The material is therefore held by two cube-shaped plastic containers.

Table 1: Dimensions of PCM storage (FLEXSAVE MONO PCM)

Outside measurements	Length	1250	mm
	Width	900	mm
	Hight	2200	mm
Outside volume		2,475	m^2
Interior	Length	970	mm
	Width	620	mm
	Hight	1.940	mm
Inside volume		1,167	m^2
Bellow	DN25	130	m
	Surface	22,62	m^2
	Volume	83,72	dm^3
	Volume of girder	18,06	dm^3
Filling volume		1,00	m^3
Density of storage (20 – 90 °C)		159	kWh/m^3
Number of storages		2	
Storage capacity overall system		319,53	kWh
Insulation	PU foam		
Tickness		120	mm
	Termoconductivity	0,027	W/(m K)
Connecting	Number	4	-
	Measure	1	"IG
Thermowell	Number	5	-
	Measure	1/2	"IG

The generated heat energy is distributed to the building services rooms and the heat storage tanks for the three applications (water heating, underfloor heating, district heating recovery system) as required. The energy is distributed by the in-house building management system. Most of the generated heat energy is to be used within the building for underfloor heating and water heating.

The underfloor heating system is supplied with heat energy by the PCM storage tank. This tank is fed primarily by the solar thermal unit, and can also be supplied by the local Wilhelmsburg energy grid if required. Outside heating times, the PCM storage tank preheats the cold drinking water. The maximum operating temperature is 85°C.

Technically pure sodium acetate trihydrate with a melting point of 58°C is used as the PCM material. This has a shelf life of over fifteen years. The storage system consists of two cascade-connected tanks. This has the benefit that the smaller storage tank does not require a stabilising outer frame, which would reduce the storage volume. The storage tanks have a usable total inner volume of 2 cubic metres. The outer volume is 4.95 cubic metres. The storage capacity has an average temperature of 60 kelvin (20-80°C) 280 kilowatt-hours . In comparison, water has a value of 140 kilowatt-hours.

3. Long-Term Storage (Seasonal): Wilhelmsburg Central Energy Grid

As the medium-term storage system is housed within the building, excess heat can be fed into the Wilhelmsburg Central energy grid and used directly by other consumers or kept for the future. If the apartment block's stored heat is discharged, any required heat can be obtained from the local heat grid. In addition, the heat from the PCM storage is transferred to a buffer storage unit via a heat exchanger, and conveyed from there to the handover station of the local heat grid, or transferred the other way and removed from the local heat grid.

Thin-Film Solar Collectors on the South Façade

Photovoltaic elements based on thin-film technology have been used for the façades. They are particularly suitable for this building, as they offer better performance yields when light conditions are not optimal, and they are attractive in appearance. The collectors are necessary not only from a technical point of view, but also as elements of the façade design. The aim is to use 20 per cent of the electricity generated by the building's own photovoltaic elements, and to feed the remaining 80 per cent into the distribution grid. The building generates a total of 3,500 kilowatt-hoursh per annum, so it uses 700 kilowatt-hours per annum, which covers the total power required by the appliances (see Section B.3, page 18).

Fig. 10: Thin-film solar collectors

Fig. 11: Vacuum tube collectors on the parapet wall

Building Management System

The close interaction between the technical components for energy production and storage means that good coordination is required. Energy can be provided only in the same way as it is in a conventional building, on demand from a heat generator. This is only possible thanks to sophisticated control systems engineering that constantly monitors the possible energy sources and consumers, and thus uses the energy as effectively as possible. The special feature of this system is not the technical performance of the automated building components, but rather the control concept. Central building automation is required in order to adapt the different energy generation components on the building's outer shell and the use of energy within the building to one another in a smart way, and to increase efficiency. Likewise, accessing energy from and feeding it into the local heat grid is only possible if the building is automated.

The block's automated features are integrated into a programmable, configurable building management system. This consists of one or several digital-to-digital converter automation stations or controllers, which undertake control, monitoring, regulation, and management functions for the following areas: heating technology, ventilation (via meter only), and solar thermal energy. The regulating system and control processes within the appliances operate independently within the respective automation stations or controllers. Important information is displayed next to the appliances, on the power switch cabinets. The override operating level is shown on the control cabinet door (touch screen). Alarms and malfunctions are displayed on the input modules. Programs and other features can be accessed via the integrated display or via a maintenance and operator controlled laptop. This is connected to the automation station or controller via an attachment plug.

How the "Green" Curtain Works in Conjunction with Heat Protection for the Building as Part of the Façade

In addition to the photovoltaic elements contained in the railings, vertical gardens are integrated into the façade in order to provide shade. With climbing hydrangea on trellises, in summer these offer leafy green curtains that provide protection from the sun and filter solar radiation. At the same time, this natural façade design element absorbs carbon dioxide. The cooling evaporation from the plants acts as a positive influence on the microclimate around the building. The greenery of the vertical gardens serves as a feature that changes with the seasons, and offers seasonal protection against the sun: they are closed against the summer sun, but remain open for the winter sun. In construction terms, this is a unitised system. The pre-grown climbing hydrangeas are hooked onto the prefabricated tray elements on the façade. The plants are watered in the normal way, by rainwater, and are fed automatically. With its design incorporating greenery, photovoltaic elements, solar thermal energy, and smart curtains, the south façade not only showcases energy production, but also uses its

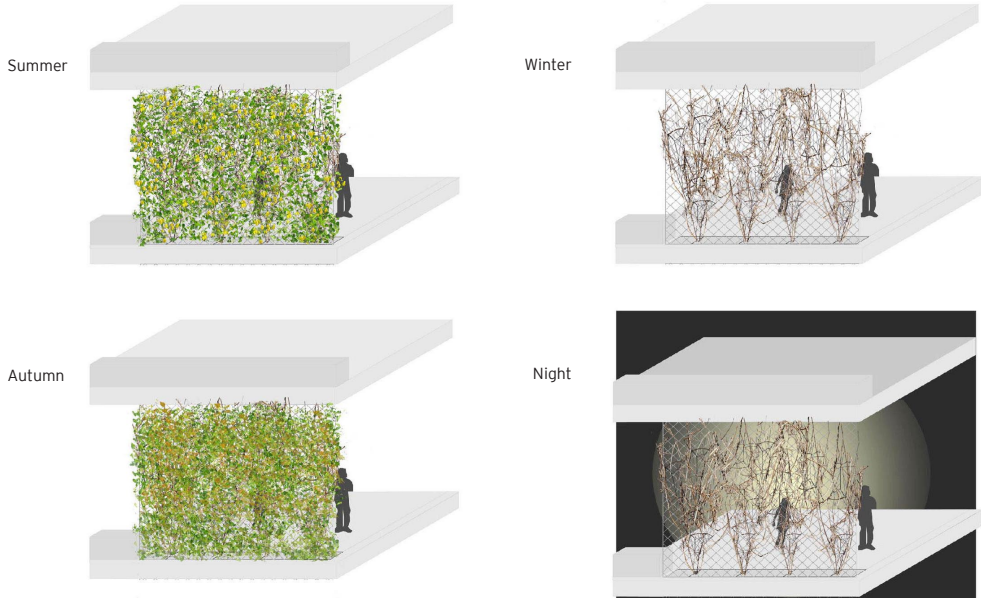


Fig. 12: How the "green" curtains work

dynamic power generation and solar protection components to demonstrate climatic conditions over the course of the year.

B.3 Building Services Concept

The building's heat requirement, according to Passive House guidelines, is roughly calculated at 19,250 kilowatt-hour per annum or 12 kilowatt-hour per square metre per annum. The apartment block is primarily heated by the solar thermal unit. The second source of heat, which is used if there is not enough heat produced by the building, is the Wilhelmsburg Central energy grid district heat network. This heat is made available by two PCM storage tanks that can hold 2 cubic metres. The PCM storage tanks are operated as latent heat stores using salt hydrate. The solar energy produced by the solar thermal units (integrated into the parapet wall area of the façades and the roof surfaces) is fed into these storage tanks. The solar units are integrated into the parapet wall railings in the façade and on the remaining roof surfaces by vacuum pipe collectors or flat-plate collectors.

The heat for the space heating is removed from the PCM tank by a heat exchanger. The underfloor heating system is set up to provide system temperatures of 35/25°C. If there is an excess of solar energy, it is fed into the local heat grid. This ensures that the heat supply is not interrupted in long periods of cold, as it is provided by the local heat grid. The building also receives renewable energy from the local heat grid.

The building has a photovoltaic unit integrated into the parapet wall railings on the south façade. It is also possible to integrate photovoltaics into the curtain elements on the east and west façades. This would meet the goal of generating all of the energy required by the block's appliances through the photovoltaic modules, providing all of the domestic electricity, and, if necessary, supplying two electric cars with charging current. These supply options will allow the building to achieve the status of a zero-energy house, which means that almost all of the energy that it requires is generated by itself.

The block also has a ventilation unit, and the exhaust air from this is used to pre-heat the fresh air. It is separate from the rest of the building services. There is a separate ventilation unit for each apartment. These supply the apartments with the minimum hygienic air change. This form of heat recovery has an efficiency of 91 per cent for an electric power input for air conveyance of 0.31 watt-hour (very good Passive House standard). Additional air is not conditioned, except for a defrosting function.

The building services concept is closely connected to the extended transport concept. The building concept was supplemented by a separate local transport concept, with the result that the

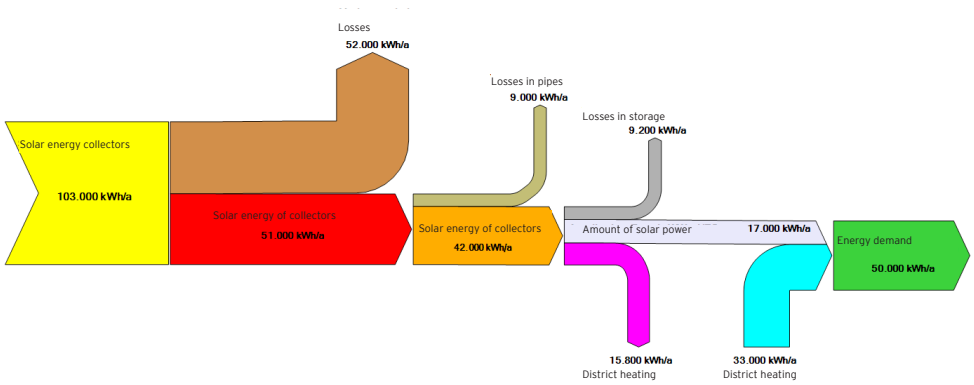


Fig. 13: "Smart is Green" energy flow diagram

bicycle storage room on the ground floor has charging stations for e-bikes. These are supplied by the energy generated by the building itself. There is also an on-site charging station for cars. In addition, two electric cars are available and can be used by any of the building's residents. This initiative was devised and funded by SPARDA Bank and is a DENA model test in using self-generated energy in-house and deploying car batteries as storage for the energy produced.

Fig. 15: Building services operations room

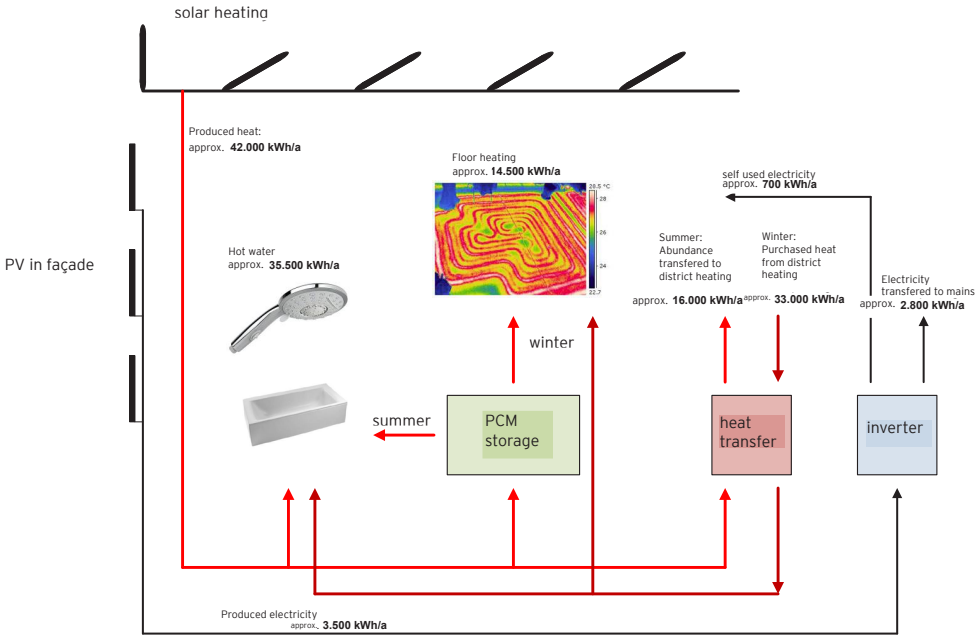


Fig. 14: "Smart is Green" technology concept diagram

B.4 Planning Process

In the first phase of the three-stage competition launched in mid-2009 a planning team composed of architects, building technicians, and landscape designers developed a concept that made "energy harvesting and storage" the apartment block's main design principle. The ideas put forward by the selected teams were refined during the second stage. It was intended that all of the walls and the roof would be able to harvest and store energy (using photovoltaic collectors and PCMs), and these features were integrated into the design of the building as much as possible. Parallel to this, a smart concept was developed for the building's internal design, which would allow adaptable apartments.

Fig. 16: Image from the competition design

The third stage involved finding investors for the concept that won the second phase. Behrendt Wohnungsbau KG (GmbH+Co.) and Sparda Immobilien GmbH were finally chosen. Construction work began in March 2013, once a number of changes had been made to the competition design. This progression from idea to detailed design and, ultimately, the finished building, involved mostly technical changes and, to a lesser extent, architectural adjustments.

Due to the elimination of the height difference on every second floor, the apartments can be divided up in a flexible way, to allow for changes within a generation cycle. All of the apartments are now therefore accessible, although this was not envisioned by the original design, which was contrary to the aim of providing living space for

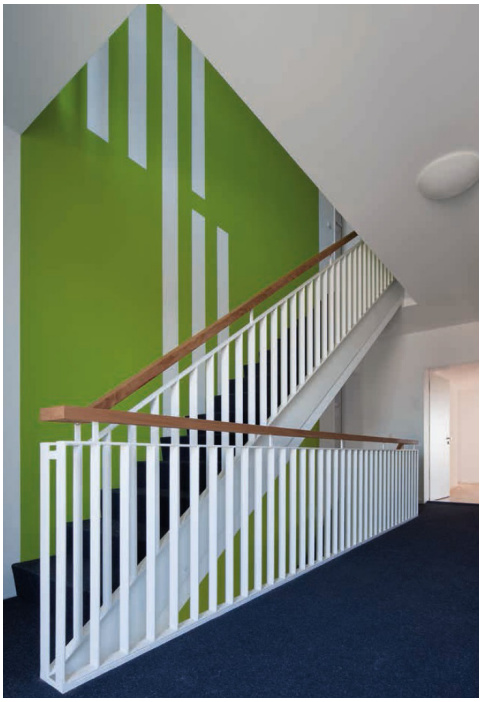


Fig. 17: Staircase in Smart is Green

several generations. The number of units on each floor was also lowered from four to three in order to ensure that two large apartments on each floor could be divided, in the interests of greater versatility.

Bringing the number of apartments on each floor down from four to three allowed the staircase to be placed adjacent to one of the exterior walls. The apartments cover a larger area as a result, making them more family-friendly. This made it possible to situate a spacious and freely accessible foyer and communal area at the entrance to the building, without having to apply additional fire safety measures.

The ground-floor commercial zone incorporated in the original design also proved to be unfeasible in terms of both building regulations and trade. The play areas originally planned for the roof were therefore integrated into the ground floor, as greater upgrading of the solar thermal system alongside the photovoltaic units was required to

Fig. 18: Building site, summer 2012

safeguard the energy concept. Due to various technical conditions and changes, spaces for energy generation were reallocated during the planning stage. When the building services concept was developed in conjunction with businesses, the positioning of the solar thermal units within the balcony railings was shown to be impractical. The high cost of installation, due to the extensive cable lengths, could not be squared with the desired energy efficiency (line losses) and the design requirements. In addition, the probable high temperatures meant that there would be a risk of injury in the open outdoor areas around the building. The solar thermal system was therefore replaced with photovoltaic units, which could be simply integrated. These are now positioned between the planted elements in the balcony areas on the south, east, and west façades. The idea of fitting all of the sun-facing façades with photovoltaic modules was not followed up for technical reasons (the convection sizes of the modules) and due to very limited efficiency coupled with high costs. As a result, the intended generation level of 7,000 kilowatt-hours per annum could not be achieved: the current performance is 3,500 kilowatt-hours per annum. Thanks to progress in technological development, especially in terms of increased efficiency, the east and west façades can be retrofitted with photovoltaic units.

As the roof surfaces were not large enough to allow all of the building's hot water and appliance electricity needs to be met, the parapet wall was added to the design. A solar thermal system in the form of visually appealing pipe collectors is located in the parapet wall area visible above the balconies, and finishes off the roof surface.

The excess energy that cannot be fed into the fully loaded PCM storage tanks is not stored in a geothermal probe, as specified in the competition design, but, rather, made available to the Wilhelmsburg Central energy grid. In return, during periods when the building is undersupplied with its own energy, it receives heat from the energy grid. It must be said that the solar thermal areas are oversized for the building and its needs. By connecting to the existing district heat network the excess energy can be virtually cached and bring the carbon balance sheet back to neutral.

The very latest technologies were planned for "Smart is Green", to support the aim of energy generation. The integration of the photovoltaic and solar thermal elements into the building's façades presented a challenge. The crisis in the photovoltaics manufacturing market severely restricted custom design options (convection sizes, special sizes, module colour). No material could be found in the field of PCM technology that could be incorporated into a storage tank and would also be suitable for a temperature range around 40°C. A PCM that was suited to high temperatures around 80°C was ultimately selected, but it was difficult to find a manufacturer that could offer the appropriate storage technology, combining high temperatures and the high corrosiveness of the salt hydrate. The solution was found at the company FSave, whose activities were otherwise concentrated in the field of energy and heat transport. FSave had sufficient experience in creating plastic storage tanks for use with salt hydrate and high temperatures.

B.5 Assessment

The PCM storage tanks caused particular problems, as there was a lack of suitable manufacturers. The technology is still in its infancy; while there is a great deal of research, not much of it has been put into practice.

The project has led to increased information about PCM storage on the part of the building service engineers who worked on it. This technique was previously unfamiliar to them, but it will now come into play on future projects. PCM technology has been "all the rage" for some time, but there were few practical examples in which this material had been used for storage tanks. Up until now, PCMs have been used in construction materials for heat storage, but not as containers that act as a substitute for water storage tanks.

As they can store twice as much heat as a water tank, the PCM tanks have a crucial space-saving advantage, as heat transfer is easier to achieve. As the use of renewable forms of energy increases, the building services areas also must be able to grow, particularly due to the need for energy storage facilities, and PCM storage tanks require much less room in comparison with conventional storage units. The space left over can therefore be put on the market. At present, as the sale of the recovered areas fetches more than the additional costs of building a PCM storage tank, the use of this technology makes sense on a large scale.

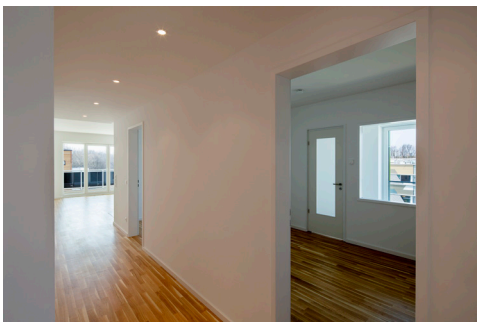


Fig. 19: First floor interior view

Fig. 20: View from the west, May 2013

"Smart is Green" has made ample use of this space advantage. It must be acknowledged that many of the materials employed in the private sector would not have been used to the same extent for building projects that did not receive funding. Often the costs were not commensurate with the actual use, as the technologies showcased as part of the project – the PCMs or the photovoltaic units on the walls – are not yet sufficiently mature in technological terms to offer reasonable payback periods. However, as "Smart is Green", as a model, is aimed at demonstrating the possibilities of energy generation and storage from various renewable sources, this does not present any problems, as the project is focused on gathering experience about the way in which the materials interact, in order to make the structures used here suitable for mass production and applicable to other types of buildings.

Not all of the ideas put forward in the competition were implemented regardless of their profitability, however Many of them were adjusted for financial reasons, so that the energy concept was changed from a plus energy house to a zero energy house. There were also some difficulties in executing the technology concept, as the various parties involved had a different understanding of what the planned energy concept would entail. In short, there was a lack of experience in dealing with the materials used, and with the completely renewable energy concept as a whole. On an administrative and political level, there is still a lack of knowledge about how to handle

Fig. 21: First floor interior

Fig 22: View from first-floor balcony, May 2013

smart materials – the environment often does not seem quite ready for the use of innovative technology beyond conventional design.

The east and west façades are not ideal for vertically placed photovoltaic units, as optimum efficiency cannot be achieved. It was also important to demonstrate the possibilities of integrating photovoltaic modules into the building. Cost is a particularly pertinent factor here – high-quality photovoltaic elements with an attractive appearance have a high price to match. Due to the low level of efficiency, the payback period corresponds to almost the entire building cycle. Further research was required before photovoltaic units could be used as an element of the façade design. In order to increase the profitability of the photovoltaic units on the façade, additional tweaks would have had to be made to the architectural design, which proved impossible in this case due to the location of the construction site and other restrictions.

Increasing the supply of renewable energy in the future means increasing the energy storage facilities within the building. The technology for this needs to be perfected, as in many cases it is not yet really economically viable. The payback periods are still too long. Yet there is no known approach to the storage technology that would enable PCMs to solve storage problems in the absence of natural underground storage (e.g. rock, stone) below the building. Due to various constraints the building services room is quite small, at only 20 square metres. Given the large amount of space required by the use of solar thermal energy (transfer station, collecting buffer, expansion vessels), such a small space was able to serve this function only by using PCM technology.

With its holistic approach and use of e-mobility, decentralised self-sufficiency, and connection to a central heat supply, this apartment block demonstrates how climate change can be actively addressed in housing construction, so that residential buildings no longer act as a drain on energy, but as energy generators and stores in their own right. Architecture and structural engineering are used to join up function and form, making versatile use of the space possible, and the result acts as an example of construction that will meet the requirements of inner-city urban housing in the years to come.

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