



Hamburg ahead

INTERNATIONAL BUILDING EXHIBITION HAMBURG

Smart Material House BIQ

July 2013



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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 ser-

vices, 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 energy, 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.

In this brochure, the architectural and technological concept of the BIQ "Smart Material House" is presented in detail. Further, the planning process is clearly shown, since it has involved many changes on the path from design to execution of the project. These changes are technically, financially, or functionally justified – so original targets had to be partially adjusted.

Especially for model projects, it always comes back to the way plans are changed – this, too, in addition to creating innovative end products, is part of the aim of an international building exhibition: to test construction processes and procedures. Only after consideration of the planning process is it possible to assess whether a model building project can be deemed an exemplary way of dealing with smart materials in the twenty-first century. This brochure is meant to provide technical details for experts, in particular to make it possible to reach an objective assessment of whether the "BIQ" model project really is of this kind, and whether or to what extent the objectives drawn up before the start of planning were actually achieved.

After this brief introduction, the "Smart Material House" is presented in the form of a fact file and then explained in detail. We start with the architectural and technological concept of the house, before describing the planning process and the evaluation of the model project. The "BIQ" coverage mainly focuses on the energy innovation, the bioreactor, and the "Living on Demand" concept.

A.2 BIQ Project Outline

FEATURES

- World's first building façade made from photobiocollectors
- New lifestyle concept: "Living on Demand"
- The building can react to the changing needs of its users and to its surroundings



Fig. 1: View of BIQ - north and west façade



Fig. 2: View of BIQ - south and west façade

The "BIQ" is a cubic, five-storey passive house designed by the architectural firm SPLITTER-WERK, Graz, with two differently designed façade types. Façades of the second type - bioreactor façades - are positioned on the southwest and southeast sides of the building. These are used for growing algae - for energy production, but also for controlling light and shade in the building. Due to the steady growth of algae, each façade is constantly moving and changing its colour.

The "BIQ" has 15 apartments, some of which are based on the concept of switchable spaces - Living on Demand - with functions that can be switched alternately or simultaneously to a "neutral" zone. Each apartment's functions, such as bathroom, kitchen, and bedroom, are located in built-in furniture that is distributed within the neutral space, or can be organised around it. The timing of the residents' schedules, and the changing programme of everyday life, thus shape the appearance of the apartment.

PROJECT PARTNERS

Idea, Concept, and Authorship

- SPLITTERWERK, Label für Bildende Kunst, Graz
- Arup Deutschland GmbH, Berlin
- B+G Ingenieure, Bollinger und Grohmann GmbH, Frankfurt
- Immosolar GmbH, Hamburg
- Strategic Science Consult GmbH, Hamburg

Investors

- Otto Wulff Bauunternehmung
- Strategic Science Consult GmbH, Hamburg

Sponsors

- Endress+Hauser Messtechnik GmbH+Co. KG, Weil am Rhein
- Colt International GmbH, Kleve
- ME-LE Energietechnik GmbH, Torgelow
- BGT Bischoff Glasstechnik AG, Bretten
- Arup Deutschland GmbH

Technical planning

- Arup Deutschland GmbH, Berlin
- sprenger von der lippe
- Technisches Büro der Otto Wulff Bauunternehmung GmbH
- Feyerabend + Gunder GmbH, Goslar

Façade system development

- Arup Deutschland GmbH, Berlin
- Strategic Science Consult GmbH, Hamburg
- Colt International GmbH, Kleve
- Gefördert von Forschungsinitiative „ZukunftBau“

Other project partners

- Hamburg Energie GmbH, Hamburg
- Immosolar GmbH, Hamburg

PROJECT DATA

Project costs

- approx. € 5 million (funded by the Hamburg Climate Protection Concept)

Plot size

- 839 m²

Gross floor area

- 1.600 m²

Size of the functional units

- 48 - 122 m²

Energy standard

- Passive House

Energy supply

- bioreactor façade, geothermal energy with heat pump, "Wilhelmsburg Central Integrated Energy Network"

Construction schedule

- December 2011 - April 2013

B BIQ Project Details

B.1 Architectural Concept

The “BIQ” is a solid cubic structure of stone-work and concrete. The building is four storeys high, with a penthouse level. The four-spanned construction with 14 single-storey apartments, and a duplex apartment, is accessed from the north via the centre of the building. Assorted functional rooms and the building services area, accessible to the public from the outside of the building, are located on the ground floor.

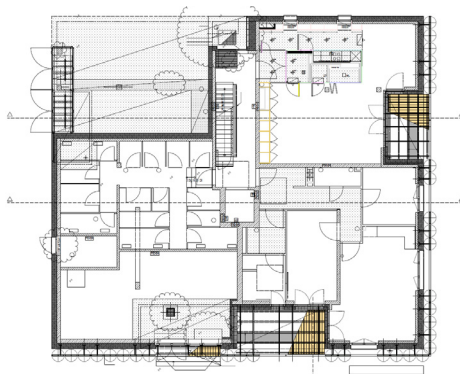


Fig. 3: Layout, ground floor

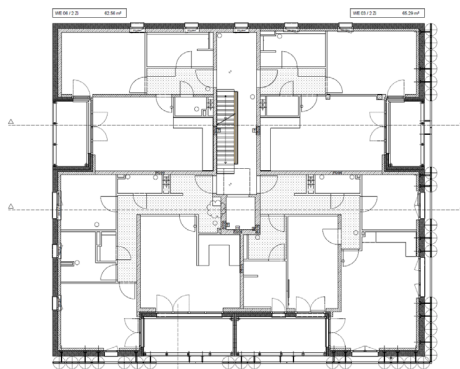


Fig. 4: Layout, 1st floor

Two apartments, one of them the duplex, are laid out with a special interior design concept in mind: there is no consistent and explicit allocation of functions to individual rooms, just an approximate assignment of possible uses that can be switched on and off, as and when needed. A room can fulfil different roles - using built-in furniture that can be adapted to it as a functional element. All the functions are hidden away in the built-in furniture that completely fills the walls,

but the functionally neutral, reconfigurable space remains. Even the windows can be closed using internal shutters or sliding partitions.

These new layout typologies can be seen as a response to the contemporary demands made

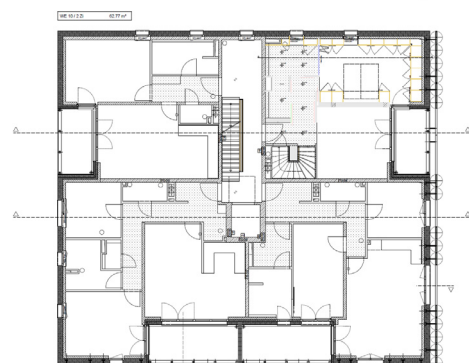


Fig. 5: Layout, 2nd floor

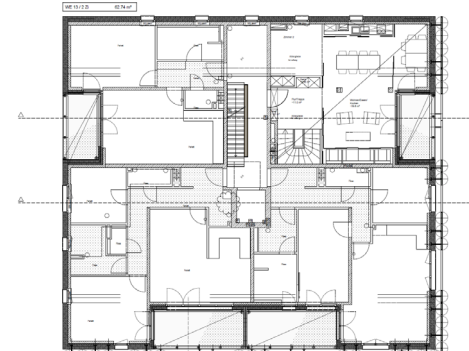


Fig. 6: Layout, 3rd floor

on apartments. The flowing spaces of Mies van der Rohe, the open layout of Frank Lloyd Wright, the spatial planning of Adolf Loos, and the economy of the Frankfurt kitchen are examples of the architectural concept of switchable rooms. This concept is currently being developed in the Hamburg and Milan apartments of the “BIQ”. Rooms are not linked together or interlaced, but functions are alternately or simultaneously - on demand - switched into a spatially minimised “neutral” zone and can then be switched again. The layout is permanently reconfigurable depending on requirements. To function-neutral zones

- called "Lagoon", "Breakfast out of Doors", "Invisible Cities", and "Grey Zone" - are attached different function zones.

Both the function-neutral and the function zones are in a variety of colours - but always the same colour for each function - in an "all-over" design. Floors, walls, and ceilings are given high quality coatings - epoxy or other suitable material components.

The interior design features very simple, neutral, and restrained furnishings that are also restricted to the respective colours of the different zones, so that the concept of the two basic typologies provides aesthetic support for a single overall scheme. And finally, accessories such as

drawings, prints, and smaller objects from the SPLITTERWERK archive provide the Milan and Hamburg flats with the special, comfortable atmosphere that is not only required for the exhibition within the context of the IBA, but is also orientated to the wishes of later residents of these apartments in the "BIQ".

This is achieved with built-in furniture, in which the functions of the flat, such as bathroom, kitchen, and bedroom, are located. The time sequences of the residents' use of the flat shape its appearance. In the design of the surfaces (colours and materials), there is also a division into function zones and function-neutral zones. There is thus no differentiation between floor, wall, or ceiling: the room itself is the defining element. The function-neutral zones have their own independent design, as do the connected function zones, each in turn of different design. Through the interaction of resident behaviour, in-built elements, and special coating of the surfaces, new spatial impressions and functional relationships are possible. In contrast with the modernist era, the aim is thus not to implement a concept of flowing spaces, but rather one of switchable rooms - on demand. Resident behaviour determines the architecture of the interior.

The central element is the design of the rooms' surfaces. In the Hamburg flat, the surfaces of the room - the floors, ceilings, and walls - are divided into areas decorated in various shades of grey. The switchable function zones are each given a customised colour design.

In the Milan apartment the surfaces of two of its three rooms are covered with photographic wallpaper: a panoramic roof landscape, "Invisible Cities", and a forest backdrop, "Breakfast out of Doors". When all the surfaces are closed, the residents find themselves in a kind of second spatial reality. Ceilings and floors are coloured. The switchable function zones each have their own colour scheme. The third room, "Lagoon", is decorated overall in blue. On the surfaces, an illu-

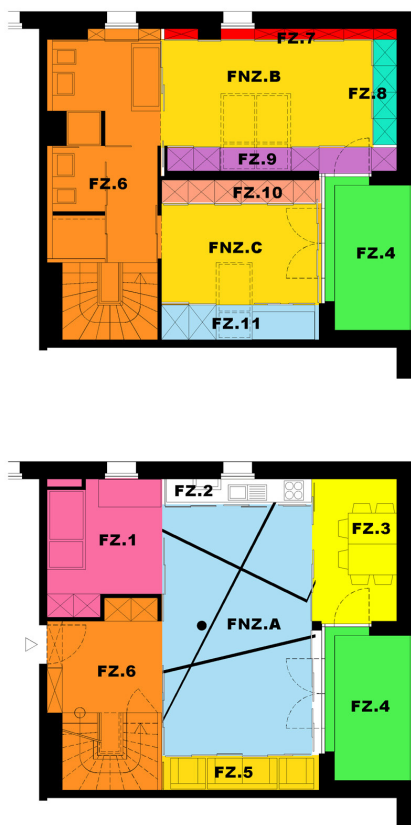


Fig. 7: Functional diagram, Milan apartment



Fig. 8: Hamburg apartment

sory perspective is created by black lines, fluorescent in the dark, that shift the room's perspectival boundaries. Here, too, the switchable function zones each have their own colour scheme.

The well-insulated façade of the building has both a services- and energy-related significance (see Section B.3, p.16), plus an optical system adapted to the seasons. The two-layer façade system consists, in the first, inner layer, of a plaster-insulated heating system with green-dyed mineral plaster. The second, outer layer is thermally decoupled and positioned, as an independent bioreactor façade, on the southeast and southwest sides of the first layer. Due to the seasonally varying coloration of the bioreactors - depending on the activity, there are changes in the transparency and thus the incidence of light through the façade elements - and the bubbles rising from the constant process of upheaval in the bioreactors, a dynamic, ever-changing appearance is created (see Section B. 2, p.12).

Generous balconies on the south side of the building offer residents an unobstructed view of greenery and the opportunity to contemplate up close the algae façade's natural power station.

But visitors can also watch the algae, and thus the energy mass, grow. The green colour of the façade shows that the algae are breaking down carbon dioxide and processing it by photosynthesis. The renewable energy production is outwardly visible and forms part of the architectural concept.

The issue of energy production thus changes the architectural appearance of the building on a daily basis. Part of the dynamics is the regulatory technology, which is located behind the bioreactors, colour-coded by its red and white stripes. Opposite the two dynamic façades on the sun side stand the two shadow-side façades, with green-coloured plaster. These façades, with uniform, small window openings, draw their own dynamism from the applied speech bubbles that highlight, visually and communicatively,



Fig. 9: Milan apartment

the process of algae production on the sun side.
The penthouse is treated as an independent
component, different in colour and design, and
separated from the rest of the structure.

B.2 Smart Material Concept

A façade can be far more than the aesthetic or energetic clothing of a building. Rather, façades will in the future be able to take on multifunctional tasks. With intelligent technologies, the “BIQ” can generate energy through its own envelope, store it, and use it itself. Therefore, the smart materials used in the “BIQ” are on the façade. This includes, notably, the components of the bioreactor façade, the structure and function of which is explained below.

Bioreactor Façade

The bioreactor façades on the southeast and southwest sides of the building are used for production of biomass and heat. A bioreactor façade consists of 129 reactor modules, called photobioreactors (PBRs), 70 cm wide, 270 cm high and 8 cm thick, arranged in groups. The PBRs are mounted on a steel frame that is simultaneously used for wiring. The PBRs are filled with water (culture medium), in which microalgae are cultivated. As a nutrient, CO_2 is added to the culture, for which flue gas from a biogas-fuelled micro-CHP (combined heat and power unit) is used. The CO_2 converts the growing algae to biomass.

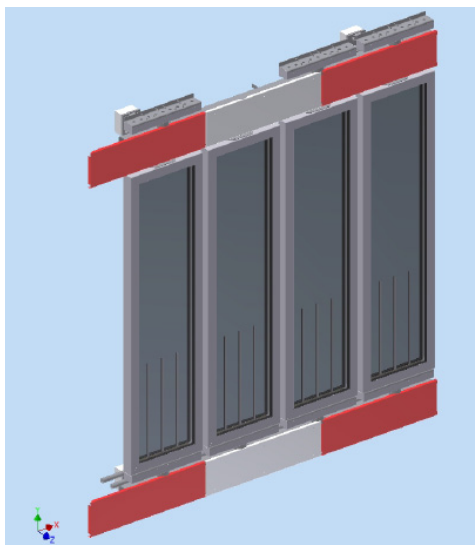


Fig. 10: Façade element, front

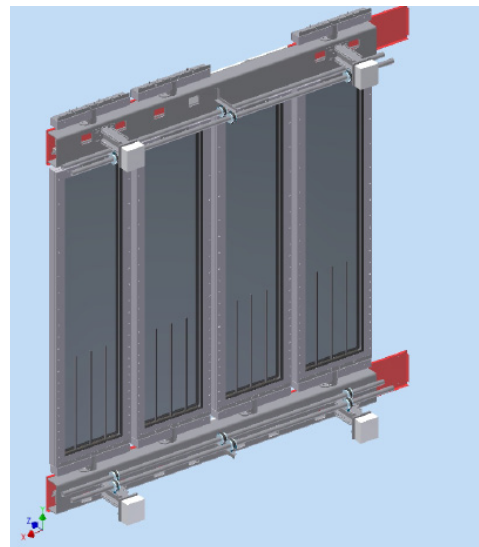


Fig. 11: Façade element, back

The PBR, without supports, is a 1.7 cm wide, disc-shaped hollow body of transparent, clear glass (laminated safety glass (LSG) on both sides), filled with an aqueous solution (the culture medium). This contains the nutrient salts necessary for algae growth. To avoid the microalgae sinking and remaining in suspension, the culture medium is continuously stirred by the supply of compressed air into the PBR (through an airlift). The high flow velocities along the inner surfaces of the bioreactor, and the lattice-like beads (scrappers) enclosed within it, inhibit the deposition of microalgae and biopollution. This CO_2 is added continuously as a nutrient.

When in operation, the bioreactors are connected in series, so culture medium circulates through all of them. When light falls on them, during the day, the bioreactors can heat up to a temperature of 35°C . So their function corresponds to that of solar thermal absorbers. The water is circulated through the building services centre, where biomass is collected at a central location (by filtering out) and heat drawn off (through a heat exchanger). The heat energy produced is distributed in the energy centre for various uses: heating, and preheating of hot water. Excess energy

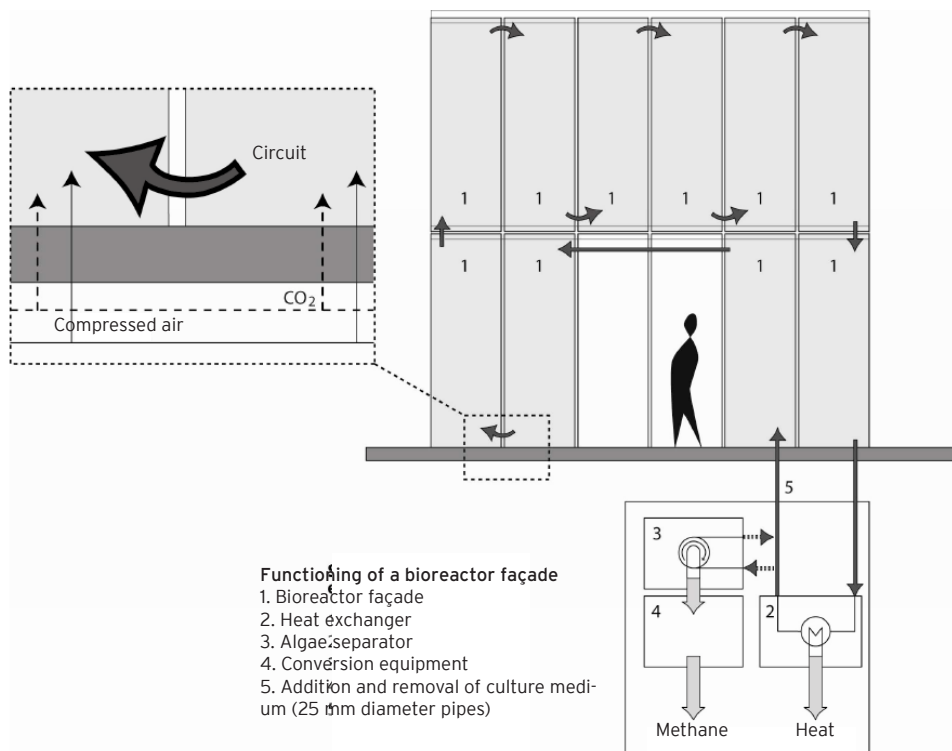


Figure 12: Functioning of a bioreactor façade

is stored in geothermal boreholes, from which energy is drawn with heat pumps as required. The biomass obtained is filtered out in the energy centre, collected, converted into biogas in an external biogas plant, and used to supply energy to the city (see below). Simultaneously, the CHP is required to produce flue gas as a nutrient for the bioreactors. The resulting waste heat is also used to heat water, or surpluses are stored in the district heating system of the energy network and taken from the district heating system again if necessary.

Operation of a Bioreactor Façade

For the cultivation of algae, the PBRs are filled with drinking water enriched with plant nutrients (nitrogen, phosphorus, trace elements). The nutrient composition of this culture medium is selected or varied so that optimal growth of algae may be obtained. To keep the nutrient concentration constant, the culture medium is continuously tracked in the PBR. In proportion to the volume added to the culture medium, algae suspension flows out of the PBR. Through this sequence, the harvesting of the algae is ensured simultaneously. The separation of the algae from the culture medium (necessary for harvesting) takes place in a flotation system, specially developed together with the company AWAS International GmbH.

After the separation, most of the culture medium is returned to the PBR. Only a small amount of the culture medium is removed from the system

and discharged via a drainage arrangement into the public sewer. When operating the bioreactor façade, every effort is made to keep the drainage as low as possible and to carry out the cultivation with a largely closed circuit for water and nutrients, thus using few resources. The supply of CO₂ to the algae is ensured via a saturation device, through which flue gas from the micro-CHP is introduced directly into the water circuit, and with which the amount of bioactivity and thus the degree of bioreactor coloration can be controlled. The use of the CHP is controlled as needed for the desired growth of algae.

A monitoring network has been established to check continually all the parameters relevant to the process. Control of the system is almost fully automated.

How Algae Technology Works: Conversion of Sunlight into Biomass

Microalgae are tiny, mostly single-celled organisms, about 5 micrometres (nm) wide. Like other plants, microalgae draw on sunlight as an energy source and use it, together with CO₂ and the nutrients nitrogen and phosphorus, to build up biomass. This process is called photosynthesis, which in nature occurs in the same way in all plants. Microalgae, however, are much more efficient in the conversion of light energy into biomass than multicellular plants, because they are single-celled and each individual cell performs photosynthesis. Microalgae can divide up to once a day, doubling their biomass, which is an energy carrier. 1 gram of dry biomass contains about 23 kJ of energy. Through constant turbulence, the algae are prevented from turning dark due to excessive sunlight, which would mean individual algae would block light from each other, thereby reducing growth. This turbulence is generated by the continuous injection of compressed air into the PBR.

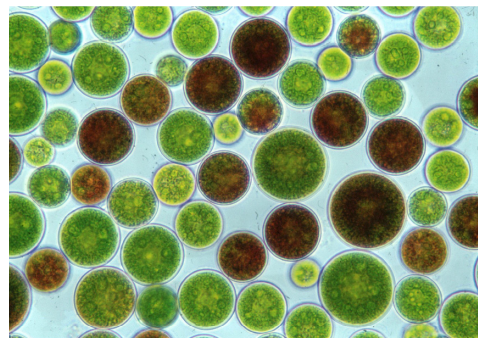


Fig. 13: Microalgae (magnified)

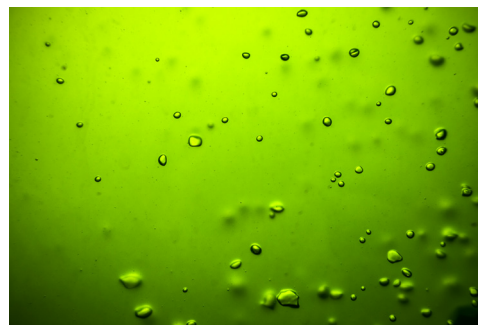


Fig. 14: Partial view of a photobioreactor

Algae Separator / Conversion

The biomass resulting from the growth of the algae is automatically harvested through an algae separator (the flotation system mentioned above) and collected in a temperature-controlled container. Removal to a biogas plant and conversion of biomass to methane occurs about once a week. The conversion of biomass to methane is not done on site, because the necessary technology is not yet ready for use in residential buildings, or is difficult from a legal point of view: instead, it is carried out externally in a biogas plant.

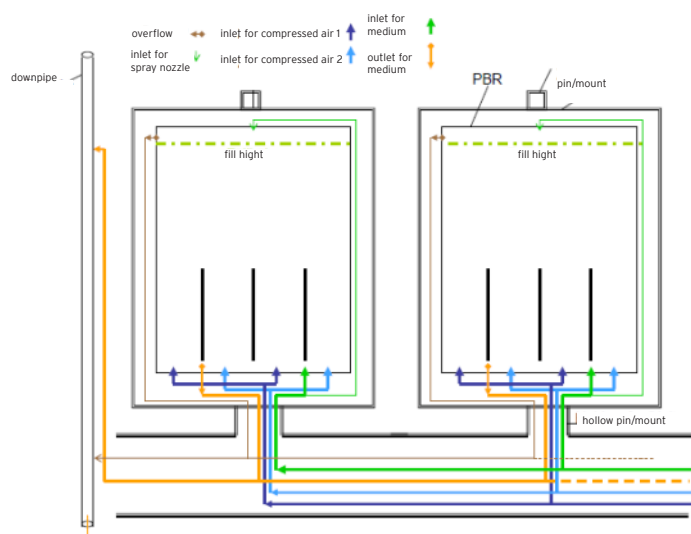


Fig. 15: Functional diagram of a PBR

Inlets and Outlets

To supply the PBR, two separate pipe systems function on the façade, a compressed air system and a water system:

1. Compressed air system (air at a pressure of about 2 bar), to operate the airlift. Each bioreactor is connected to this air system. The injection of air every 4 seconds is controlled by magnetic valves, which are integrated, like the water circuits, into the carrier system of the façade.
2. Each bioreactor is connected by an inlet and an outlet to the water system. There is a separate circuit for each storey of the building. The four circuits are brought together in the energy centre.
3. Each storey has a current distribution board to control the valves of the respective control circuits. The current distribution boards of the different storeys are merged into a main distribution board in the energy centre.

Circulation of the media is ensured by thermally insulated stainless steel wires. The temperature in the PBR is kept constantly below 40°C in the summer and above about 5°C in the winter.

Building Services / Energy Management Centre

Continuous microalgae cultivation with minimal maintenance expenditure is made possible by automated control of the process and installations, combining the cultivation of the algae with their harvesting and utilisation. The additional building services required are to be integrated as a "plugin" into standard building services equipment. Supply and disposal of water for the bioreactors is ensured directly through municipal tap water and sewage services. The system developed to control the process and facilities is in line with a common standard for complex building services control arrangements and is installed in the "BIQ", separated from the control of other building services (room temperature control, control of heating, etc.).

Heat Storage

The heat is removed via heat exchangers and then stored (in buffer storage, geothermal boreholes, the "Wilhelmsburg Central Integrated Energy Network") and/or used directly for the heating supply and hot water.

B.3 Building Services Concept

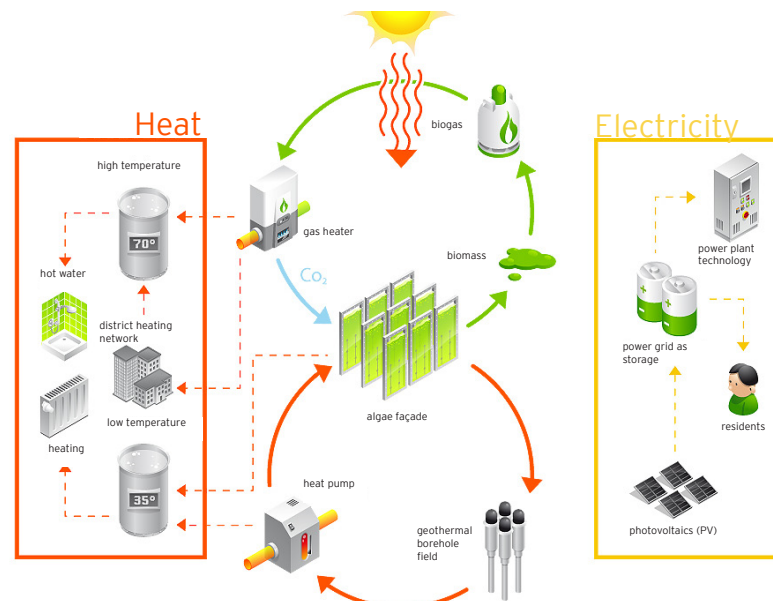


Fig. 16: Building services concept: BIQ energy centre chart

The basic idea behind the energy concept is the connection of different energy sources so that they will work together. The energy concept is thus capable of bringing together, in one circuit, solar energy, geothermal energy, a condensing boiler, district heating, and the production of biomass in the bioreactor façade.

The heat demand of the building is already relatively low, since the “BIQ” runs in accordance with the Passive House standard. Much of the heat is therefore needed on a seasonal basis for hot water. The living space has underfloor heating.

For heat supply, several components are used. The bioreactor façade, producing heat throughout the year, reaches its highest seasonal activity in the summer. Excess heat is stored in geothermal boreholes at a depth of about 80 metres and released in periods of low heat generation by the bioreactors. This is supported by the coverage of peak loads via the district heating system of the “Wilhelmsburg Central Integrated Energy Network”. In addition, the ventilation sys-

tem is equipped with a heat recovery function.

The hot water supply is stored, firstly, by the micro-CHP, which is operated with biogas. The CHP is required to produce flue gas, which is then introduced as a nutrient into the bioreactor façade. Secondly, space heating is ensured by a share of the hot water supply from the bioreactor façade and, thirdly, peak loads are covered by the “Wilhelmsburg Central Integrated Energy Network”.

The various elements of energy production are rendered usable for the building through a central heat exchanger (energy controller) and made available, as needed, and energy-optimised, via the automatic building services control system. The control of building services for each apartment is ensured automatically by a control system for the whole block.

The original plan envisaged the use of photovoltaics on the extensively greened roof surface but this was not implemented. Nevertheless, photovoltaic elements can easily be retrofitted

to the roof of the building as required. Until then, all electricity will be drawn from the grid. Building services are particularly focused on the bioreactors, which can provide a not insignificant amount of heat, as the following output summary shows:

Basic data per m² bioreactor area

Biomass production	15 g TS/m ² /day (900 kg/year)
Energy production in biomass	345 kJ/m ² /day
Biogas production from biomass	10.20 L methane/m ² /day

Energy indicators for 200 m² bioreactor area with 300 days of production per year

Biomethane production	612 m ³ methane /year
Energy in methane	6487 kWh/year
Energy loss (auxiliary power, etc.)	30 per cent of production
Net energy as methane	approx. 4541 kWh/year
Net energy from heat	approx. 6000 kWh/year

This results in the following, provisional forecast for the annual energy balance (the actual energy balance will, due to the pilot status of the bioreactors, be known only after taking into account the total use over a whole year):

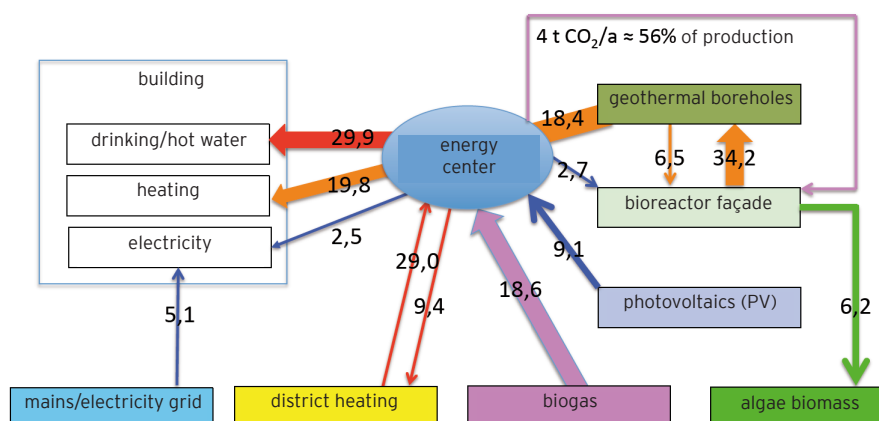


Fig. 17: Annual balance of energy flows in MWh/year

B.4 Planning Process

In the first period of the two-stage competition that began in late 2009, a concept was developed by a planning team of architects and specialists, suggesting a set of proposals for the use of different building materials and technologies for air conditioning and energy supply. Even back then, the jury – despite their praise – expressed some doubts as to the implementation of all the technologies and materials of the “Smart Treefrog”, on the grounds of cost-effectiveness, and they recommended that the concept be sharpened and focused on a core area. The concept was based on a multi-skinned building with a core zone for living and a peripheral area for open space use and development within a glass façade (on the house-within-a-house principle).

In the revisions up to the end of 2010, the original concept of the house-within-a-house was

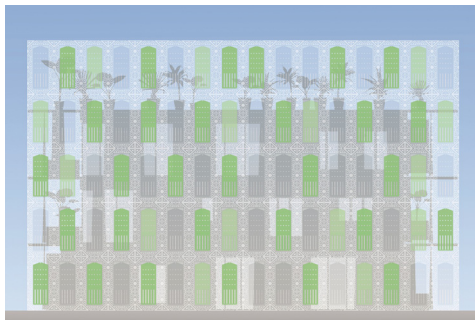


Fig. 18: View from the first phase of the competition

abandoned, though the energy objectives of the project were maintained: the construction of a building that would be self-sufficient in energy through the use of algae.

The final version, implemented at the end of April 2013, included several changes from the competition design. There was a focus on the bioreactor façade and a first prototype was realised in a multi-storey residential buildings. The Living on Demand concept was also transferred to the now more compact structure in the form of individual apartments.

The biggest challenge during the planning process was the implementation of the bioreactor façade. The basic idea of a living façade was, from the creative point of view, easily implemented; the technical side, however, was until recently unclear, since this technology has never before been incorporated in this form. Numerous variants were tried, and the plans changed on an almost weekly basis, as the solution of one existing problem with the integration of the bioreactor façade into the building services kept throwing up new problems. By itself, the planning process for the bioreactor façade was more expensive than some other plans for whole buildings and could be completed only at a great cost in time and personnel.

The originally planned photovoltaic system on the roof was dropped for cost reasons – but it can be retrofitted when needed. The use of micro-algae technology and its implementation in the “BIQ” was preceded by development and testing during the course of the IBA Hamburg, but independently of it.

From early 2008, SSC GmbH carried out extensive research to develop processes and systems for the large-scale cultivation of microalgae. With the support of the city of Hamburg and in cooperation with E.on Hanse AG, a pilot installation in Hamburg Reitbrook was put into operation in August 2008. With this pilot, in collaboration with various colleges and universities in North Germany within the framework of the interdisciplinary



Fig. 19: Assembly of the PBR, March 2013

R&D project TERM (Technologies for Developing the Resources of Microalgae), the conditions for using microalgae technology in the façades of buildings could be created.

These conditions are:

- Ability to cultivate microalgae in the open in Northern Europe throughout the year, under different light and temperature conditions (summer and winter).
- Using newly developed reactor technology, reaching high cell densities in the reactor and thus achieving high production rates (10-100 g dry weight per square metre of reactor surface per day), with incoming light converted into algal biomass at an efficiency of 5-8 per cent.
- Prevention of fouling of the reactor surfaces (known as biofouling)
- Continuous cultivation with minimum maintenance costs through automated control of the process and the installation.

Since November 2010, the firms SSC GmbH, Arup Deutschland GmbH and Colt International GmbH have been working within a federal project funded by Building for the Future (on behalf of the Federal Ministry of Transport, Building, and Urban Development, BMVBS) on the development of a façade system that permits the controlled use of microalgae technology on buildings (i.e. bioreactor façades). The result has been the development of a functioning bioreactor that could be used as a façade element.



Fig. 20: Reactor test facility in Hamburg

The adaptation and partial development of the individual bioreactor and its integration into a systemic approach to façade construction was carried out by the "BIQ" project. This included a support system, a control system, and a management system integrated into the building services.

The construction of the glass bioreactors was given legal building regulation approval through agreement on the individual case, based on the successful implementation of appropriate building component tests. Ultimately, all the necessary steps were completed on schedule and achieved licensable results, so the bioreactor façade could be installed in its present form in mid-March 2013.



Fig. 21: Mounting a PBR element, March 2013

B.5 Assessment

The “BIQ” is the world’s first building with a bioreactor façade. The efficiency of the operation has still to be proven, yet it is a model for other new buildings, refurbishment work to provide clean energy, and plans for housing developments, as bioreactors can, with appropriate building technology, be installed without major construction difficulties.

The “house with Bio-IQ” (“BIQ”) is a pilot project, a building façade that we can learn from. The approx. 200 square metre main algae façade comes with a net annual energy yield of about 4500 kilowatt-hours of electricity. This is somewhat more than an average household consumes in a year (3500 kilowatt-hours per year). In the “algae building”, there are 15 apartments – so only one of them could in principle be completely supplied with electricity from the bioreactors. A much larger proportion of the apartments can, however, be provided with heat, hence the bioreactor façades are used for heat generation (6000 kilowatt-hours per year) and not for producing electricity. This corresponds approximately to the supply of four apartments with heat, from the bioreactors alone.



Fig. 22: South façade of BIQ, April 2013

The future of energy supply seems to be organised on a decentralised basis, coming as it will from energy of various sources. View, the bioreactor is making a contribution to this that is complemented by the use of geothermal and other renewable energy sources via the district heating network. The bioreactor is thus another piece of

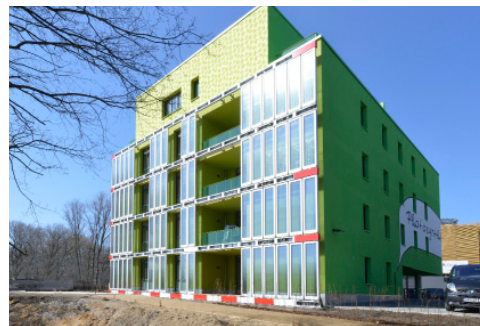


Fig. 23: East façade of BIQ, April 2013

the jigsaw, leading to a fully renewable, decentralized energy supply for buildings. What this may look like can be seen here with the “BIQ”.

With the layouts of the Milan and Hamburg apartments, the concept opens up fundamentally new possibilities for living in the twenty-first century. Alternating between compactness and versatility requires appropriate behaviour from the user, however. The maximum configuration of the surfaces means that a work of art is created, into which the user must fit and with which they can live – and bring something of their own to the table; as a user they must be able to tolerate the reduced opportunities for their own design ideas.

Transferred to a reduced form of the design, the model does open up new perspectives for domestic life, especially in the debate as to whether it is not more sensible to use space in a very compact way, through built-in elements, rather than consuming too much space for maximum individualism.

The bioreactor façade system is suitable for a variety of different types of building, whether we are talking of industrial and commercial constructions, buildings for public infrastructure, trade, or residential buildings. Due to the decoupling from their own façade, bioreactors are buildable practically everywhere. Since the façade system stores CO₂ and flue gas, integration into halls of industry and commerce is possible, to dissipate the CO₂ arising from the process. Also, the ex-

pansion of the façades and roof surfaces used in low-rise industrial buildings can permit the economic operation of bioreactors. The bioreactor façade can, however, be considered not only for new buildings, but especially for the retrofitting of existing structures. On the residential level, in conjunction with photovoltaics and a CHP, even the complementing of solar thermal energy by bioreactors as heat providers could be possible in the long term. At the IBA Hamburg in 2013, with the first use of this system, the foundation for further development was laid: a start was made on the house level, but the greatest potential probably lies in the area of large industrial, commercial, and public buildings.

A calculation of exact power consumption and wastage is not yet possible and only experience can provide this information. The firms of Arup Deutschland GmbH, SSC GmbH and Colt International GmbH will, together with the HafenCity University Hamburg, carry out 24 month monitoring of energy and technical capacity, with the recording of user acceptance, in order to develop a reliable evidence base and evaluate the “BIQ” model project in terms of the algae façade.

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