Smart Cities – Good Practice

**Buildings**

# BIQ House+SolarLeaf – the use of microalgae

**Hamburg, Germany**

**The world's first bio-reactive façade system for low-carbon buildings**

**The BIQ (*Bio Intelligent Quotient*) house represents the world's first pilot project for the implementation of a bio-reactive façade in residential buildings [1]. The bio-reactive façade, called SolarLeaf, generates renewable energy from algal biomass and solar thermal heat. In particular, the BIQ house in Hamburg has 200 m$^2$ of algae filled bio-reactive paneling, which supplies the building with all of the energy it needs while reducing carbon dioxide ($CO_2$) emissions by 6 tons per year. This pilot project exemplifies a building integrated system absorbing $CO_2$ emissions, while cultivating microalgae to generate biomass and heat as renewable energy resources. The environment for photosynthesis is provided by glass photo-bioreactors installed on the south-west and south-east sides. At the same time, this innovative system integrates additional functionalities such as dynamic shading, thermal insulation and noise abatement, highlighting the full potential of this technology. Through this system, the BIQ house can produce energy in a carbon neautral way while working at the same time as a carbon sink through the use of algae for capturing $CO_2$. For these reasons, it represents a good practice for future building development to promote a low-carbon urban future and shape better cities in which to live and work.**

## Country/ City Profile


| Country | | City | |
|---|---|---|---|
| **Population (2014)** | 80,889,505 [3] | **Population (2014)** | 1,762,791 (city) [9]<br>5,100,000 (metropolitan) [5] |
| **Land area (km²)** | 357,170 [3] | **Land area (km²)** | 755.3 (city)<br>26,000 (metropolitan)[5] |
| **GDP per capita (2014, current international $, at purchasing power parity)** | 45,802 [4] | **GDP per captia (2014, US$, at purchasing power parity)** | n/a (city)<br>49,757 (metropolitan) [10] |
| **Region**<br>Europe | | **Region** | north side, sea, lakes |

| City's physical geography | | |
|---|---|---|
| | **Location** | ✓ Situated close the North Sea and the Baltic Sea, latitude 53.34° N, longitude 10.00° E **(rising storm floods, rising sea level, drier summers, change in precipitation)**<br>✓ Situated in a fertile soil and sand dunes landscape<br>✓ Low altitude (8 m above sea level) |
| | **Climate** | ✓ Mild, oceanic climate ( average monthly temperature: 18.5 C°)<br>✓ 716 mm/year annual rainfall |

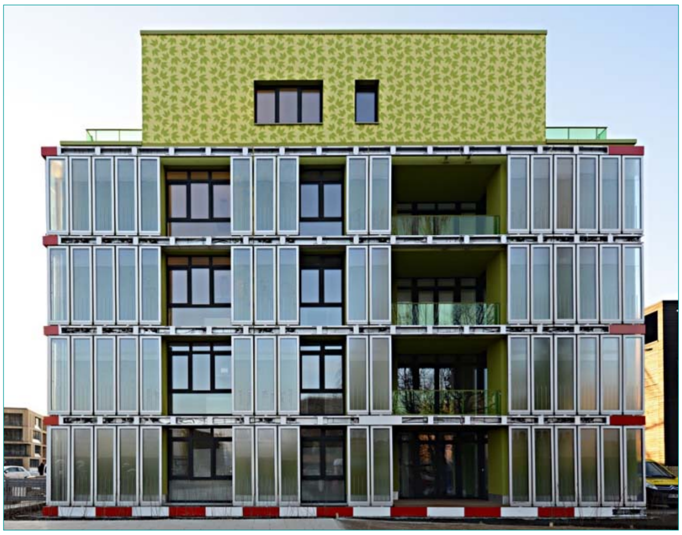
## Initiating context

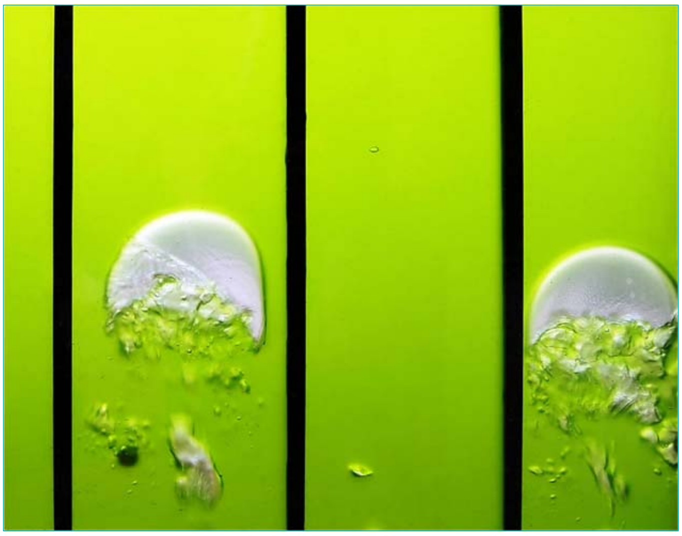
The building sector is one of the key sectors to achieving the EU's 20/20/20 targets. From 2020, zero-energy houses will be obligatory in Germany and in some other European countries. Every new building will need to produce the same amount of energy as it consumes [6]. To achieve these results, there is a need for technological advances in the energy industry that are not only economically possible, but efficient and environmentally friendly also.

In this context, the BIQ house project team started with the idea that algae colonies are efficient absorbers of carbon dioxide and producers of biomass, which means that they reduce the negative effects of climate change – with regard to GHG emissions in cities – and, at the same time, generate energy on-site for the structures they adorn. Strategically the algae, as bio-reactor systems, can improve sustainability and environmental health in any type of new or existing buildings (residential, public, commercial, industrial), as they are able to absorb $CO_2$ in a natural way due their higher photosynthesis efficiency [7].

Using bio-chemical processes in the façade of a building to create shade and energy may therefore develop into a sustainable solution for energy production/carbon sequestration in urban areas.

## Project description





[11]

With 200 $m^2$ of integrated photo-bioreactors, the BIQ house is a passive energy house that generates both biomass and heat as renewable energy resources. The microalgae used in the façades are cultivated in flat panel glass bioreactors measuring 2.5 m x 0.7 m. In total, 129 bioreactors are installed on the south-west and south-east sides of the residential building. The heart of the system is the fully automated energy management centre where solar thermal heat and algae are collected in a closed loop to be stored and used to generate hot water. Hence, the heat is directly available to the house as heating energy; the biomass is energetically exploited in another location and converted into biogas [7].

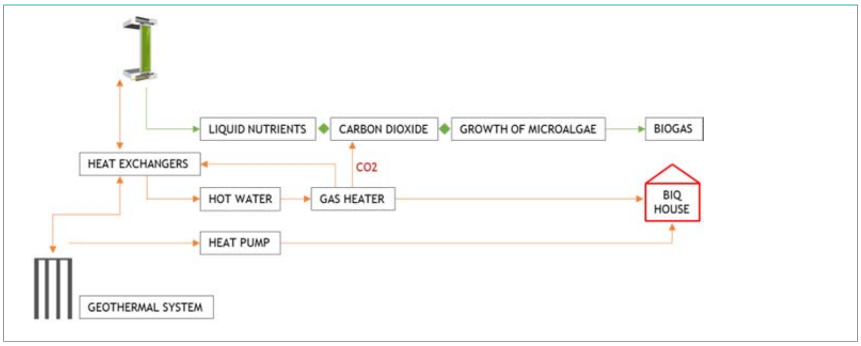
The panels can rotate along their vertical axis to track the position of the sun, and when fully closed, they form together a continuous outer skin providing a thermal buffer. The two inner layers form an 18 mm wide cavity with a capacity of 24 litres for the circulation of water and growth of algae. For safety and thermal insulation the photobioreactor is clad on both sides with laminated safety glass. Compressed air is introduced to the bottom of each bioreactor at certain time intervals. The gas emerges as large air bubbles and generates an upstream water flow and turbulence to stimulate the intake of $CO_2$ and light by the algae. At the same time, the inner surfaces of the panels are washed by the mixture of water and air that is visible to the people [6].

The conversion of light to biomass is a biochemical process facilitated by microscopically small algae, called microalgae. Microalgae use sunlight for the photosynthetic process and this is linked to the process of conversion of $CO_2$ to organic matter. In fact, microalgae are very efficient in the conversion of light to biomass because they consist only of single cells, each of which is capable of photosynthesis [6].

The use of a photovoltaic system on the extensively greened roof surface was not implemented for economic reasons; however, it can easily be retrofitted to the roof as required [7].

A central building management system controls all of the processes necessary to operate the bioreactor façade and to fully integrate it with the energy management system of the building.

In this sense, these innovative façades contribute to the reduction and removal of $CO_2$ emissions from buildings.




[1]

## Implementation process

| Project implementation details | |
|---|---|
| **Process** | SolarLeaf façade was installed for the first time on the BIQ house at International Building Exhibition in Hamburg in 2013.<br>The steps of development included:<br>✓ 2009: the idea was developed by Arup and Splittelwerk architects as project and design team<br>✓ Discussion about the idea of getting photo-bioreactors integrated into the exterior skin of the building<br>✓ Involvement of the Strategic Science Consult of Germany for technology support<br>✓ Arup involved Colt International to contribute to the realization of the façade system for the BIQ house<br>✓ 2011: construction of the house began<br>✓ 2013: BIQ house was showcased for the first time at the opening of the International Building Exhibition on March 23rd<br>✓ 2013: official presentation of the innovative system at an inauguration event for the media on April 25th<br>✓ 2014: SolarLeaf and the BIQ house won the Applied Innovations Category of the Zumtobel Group Award |
| **Leadership [7]** | ✓ Idea, Concept, and Authorship: Splitterwerk Architects (Graz), Arup (Berlin), Strategic Science Consult (Hamburg), B+G Ingenieure (Frankfurt), Immosolar (Hamburg)<br>✓ Investors: Otto Wulff Bauunternehmung (Hamburg), Strategic Science Consult<br>✓ Sponsors: Endress+Hauser Messtechnik (Weil am Rhein), Colt International (Kleve), ME-LE Energietechnik (Torgelow), BGT Bischoff Glastechnik AG (Bretten), Arup<br>✓ Technical planning: Arup<br>✓ Façade system development: Arup, Strategic Science Consult, Colt International |
| **Financing [7]** | Project costs: approximately € 5 million (funded by the Hamburg Climate Protection Concept) |

## Results

The SolarLeaf façade uses the bio-chemical process of photosynthesis to make a building and its components more energy efficient. The system has three main benefits: a) it generates high-quality biomass for energy purposes, b) it produces solar heat energy, and c) it can be used as dynamic shading and natural daylighting. The cultivation of microalgae in the photo-bioreactors panels does not require any additional land use and is largely unaffected by weather conditions. The carbon needed to feed the algae is obtained from a combustion process located close to the façade system to ensure a short carbon cycle, which prevents carbon emissions.The 200 $m^2$ of integrated photo-bioreactors algae façade comes with a net annual energy supply of about 4,500 kW/h of electricity more than an average household consumes in a year (3,500 kW/h per year) [7].

As the BIQ house has 15 apartments, only one of them could in theory be completely supplied with electricity from the bioreactor panels. However, a much larger proportion of apartments can be provided with heat. Hence, the bioreactor façades are used for heat generation (6,000 kW/h per year), not for producing electricity. This corresponds with the ability to supply four apartments with heat, from the bioreactors alone [7].

In addition, thanks to the algaes ability to function as a carbon capturing system, the building is able to eliminate 2.5 tons of $CO_2$ per year [6].

| Photo-bioreactors panels energy indicators [7] | |
|---|---|
| *INDICATORS FOR 200 $m^2$ BIOREACTOR AREA WITH 300 DAYS OF PRODUCTION/YEAR* | |
| **BIOMETHANE PRODUCTION** | 612 $m^3$ methane/year |
| **ENERGY IN METHANE** | 6,487 kWh/year |
| **NET ENERGY AS METHANE** | approx. 4,541 kWh/year |
| **NET ENERGY FROM HEAT** | approx. 6,000 kWh/year |
| **CARBON DIOXIDE EMISSIONS REDUCTION** | 6 tons per year |
| *BASIC DATA PER $m^2$ BIOREACTOR AREA* | |
| **BIOMASS PRODUCTION** | 900 kg/year |
| **ENERGY PRODUCTION IN BIOMASS** | 345 kJ/$m^2$/day |
| **BIOGAS PRODUCTION FROM BIOMASS** | 10.20 L methane/$m^2$/day |

[11]

## Lessons learned

The BIQ house plays an important role as a pilot scheme for $CO_2$ reduction and carbon sequestration in the building sector, and in general, as a low-carbon approach for buildings in future urban environments. With a sustainable energy design for energy efficient buildings, it can generate energy through its own envelope, store it, and use it itself [7].

In fact, it is able to generate energy using the algae biomass produced by its own façade. Moreover, the façade collects energy by absorbing the light that is not used by the algae and generating heat, like in a solar thermal unit, which is then either used directly for hot water or heating [8].

In this sense, the panels of algae that cover the south-east and south-west façades of BIQ house produce heat and biomass to supply the building with energy from renewable sources. In addition, the façades also serve the conventional purposes of insulating the building from sound, heat, and cold, while providing shade in bright sunlight [8].

Through the carbon capturing property of algae, the building not only generates clean energy, but also stores carbon emissions and hence removes them in the atmosphere.The project demonstrates the establishment of innovative energy production and air pollution reduction in urban development.Using a smart energy solution, it exemplifies a good practice for future urban contexts and low-carbon development in which cities are the natural place to start.

## References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[4] World Bank: GDP per capita, PPP: http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD

[5] The City of Hamburg webpage: http://english.hamburg.de/metropolitan-region/

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[7] EU Buildings - Smart Material House BIQ: http://www.buildup.eu/en/practices/cases/biq-house-first-algae-powered-building-world

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