1 Introduction

In March 2013 a unique pilot project was completed at the International Building Exhibition (IBA) complex in Hamburg: the “BIQ”, a four-storey block of flats that is the first ever building to feature photobioreactors (PBRs) on its facade. PBRs are transparent vessels for cultivating microalgae that can then be converted into renewable energy in the form of biomass and heat. The system was developed in close collaboration between Arup Deutschland, SSC and Colt International.

2 Background

2.1 Biomass: stored solar energy

Biomass is “stored solar energy”. As a fuel it has the great advantage of being able to store energy with virtually no loss at all. Of all renewable energy sources, bio-energy accounts for the largest share of final energy consumption in Germany – 8% in total. Biomass can be used for a wide range of purposes, for producing electricity, heat and fuel. It is a carbon-neutral energy source, because burning it simply releases back into the atmosphere the carbon dioxide that was absorbed when it was formed in the first place.

2.2 Microalgae technology and photobioreactors

Like other plants, microalgae form biomass from CO₂ and nutrients by photosynthesis, using sunlight as an energy source. Microalgae convert light energy into biomass much more efficiently than higher-order plants. Unlike fuel crops such as maize, algae does not take up land that could otherwise be used for growing food crops, because microalgae can be grown in photobioreactors (PBRs). PBRs are hollow, translucent, sealed vessels containing a culture medium. They can be installed
2.3 The backstory

In 2010 the architects SPLITTERWERK won the first prize in a planning competition for their design of a Smart Material House put out to tender for the IBA Hamburg 2013. The distinguishing feature of the resulting house was its bioreactor facade, which covers an area of more than 200 m². SPLITTERWERK developed the idea for the facade jointly with Arup, who then planned and designed it. For the purpose of the competition the building was called “The Smart Treefrog”, but it was later renamed “BIQ” by the investor Otto Wulff.

After the competition, between 2010 and 2012, the companies Arup, Strategic Science Consult (SSC) and Colt International collaborated on a research project partially funded by the German government’s “ZukunftBau” research initiative, in which they developed a facade system involving sun-tracking flat-plate photobioreactors. This system is now being marketed under the brand name “SolarLeaf”. In parallel with this, Arup developed the energy and building services concept for integrating the new technology into the BIQ building. The pilot project was completed, and the system placed into operation, on schedule in March 2013. Since then the consortium has been commissioned with monitoring the system on a biennial basis. This involves not just investigating and analysing the building’s energy and technical per-

in places that would otherwise be too dry, or not provide enough nutrients, for cultivating algae – for example in the centre of major cities.
formance, but also constantly assessing the acceptance of the new system by the building’s occupants.

2.4 State of the art

The convection reactor developed by SSC in its TERM pilot project in Hamburg can operate successfully outdoors all year round in a northern European climate. It is also considerably more efficient than other reactor systems, capable of converting some 8-10% of solar energy into biomass. Thanks to the automatic process and system control technology used, algae can be kept growing in the reactor with very little maintenance. The efficiency of the conversion of sunlight to heat is around 40%.

3 Integration in the facade

3.1 Potential

Thanks to the way in which the PBRs work, the following benefits can be achieved by growing microalgae in bioreactor building facades:

- Flue gas and CO₂ emissions can be utilised in situ to form biomass.
- The resulting biomass is a renewable energy source that can be transformed in situ into methane (biogas) through hydrothermal conversion.
- Like solar collectors, PBRs collect heat that can be exploited in the building with the help of heat exchangers, heat pumps and thermal energy store.

![Diagram of building fitted with PBRs](Image)
• PBRs are multifunctional facade elements that also perform a solar control function, insulate against heat and cold, and provide sound insulation.

3.2 Framework conditions

The photobioreactors used in the SolarLeaf system are integrated into storey-height vertical panels with a width of around 70 cm.

To maximise the amount of light hitting the reactors, they are fitted to the outside of the building facing in directions between south-west and south-east. The support system on which the PBRs are mounted performs a number of very important functions: it acts as a base for fixing the reactors in place, determines the direction in which they face, and if necessary also enables them to track the movement of the sun. At the heart of the PBR circuit, which is arranged in a floor-by-floor pattern, is the central building services control room. Here, biomass and heat are removed from the mixture drawn from the PBRs and stored or distributed as necessary.

The biomass formed as the algae grow is harvested with the help of an algae separator. Because all processes and systems are controlled automatically, the algae can grow, and potentially also be exploited, in situ with virtually no need for any human input. The bioreactors are supplied with water from the public water supply, and the waste water generated by them is discharged into the municipal sewage system.

4 Outlook

Photobioreactors are essentially advanced solar thermal elements, and as such are suitable for use in conjunction with building-integrated photovoltaics, notably in energy-plus houses. The benefits of PBR facades lie in their ability to produce biomass and heat for energy purposes, absorb CO₂, and regulate the amount of heat radiating into the building. PBRs can be installed in a variety of ways on roofs and facades; a number of research projects are currently underway in this area, simulating and analysing the options available.

The system has the potential to become a key technology for the realisation of carbon-neutral settlements and districts. It is important to incorporate the system into plans at an early stage, and investigate how the various material flows can best be integrated and interconnected at the property. To take full advantage of the synergies available in terms of the flue gas supply, production of the right quantities of biomass and heat, and treatment of grey water by the photobioreactors, a transdisciplinary approach at neighbourhood level is needed.
Photobioreactors on facades for energy generation

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