

# Energy savings go through the roof

New building materials and a holistic approach to architecture are dramatically lowering domestic energy consumption. **Valerie Jamieson** surveys recent projects



Hot spot – Hermann Heinrich, a building physicist at Kaiserslautern University, studies the infrared radiation emitted by a house to find any hidden heat losses. Before the 3 litre house was renovated, large amounts of heat escaped through the walls and the lintels above the windows (top left). These thermal bridges were subsequently eliminated after conversion (top right). Improved insulation and window shutters have dramatically reduced heat losses from all sides of the building (bottom).

From the outside, Sabine Glaser's apartment block in Ludwigshafen looks like any other building in the street. But there is more to the 70-year-old property than meets the eye – it is the first old building in Germany to be converted from a draughty energy-guzzling residence to energy-efficient homes. Dubbed the "3 litre house", the heating bills for Glaser's 100 m<sup>2</sup> apartment have been slashed from €700 a year to just €100 thanks to the latest advances in insulation and building technology.

Heating an old house consumes the equivalent of 20 litres of oil per square metre each year and leads to the production of 60 kg of carbon dioxide per square metre. As its name suggests, the fuel consumption of the 3 litre house is significantly lower. And with at least 24 million apartments in Germany in urgent need of renovation to improve their thermal insulation, it is clear that the potential energy savings are massive.

New legislation that forces every new house in Germany to consume less than 7 litres of oil per square metre came into

effect earlier this year. However, the chemical company BASF set itself the more ambitious goal of bringing an older property, just outside the gates of the company's offices in Ludwigshafen, to well beyond modern standards.

The renovations were completed last year and nine families – including Glaser's – have moved into apartments that contain a raft of sensors installed by Hermann Heinrich, a building physicist at Kaiserslautern University. Over 150 sensors monitor aspects such as the temperature of the rooms, the energy flux into the building and the air quality to shed light on the energy consumption and heat losses.

The measurements are being made over three years so that Heinrich and co-workers can understand how energy usage changes, for example when the residents go on holiday. "After one year of measurements, we have hints that the energy consumption is, in fact, lower than 3 litres per square metre," says Heinrich. "The building appears to have fulfilled the architects' plans."

## Changing rooms

Insulation has played the biggest role in dramatically cutting the fuel consumption of the property. The façade of the building is clad with 20 cm thick panels of NEOPOR, a new type of thermal insulator developed by researchers at BASF. The polystyrene-based material contains microscopic flakes of graphite that reflect heat, making it difficult for thermal radiation to penetrate. Indeed, the thermal conductivity of NEOPOR is significantly lower than that of expanded polystyrene, a common insulator in homes.

As a result, only half the amount of NEOPOR is needed to provide the same level of insulation as conventional polystyrene, making it ideal for old buildings that have little space between cavity walls. The existing insulation in the roof, ceiling and cellar of the building has also been replaced with NEOPOR. About 10 litres of crude oil are needed to produce a NEOPOR panel with an area of 1 m<sup>2</sup> and a thickness of 20 cm, but estimates show that this will save some 1200 litres of heating oil over a period of 50 years.

The interior walls of the building are coated with a special plaster that helps to keep rooms cool in summer without air conditioning. Also designed by BASF, the plaster contains microcapsules filled with wax particles that store latent heat – if it is very warm outside, the wax melts, thereby soaking up heat without raising the temperature of the room. Tests have shown that a 2 cm thick layer of the new plaster has the same heat absorption capacity as a 20 cm thick timber-bricked wall.

## Knocking down bridges

As well as focusing on good insulation, the designers have also reduced the influence of "thermal bridges", such as thick bolts and screws that can conduct heat past the insulation. For example, to minimize heat losses, the apartment balconies are built as separate free-standing structures that just touch the house instead of being bolted directly onto the building. In addition, the windows are triple-glazed to cut the heat loss by a factor of five compared with a single pane of glass, while the window frames are made of a plastic that is insulated with a polyurethane core. But the large windows play another important role – as well as improving the amount of natural light entering the lounge and bedrooms, they allow solar radiation to heat south-facing rooms.

Although the building is virtually airtight, an energy-saving ventilation system provides residents with fresh air. Warm, stale air is drawn up from the kitchens and bathrooms to a heat exchanger in the attic, which transfers 85% of the heat to the incoming air. This fresh air is then heated further before being pumped into the living rooms and bedrooms. Heinrich and co-workers at Kaiserslautern also monitor the

amount of carbon dioxide breathed out in some of the apartments to tell how well the ventilation system is working. "If the levels of carbon dioxide are too high, the ventilation rate needs to be increased," explains Heinrich, "but if they are too low then the ventilation can be decreased to save even more money."

Next year BASF plans to install a polymer-electrolyte-membrane fuel cell in the basement to generate electricity with fewer greenhouse-gas emissions. The miniature power plant will first convert natural gas into a more hydrogen-rich gas, which will then be pumped into the fuel cell to produce an electric current (see pages 30–31). BASF has invested €500 in every square metre of the 3 litre house in Ludwigshafen. But with signs that a market for the renovation of old buildings worth over €400bn is beginning to emerge, the company clearly views their investment as money well spent.

### Cool in summer, warm in winter

BASF is not the only organization developing energy-saving building materials. Norbert König, a building physicist at the Fraunhofer Institute for Building Physics in Stuttgart, Germany, and colleagues have developed a new type of double-glazing, called T-OPAL, which turns opaque at high temperatures to prevent buildings from overheating in the summer. Many glass buildings – including greenhouses, conservatories and offices – currently have blinds or air conditioning installed to keep their interiors comfortable in hot weather.

T-OPAL has been designed to be a cheaper alternative, costing just one-tenth of the price of shutters with the same area. The insulating gap in the new type of double glazing is filled with a "thermo-optical polymer", which has optical properties that change with temperature. On cool days, the polymer exists in its crystalline form and transmits light. However, on hot days, the polymer undergoes a phase transition into a melted state that reflects more light and infrared radiation than it transmits. The glass, which has been patented by the Fraunhofer Institute, is currently in the early stages of production and should be on the market next year.

König's colleagues in Stuttgart have also developed an inorganic thermal insulator made from recycled glass as an alternative to polystyrene and mineral wool, which can cause respiratory problems if used incorrectly. Shards of glass are ground down and mixed with an expanding agent to create a granular material that can be moulded into shape. During a final stage of heat treatment, the expanded glass granules bond together at certain points to produce a porous insulator with a low thermal conductivity. Known as REAPOR, the new material can withstand high pressures so that it can be integrated with other fixtures and fittings. It



Green houses – the BedZED development in London generates some of its electricity from solar panels fitted to the top floor of south-facing homes.

is important, says König, for building physicists to develop materials that will work in practise, satisfying both building regulations and construction companies' budgets.

So, is it possible to build environmentally friendly homes for about the same price as conventional residences? Architect Bill Dunster believes that it is possible. The key, he says, is to include renewable-energy devices and energy-saving features at every decision in the design process, rather than bolt them on as an expensive afterthought. His company has already developed detailed designs, tracked down high-quality building materials and tested them in existing energy-saving buildings, thereby reducing the cost for future developments.

One of Dunster's most ambitious projects is the Beddington Zero Energy Development (BedZED) – the first large-scale "carbon neutral" housing development situated in Sutton, south west of London. Built on the site of a reclaimed sewage works, the 82 homes are a mixture of apartments, maisonettes and town houses made from reclaimed bricks, timber and steel. The homes are heated by a combined heat and power plant that is fuelled by wood chips from local tree surgeries, which would otherwise be sent to a landfill site, while photovoltaic panels mounted in the cladding and roofs provide additional electricity (see pages 35–36). Some of this electricity will soon be used to power a fleet of electric vehicles belonging to a car pool.

Like the 3 litre house in Ludwigshafen, the south-facing rooms have large triple-glazed windows to benefit from the warmth of the Sun, and insulation with a low thermal conductivity is fitted to all the external walls, roofs and ground floors to reduce heat

losses. Meanwhile, each kitchen is equipped with the latest energy-efficient appliances and waste water from the sink and the bath is recycled for use in the toilet and to water the roof gardens – thus cutting water consumption by one-third. All 57 of the houses that are for sale have been snapped up – the remaining 25 will be rented out and the first residents moved in a few weeks ago.

### Flower power

Many of the energy-saving features of BedZED are incorporated in another of Dunster's designs, the FlowerTower – so-called because it comprises four petal-shaped towers arranged like a flower. Still firmly rooted to the drawing board, the high-rise block is expected to generate all its electricity from a combination of photovoltaic panels and a wind turbine housed in the gap between the towers.

The plans have been developed so that the towers channel the wind, boosting its speed by a factor of four and making wind power possible in urban areas. Dunster believes that the same vertical-axis turbines found on oil rigs are ideal for the project because they are almost silent and only need maintenance once every five years.

Whether the FlowerTower design takes off remains to be seen, but it is clear that architects and building physicists can play an important role in producing environmentally friendly buildings that will help to reduce our impact on the planet.

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