# Hot swap

New materials could lead to more efficient solar-power systems

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THE DEPLOYMENT of large-scale solar energy utilities could be made more economically viable with photovoltaic (PV) materials that are being developed in Oxford.

The technology has been developed by researchers at ISIS Innovation, Oxford University's technology transfer company.

Andrew Watt, from Oxford's Department of Materials, explained that the new ISIS photovoltaic system is based on visible-light-absorbing metal oxides commonly used as pigments in paints.

'Current PV technologies are costly, around $0.25/kilowatt hour compared to oil, gas, coal, nuclear and wind, which come in around $0.05/kilowatt,' he said. 'The reason for this is partly associated with the cost of manufacture and partly the materials used.'

Scientists have looked for a number of years for replacements for silicon, which is commonly used in photovoltaic systems.

Watt said a number of thin-film inorganic systems are commercially available. Those include CIGS (copper indium gallium diselenide) or Cadmium Tellurium devices, which offer good solar-power conversion efficiencies. However, the systems rely on rare elements and contain highly toxic materials.

Cheaper semiconductor technologies may permit large-scale solar utilities

'There is now a resurgence looking at cheaper and more environmentally friendly semiconductor technologies that do not use Cadmium or expensive metals such as Indium, which has a projected supply of 20 years,' he added.

Watt said the challenge for the ISIS team in its new photovoltaic system was changing the semiconducting nature of its material for photovoltaic devices. To accomplish this, he explained that the team had to reconfigure the crystal structure of the photovoltaic system, adjust its chemistry and create a new doping process.

Otherwise the design of the device is similar to existing technologies, which include a metal anode-cathode with p- and n-type semiconductors in between them.

Watt added that the inorganic thin-film photovoltaic system is not yet ready to compete with silicon on a performance level. 'At the moment, our power conversion efficiencies are lower than standard silicon devices,' he said. 'We hope to push efficiencies to between 6–8 per cent in the next three years.'

Yet Watt said it offers other advantages. 'The real advantage comes from cost of processing,' he added. 'A ten-fold decrease in efficiency makes devices 100 times cheaper. So if space is not an issue the material is ideal. Think solar farms in desert area converting sunlight to electricity to hydrogen for distribution around the world.'

The ISIS team points out that its system has good photochemical stability relative to other low-cost organic systems. It is compatible with existing industrial coating methods and the system's metal oxides offer aesthetic advantages such as transparency and the possibility to create a variety of colours.

Stuart Wilkinson, project manager with Isis Innovation, said the technology is patented and the group hopes to attract investors and development partners.

'We aim to develop a suite of materials with bespoke semi-conducting and light-absorbing properties,' he added. 'Then using a device modelling package we can optimise the device's design and generate the highest efficiency devices possible.'

**Siobhan Wagner**

# Controlling the elements

**LARGE-SCALE production of hydrogen from water and sunlight could be possible with a new catalytic system that takes its inspiration from nature.**

**The EPSRC-sponsored research project aims to create a compound that mimics the active site of the enzyme organisms used to convert hydrogen ions to hydrogen gas during anaerobic respiration.**

**Oxford University chemist Dr Erwin Reisner, leader of the effort, has already demonstrated the ability to produce these enzymes, called hydrogenases, with nickel and iron in their active sites.**

**Through previous experiments, he showed that shining light on the enzymes, which were steeped in water and a solution that provided electrons and protons, will produce hydrogen.**

**Reisner now wants to determine if hydrogen production will work with only the active sites of the enzymes.**

**'The active site should in principle do the same catalysis as the enzyme, but it will be much cheaper,' he said. 'The enzymes are expensive and have a very large footprint. Small molecules would have a much smaller footprint and possibly better longevity.'**

**The active site will still be based on iron and nickel, and surrounded by cysteine (an amino acid), carbon monoxide and cyanide ligands.**

**'It shouldn't be too difficult to get a molecule that looks like the active site, but it's another story to get it to work and do what you want,' he added.**

**The operation of the catalytic system will be observed through spectroscopy techniques provided by project partners Carnegie Mellon University in the US and Manchester University. The results will tell Reisner how to improve its design.**

**Reisner hopes to have a fully functional catalytic system in five years and he predicts that within a decade his efforts could help bring about large-scale production of hydrogen.**

# Solar solution

*A new class of economically viable solar power cells has come a step closer. **Chris Shaw** reports.*

The studies at the National Institute of Standards and Technology (NIST) have resulted in a deeper understanding of the complex organic films at the heart of the devices. Organic photovoltaics, rely on organic molecules to capture sunlight and convert it into electricity, so in principle, have significant advantages over traditional rigid silicon cells.

Organic photovoltaics start out as an 'ink' that can be applied to flexible surfaces to create solar cell modules that can be spread over large areas. However, the market share is currently limited as even the best organic photovoltaics convert less than 6% of light into electricity and last only a few thousand hours.


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NIST researcher, David Germack, said: "The industry believes that if these cells can exceed 10% efficiency and 10,000 hours of life, technology adoption will really accelerate. But to improve them, there is critical need to identify what's happening in the material, and at this point, we're only at the beginning."

The NIST team's effort is said to provide a 'powerful new measurement strategy' for organic photovoltaics that reveals ways to control how they form. In the most common class of organic photovoltaics, the 'ink' is a blend of a polymer that absorbs sunlight, enabling it to give up its electrons, and ball shaped carbon molecules (fullerenes) that collect electrons. When the ink is applied to a surface, the blend hardens into a film that contains a random network of polymers intermixed with fullerene channels.

In conventional devices, the polymer network should ideally all reach the bottom of the film while the fullerene channels should all reach the top. This allows electricity to flow in the correct direction from the device. However, if barriers of fullerenes form between the polymers and the bottom edge of the film, the cell's efficiency is reduced.

By applying Xray absorption measurements to the film interfaces, the team has discovered that this changes the nature of the electrode surface and repulses fullerenes while attracting the polymer. The electrical properties of the interface also change dramatically. The resultant structure gives the light generated photocurrent more opportunities to reach the proper electrodes and reduces the accumulation of fullerenes at the film bottom, both of which could improve the photovoltaic's efficiency or lifetime.

Germack noted: "This knowledge is really important to help industry figure out how organic cells perform and age so that their life spans will be extended."

## 4G technology assets acquired for $1.13billion

The wireless equipment unit of Nortel Networks is to be bought by Ericsson for $1.13billion. The deal will see Ericsson acquire the majority of the operations currently providing many operators with 3G mobile voice and data technology. Presently, 400 of Nortel's employees work in the field of 4G technology.

Over the next five years, the acquisition could boost Ericsson's global market share by more than 5%, while in North America, the figure could reach 30%.

## University 'supercomputer'

The University of Southampton has invested £3million in what it claims is the 'UK's most powerful university owned supercomputer'.

The new supercomputer, built using IBM iDataPlex server technology, is capable of over 74trillion calculations per second and contains over 8000 processors.

It will be the first IBM System iDataPlex in a UK university and will be used by researchers to make highly complex computations in a range of fields from cancer research to climate change.

## New low power chip

Intel has announced a new low voltage version of the Intel Xeon 5500 series processor.

The Intel Xeon L5530 processor is said to improve the frequency of 60W LV Xeon 5500 SKUs running at 2.40GHz, providing performance per watt improvements in blades and high density computing.

Intel also revealed a dual socket workstation chip, the Intel Xeon W5590 processor running at 3.33GHz; and two single socket workstation chips, the W3580 running at 3.33GHz and the W3550 running at 3.06GHz, all designed to improve performance in threaded and non threaded workstation environments.

# Fuel-cell tugs cut electricity bill

## Methanol fuel cells power materials handling tugs to slash overheads at US car plant

NISSAN has become the first carmaker to use methanol fuel cells to power materials handling tugs in one of its plants.

The tugs are used to transport thousands of vehicle parts throughout the 5.4 million ft² Smyrna factory in Tennessee. The company said the switch to methanol would reduce its electricity bill and eliminate more than 300 tons of $CO_2$ emissions that were being released into the atmosphere.

By using the fuel cells from Oorja Protonics, Nissan has been able to get rid of more than 70 battery chargers that were consuming almost 540,000kWh of electricity annually.

Shopfloor transport: Fuel-cell tugs cut carbon emissions

Methanol is derived from various sources including wood, grass, landfill sites, natural gas and coal. The fuel cells generate electricity by converting the chemical energy stored in the fuel into electrical and thermal energy. The by-products of the electrochemical reaction are pure water and heat. The fuel cell provides a constant charge that puts less strain on the tug's electrical system, increasing the life of the battery and other electrical parts.

Materials handling manager Mark Sorgi said: "The fuel cells have made us more productive by saving us 35 hours a day that were spent by employees changing out batteries. There's no changing out of low or dead batteries, which involves a battery technician and 15 to 20 minutes. Now the tug driver can refill the fuel cell in less than one minute and they're on their way."

# Sharp sensors activate airbags earlier

CONTINENTAL has introduced a new generation of passive safety sensing systems that interact with devices such as airbags to offer drivers better protection.

The company hopes to integrate the technology in cars so that critical situations can be detected before a crash occurs. Airbags and other safety systems can then be activated at the most effective moment.

Continental said: "From data analysis of the electronic stability control already installed in many vehicles, and by incorporating the radar or camera sensors from driver-assistance systems into the passive safety system, it is now possible to detect an imminent accident fractions of a second earlier.

"This results in airbags, seat-belt tensioners and head restraints being activated more quickly so that drivers and front-seat passengers are even better protected."

Dr Andreas Brand, executive vice-president at Continental, said: "Linking the crash sensors to the technology in driver-assistance systems opens up new opportunities for passive safety systems to recognise critical driving situations for what they are and categorise them before a crash occurs."

The timeframe for activating safety systems is short. "One of the challenges for the sensors is to categorise the accident early on so as to provide maximum occupant protection," said Brand. Until now, the airbag control system's acceleration sensors only felt the accident on first contact with the other vehicle involved, Continental said. Its system can react earlier.

# Software keeps tabs on cars in production

SPORTS CAR maker Aston Martin has installed a precision realtime location system at its Gaydon plant in Warwickshire to give it complete visibility of its production processes.

The Ubisense system involves tags being attached to the inside of the windscreens of cars as they begin their off-line finishing process. From then on, process tracking software provides Aston Martin with visibility of each vehicle as it progresses through the plant.

Using a web browser, engineers can locate any car on a map, and watch its progress in real time. They can also view a log of which process steps a car has been through and the time spent in each. An alert is raised if a car deviates from the process.

# Plug-in recharge system talks to grid

FORD has developed a vehicle-to-grid communications and control system for its plug-in hybrid electric vehicles that "talks" to the electricity grid in the US.

The technology allows the vehicle owner to program when to recharge the vehicle.

Price check: Driver can choose to recharge at off-peak rate

When plugged in, the battery systems of specially equipped hybrid Escapes can communicate with the grid via smart meters provided by utility companies through wireless networking. The owner uses the vehicle's touch-screen interface to choose when the vehicle should recharge, for how long and at what utility rate.

# In-car breathalyser stops drink-driving

JAPANESE carmaker Toyota is developing an alcohol detection system that will lock the vehicle's ignition if it calculates that the driver is over the limit.

The system, being developed with Hino Motors, is aimed at helping companies to manage their fleet operations better. It is being installed on trucks of Japanese transport firms and tested until the end of November. Drivers will conduct self-breath tests before they operate a vehicle and, after use, fleet administrators will verify the test results recorded on the vehicle's digital tachograph.

Breath test: Alcohol check

The system features a hand-held breathalyser and a camera that photographs the driver's face for identification. If the test is positive, the system either warns the driver or locks the ignition, depending on the amount of alcohol detected.

A lack of government support pulled the rug from under the fledgling Concentrating Solar Thermal Power (CSP) industry. Twenty years later, as **David Hopwood** discovers, the technology is enjoying a renaissance.

# the new hot ticket

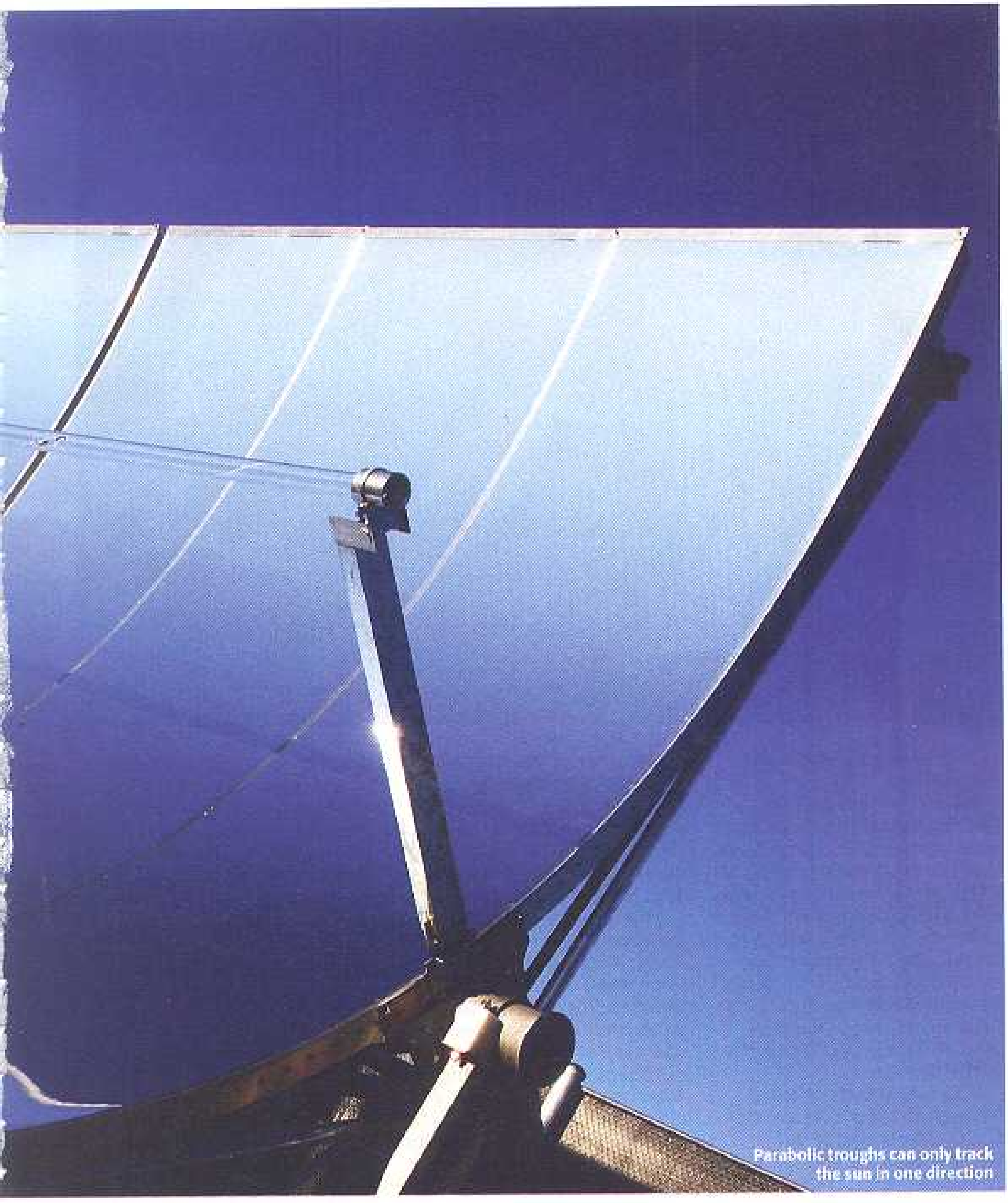
ASK PEOPLE what they think the new age of solar power will look like, and most see images of flat solar panels stuck to roofs, providing heating or hot water. A smaller number will have heard that you can generate electricity from the sun too – through panels that use semiconductor materials (mostly silicon in crystal or amorphous form) to convert light into electricity – so-called solar photovoltaics (PV).

That's probably as far as it goes. Many people remain sceptical that solar power could produce cost-competitive, utility-scale electricity generation.

But that's exactly what the Concentrating Solar Thermal Power (CSP) industry has been striving for many years to achieve, despite a false dawn in the 1980s when CSP's early pioneer (Luz International, which built nine CSP plants in California's Mojave Desert) went bankrupt. This signalled the start of a dormant period as CSP technology gradually faded into the background of the renewable electricity sector, surpassed by robust interest in the more 'glamorous' technology of PV.

## CSP BASICS

As opposed to PV, CSP generates electricity using technology common to most single-cycle or combined-cycle power plants. But, instead of using natural gas



Parabolic troughs can only track the sun in one direction

or coal as a fuel source, the sun produces the steam that drives the engines or turbines in a plant. The clever part, and this elicits much debate in CSP circles, is how best and most cost-efficiently to capture the sun and turn it into heat energy. Parabolic Trough CSP plants, for example, consist of large parallel arrays of parabolic trough solar collectors, which constitute the solar field. Power Towers consist of a tower surrounded by a large array of heliostats, which are mirrors that track the sun and reflect its rays onto a receiver at the top of the tower.

Other technologies are being developed too – Fresnel mirror CSP systems have long flat mirrors at different angles to focus sunlight on one or more pipes containing heat-collecting fluid, which are mounted above the mirrors. And Solar Dishes consist of a dish-shaped concentrator that reflects solar radiation onto a receiver mounted at the focal point; this receiver can either be a Stirling engine and generator for dish/engine systems, or a type of PV panel that has been designed to withstand high temperatures – in Concentrating PV (CPV) systems.

As the number of megawatts generated through CSP has grown, so the scale and size of the projects planned has increased. There is now around 6GW of CSP capacity in the USA (installed or under contract), and 3.7GW active or planned throughout the rest of the world. Operational CSP installations range from 1MW through to 64MW – Solar Nevada One in the USA.

But there is also an increasing number of utility-scale projects in the pipeline that could result in plants of 100MW plus over the coming years. One example is US utility PG&E's deal with Solel for the 553MW Mojave Solar Park (scheduled for 2011). And Southern California Edison (SCE) recently signed a Power Purchase Agreement with BrightSource Energy to use power from the latter's 1,300MW of planned Power Tower CSP plants, also planned for the USA.

These deals alone suggest that the utilities themselves believe CSP has a bright future.

## CSP REVIVAL

Currently, Spain and the USA's south west host much of the commercial, large-scale activity in CSP. But technology could also be deployed in countries like Algeria, Morocco, South Africa, Israel, India, and China.

Seville, Spain, has two commercial plants – Abengoa Solar's PS10 and PS20 (11 and 20MW respectively). Recently constructed, when both these plants become fully operational they will provide energy for 200,000 people. PS10 is operational, PS20 is currently in the start-up phase.

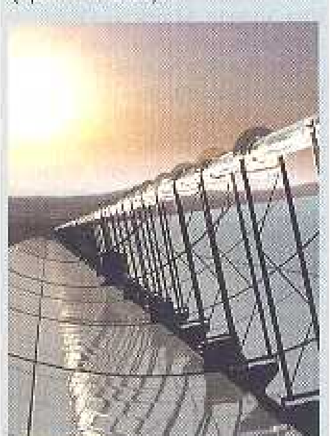
In the USA, States like California, Arizona, Nevada, New Mexico, Colorado, some of Utah, and Texas could host a large amount of CSP generation. The south west of the USA, for example, has 87,000 sq miles of land that could be used for CSP, potentially generating a staggering 11,200GW, believes ▶

## csp spotlight

### THE PARABOLIC TROUGH

Troughs consist of large parallel arrays of parabolic trough solar collectors, which constitute the solar field. The parabolic collector is made of reflectors, which focus the sun's radiation onto a receiver tube filled with oil. The oil, which hits 750°C, boils water to make steam, which propels a turbine. Excess heat can be stored in molten salt to run turbines after sundown.

- Pros: well established and proven track record; thermal storage possible; can be used as hybrid power station with gas;
- Cons: The mirrors can only track the sun in one direction, from east to west; steam also has to be condensed back into water; mirrors are currently expensive to manufacture;
- Cost: depends who you talk to – US$0.12-$0.18/kWh, according to REN21's Renewables 2007 Global Status report (costs decrease as plant sizes increase); $0.06-$0.08 according to Chicago consultants Sargent and Lundy (2003 study);
- Selected plants: SEGS, 1991, (California – 354 MW); Nevada Solar One, 2007, (Nevada – 64 MW); Solana, 2011, (Arizona – 280 MW); Andasol 1, 2009, (Spain – 50 MW).



The parabolic trough is made of reflectors that focus the sun's radiation onto a receiver

GETTY IMAGES

Solar plants are generally built away from large centres of population

◀ Dr Fred Morse, a specialist in CSP.

Looking beyond 2012, by which time many of the current generation of CSP plants will be operational, there is also talk of CSP plants situated in northern Africa transmitting electricity to Europe via high-voltage direct current (HVDC) cables across the Mediterranean. One Project – the Mediterranean Solar Plan (Med Solar) – aims to have in place 20,000MW of CSP in north Africa by 2020.

This may seem far-fetched, but some scientists believe that less than 1 per cent of the world's deserts, if covered with CSP plants, could produce as much electricity as the world currently uses.

Aside from an increased focus on renewables brought about by climate change, security of supply, and depleting fossil resources, CSP has benefited from the shortcomings of other high-profile renewable electricity technologies. The high cost of PV is one contributing factor that has gone some way to reviving interest in CSP. "Truthfully, without the silicon shortage and the resulting constraints on supply [for PV], CSP might still be struggling," says Paula Mints, a PV expert with Navigant Consulting.

Wind power too, whose installed capacity worldwide now stands at a respectable 120GW, has its own well-documented disadvantages. The biggest of these is its intermittency, combined with a lack of electricity storage, so until there is a commercially viable way of storing wind for use during periods of high demand, wind will always be at a disadvantage when compared with baseload energy technologies.

CSP can be much more predictable and better aligned with peak demand, as Direct Normal Insolation (DNI) – the 'fuel' for CSP, is strongest during the day when people need power.

### THERMAL STORAGE AND UTILITY

Certain CSP technologies, such as Parabolic Trough and the Power Tower, can incorporate thermal storage, in the form of, say, steam or molten salt. Excess heat is pumped into vats of salts, turning them into a molten, lava like consistency. Heat can then be released from the salts when there is no sun to keep the turbines going. The 50MW Andasol 1 in Spain uses fertiliser salts – a mix of sodium and potassium nitrate – as thermal storage.

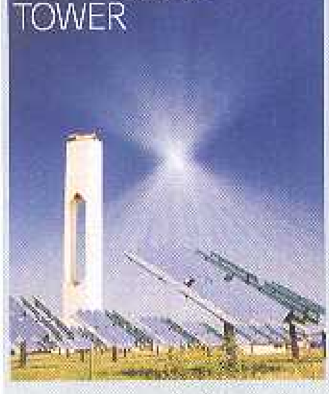
It is also possible to use gas as a stop-gap source of heat when there is not enough sun. CSP with heat storage and/or hybridisation with gas firing allows CSP plants to provide baseload power, which is extremely valuable to a utility.

Add to that the high cost of technologies such as PV – alongside intermittency concerns of wind – and you find CSP looking a lot more attractive – especially those projects such as Andasol 1 that include thermal heat storage: "Higher prices for crystalline flatplate technologies," says Mints, "drove the price of PV technology up in the short term; this has opened a

> 'CSP has a grant instead of the investment tax credit, and a federal loan guarantee, which should help on the debt side. Those are extremely important.'

## csp spotlight

### THE POWER TOWER



Power towers consist of a tower surrounded by a large array of heliostats, which are mirrors that track the sun and reflect its rays onto the receiver at the top of the tower. Power towers also reportedly have higher conversion efficiencies than parabolic trough systems. They are projected to be cheaper than trough and dish systems, but a lack of commercial experience means that there are technical and financial risks in deploying this technology now, though the PS10 and PS20 plants in Spain are making good progress.

■ Pros: Tower/heliostats can operate at higher temperatures, and electricity has the potential to be cheaper than troughs; field mirrors can tilt in two directions rather than just one; Heliostats can also be air-cooled, or cooled by hybrid systems, which combine air and water cooling;

■ Disadvantages: There is limited experience and the towers could be expensive to build; Dry cooling can also potentially raise the price of power and make it tough to produce power at peak times.

■ Cost: early days, though Sargent and Lundy estimated solar towers could become the lowest-cost form of CSP. They estimated that towers might be able to generate electricity at a levelised cost of energy around US$0.04 cents/kWh by 2020 (2003 study).

■ Selected plants: PS10, 2006, (Spain – 11 MW); PS20, 2007, (Spain – 20W).

window through which CSP – with its storage capabilities – climbed through."

While CSP still can't be directly cost competitive with wind, that's actually not always the major issue. Solar thermal electric technologies function like most single-cycle or combined-cycle power plants. And while wind power generation prices (per kWh) may currently be cheaper, another important consideration is the value of the technology to the utility, and the reliability/dispatchability that can be factored in.

"The value of energy is not a straightforward calculation", explains Barbara D. Lockwood, manager – renewable energy at the Arizona Public Service Company (APS): "With solar [CSP] for example, we know that we can count on it and it is producing in the extremely peak parts of the day so it's worth a whole lot more to us. The cost gap is not linear – you can't just subtract the price of wind from the price of solar and say 'it's that much cheaper' and conclude that 'that's what the value is'. The value of wind is generally less than the value of solar because solar produces power during periods of high demand."

### BARRIERS TO CSP

Of course, CSP still faces significant challenges. The major one is cost, especially compared with wind power. Costs for CSP, currently around 9-18¢ (US) per kWh – depending on technology, plant size and scale, and whether heat storage is incorporated – are predicted to fall to about 6¢ per kWh over the next decade, thanks to scale and improved technology. But wind is still a cheaper option at around 4-6¢ per kWh (though offshore wind would be more than this).

CSP is also capital intensive, and the credit crunch hasn't helped. However, in an industry that admittedly still needs government support, President Obama has so far been kind to the solar industry in the USA, a fact that Fred Morse acknowledges: "We now have a grant instead of the investment tax credit, and we have a federal loan guarantee, which should help on the debt side. Those are extremely important."

Perhaps an even bigger problem faced by CSP developers is transmission. Plants by their nature are generally built away from large centres of population and this makes transmission a huge challenge that needs to be addressed before CSP really has a chance to shine: "It's only when you can access the sun-rich parts of the country that CSP could start to meet a broader market," says Morse.

But addressing the transmission issue is hugely complex: "It's a problem of three dimensions," he explains. "One is planning; then there is a major issue of siting. And then how do you allocate the cost of this new high voltage that they call a 'backbone' transmission system? Who pays? What if a line goes through a State and none of the power comes off in that State? Do they pay at all?"

Despite a promised concerted effort in the USA under the new administration to address the issue of transmission, Morse's best guess is that no new transmission will open up for at least five years, and this could stifle the conception of new CSP projects and partnerships, at least in the USA.

Finally, CSP also has detractors who justifiably point to the large amounts of water needed as part of the process, though much effort is being undertaken to improve efficiency and reduce the water requirements. Other concerns centre on the effects that large solar power stations have on fragile desert ecosystems, as well as the perception that CSP might turn out to be another case where rich countries take what they need from poor countries, and leave little for them except pollution.

But in a world that needs to to wean itself off fossil fuels and put GW-scale alternative energies on the ground, many believe that CSP simply can't be overlooked this time around. ■

## IMPROVING CSP

Build costs and ongoing operational costs for CSP are both being improved through optimised system design and better specification of materials. Larger-scale manufacture, more modular manufacturing processes and better organised deployment to site are also forecast to drive down the cost significantly.

Across the system, measures need to address thermal efficiency, durability, ease of manufacture and on-site construction.

In the solar field itself, developments are targeting the optical performance of mirrors, their longevity, the support structures, the durability of the heat collection elements used in trough systems, and the electrical/electronic systems used to direct heliostats.

Instead of steel for framing its solar troughs, for example, the Solargenix collector used at Nevada Solar One is made from extruded aluminium. The lower weight collector has a unique organic hubbing structure, initially developed for buildings and bridges. Manufacturing is simplified and no field alignment is needed.

And, while most parabolic troughs are made out of glass, SkyFuel's SkyTroughs are made from the company's own mylar-like ReflecTech film. SkyFuel claims using this material can bring down the cost of a solar system by 25 per cent. NREL's Advanced Materials programme is continuing to assess a range of solar reflector materials including thin glass, thick glass, aluminised reflectors, front-surface mirrors, and silvered polymer mirrors.

Storage can also make CSP electricity a much more attractive financial proposition as it allows CSP to provide baseload power. The most well-known variant is the indirect thermal energy storage technique – it uses molten potassium and sodium nitrate salt in a two-tank system (this is used at the Andasol 1 parabolic trough plant).

# When the wind slows

Windworks' VAWT rotates at low speeds, meaning it needs less wind to produce energy than conventional turbines

Windworks' turbines are said to operate at very low noise levels

WINDWORKS Engineering has taken the wraps off a new Vertical Axis Wind Turbine (VAWT) and disclosed that it had erected a 7kW prototype at its testing facility north-east of Perth, Australia.

The 7kW design, with a wing height of 5.5m, will now be tested to evaluate its aerodynamic performance as well as stability, sound and vibration levels under various wind regimes. This will be followed by the trialling of a selection of permanent magnet generators.

The Windworks turbine, which has its main rotor-shaft arranged vertically, as opposed to horizontally, does not, like its Horizontal Axis Wind Turbine (HAWT) cousins, need to be pointed into the wind to be effective. It also rotates at low speeds and hence emits little noise, an advantage on urban sites where wind direction is highly variable.

Despite their benefits in low-wind situations, VAWT turbines are not as efficient as their more common horizontal counterparts, a fact acknowledged by the engineers at Windworks Engineering. It admitted that while the efficiency of HAWTs in wind-tunnel testing may be as high as 45 per cent, a typical VAWT design may only achieve between 25–35 per cent efficiency.

However, it also claimed that efficiency of HAWTs in operation is significantly reduced due to inefficiencies resulting from the turbine not fully facing the wind at all times, as well as lengthy maintenance shutdowns. This, the German company said, causes the effective efficiency of the HAWTs to drop to about 25 per cent over their lifetime.

Windworks also added that its design will be considerably less expensive than a horizontal design to commission. That is because, while horizontal turbines require deep foundations, the vertical turbine can be built on much shallower foundations and can be erected without the need for cranes.

The Windworks VAWT, with a vertical-support column and three vertical, aerodynamic wings, sports a generator that sits low to ground level, minimising maintenance costs, as well as reducing the complexity of the foundations.

The new turbine is also said to eliminate problems that have arisen at many HAWT windfarms, where birds and bats have been known to fly into the spinning blades. Engineers at Windworks claim that because their design appears as a solid mass to wildlife, the design does not have the see-through effect common in HAWT designs and so birds and bats fly around it.

The turbine is silent too because there is no compression of air between the wings and the support column as with the HAWT. The Windworks VAWT is also smaller than a comparable HAWT and creates less shadow and visual impact.

Windworks does not plan to build or own a manufacturing facility to build the VAWT turbines. Contractors manufactured the prototype turbine in Australia and future manufacturing will be sourced and tendered from Asian companies under the supervision of Windworks. Agreement in principle has been reached with Siemens to build and supply the electric system for the turbines.

Windworks plans to develop turbines for domestic, commercial and industrial use ranging from 2.5kW to several MWs in capacity.

**David Wilson**

# Suitcase inspection

**AIR TRAVEL could run smoother in the future with a new technology that quickly determines whether unattended luggage is a threat.**

**The Unattended Luggage Inspection System (ULIS) is being developed by EADS Sodern, a subsidiary of EADS Astrium.**

**The suitcase-sized inspection machine works using neutron-integration technology, explained Philippe Le Tourneur, chief scientist on the project at EADS Sodern.**

**When an object needs to be inspected, a fusion reaction will be initiated inside the machine's neutron tube. The machine will then eject neutrons onto the suspected object. These neutrons will react with the atoms of the object and free gamma rays.**

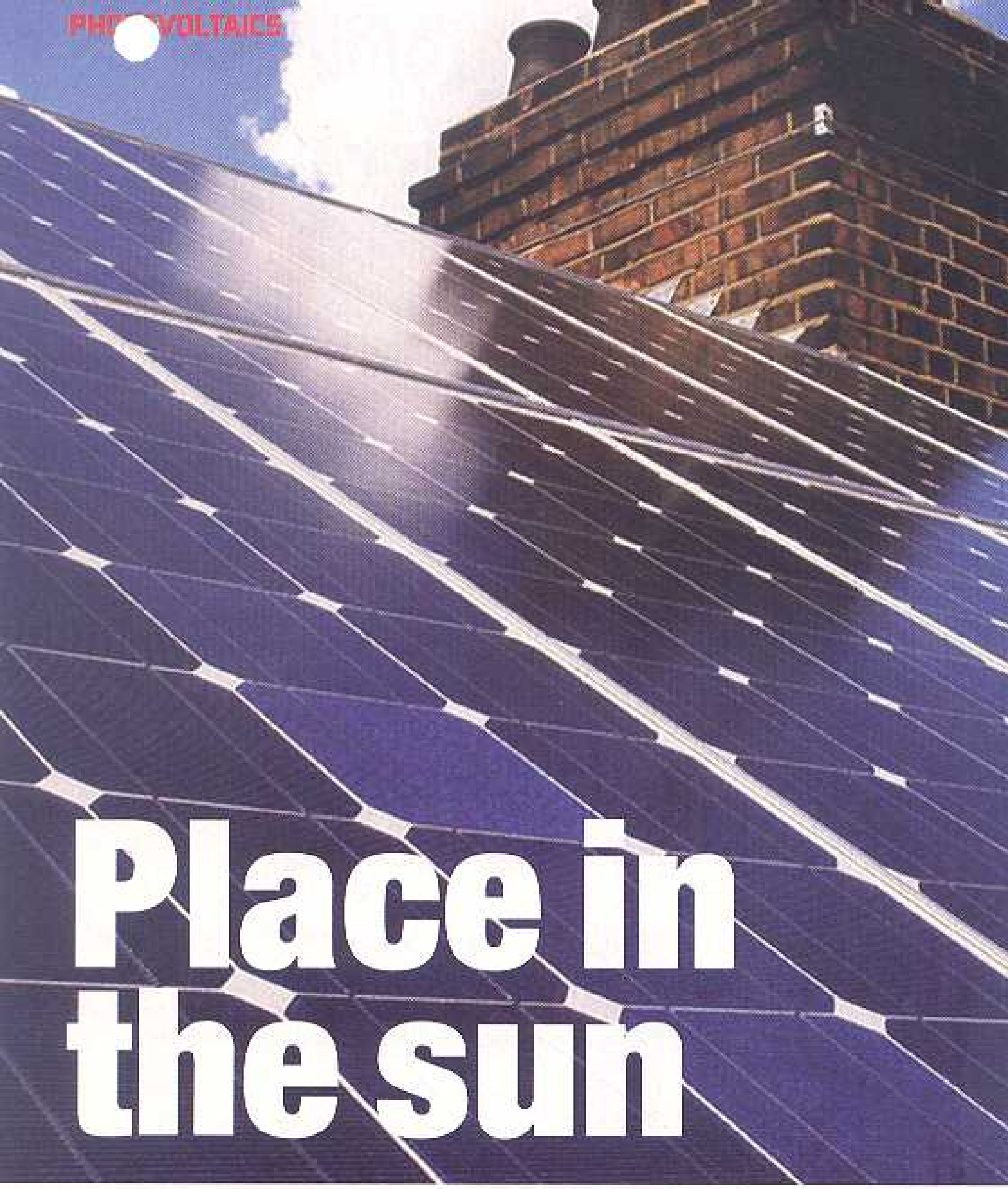
**The machine's gamma-ray detector will collect these rays to help determine the location of all the atoms in the object. When the mapping of atoms is complete, the machine transfers the information to a remote laptop computer and uses an internal database to identify the molecules and determine whether they are a threat.**

**Le Tourneur said the system can determine the presence of explosives that cannot be detected by X-ray systems or trace detectors. 'Neutrons have the capability to penetrate objects such as bags. The system is able to penetrate 30–50cm into an object. Gamma rays are able to go out of the object with the same depth.'**

**Le Tourneur said neutron-integration technology is well established but EADS Sodern is the first to miniaturise the technology so it can be used in a portable detection device. He added that faster electronics and better processing power have made this device possible now.**

**The ULIS is still in prototype form, but EADS Sodern claims early tests have proven successful.**

**Siobhan Wagner**



# Place in the sun

Photovoltaic panels integrated into building structures are making inroads in the solar energy sector. **Stuart Nathan** reports

IT'S LATE afternoon on a gorgeous August day in London and, from the high vantage point of a roof terrace in Waterloo, the city is looking at its best. The golden cross atop the dome of St Paul's Cathedral glitters in the distance and the sun sparkles off the glass panels of Waterloo Station's sawtooth skyline. On this terrace, the sun shines off some neat rows of hedging, pebbly pathways and several sections of angled roof, all of which have different types of solar panels nestled among their tiles or slates.

'This is partly a test rig and partly a sales suite,' said Alan South, chief technology officer of Solarcentury, a UK supplier of building-integrated photovoltaics (BIPV). 'We can show off our whole range of solar cells for different applications and types of building. Everything we do is building integrated, but the solar industry gets very tied up with what is and what isn't BIPV; it isn't at all well understood.'

The most accepted definition for BIPV is that the photovoltaic panels, rather than being simply bolted onto a building, replace some of the conventional building materials, forming an integral part of the structure of a building. The most obvious application is for roofing; photovoltaic cells can be built into panels that do the same job as conventional roof tiles while also generating electricity and, because the roof is exposed to more sunshine than any other part of the building, this makes sense.

Other applications for BIPV also exist, however, and new forms of photovoltaic cells are beginning to make them more practical. Solar cladding on the facades of buildings, particularly on the sunny south-facing walls, are now beginning to be seen, especially on modern commercial buildings with large wall areas.

Meanwhile, the newer thin-film photovoltaics may be about to make a splash in the BIPV market. Not as efficient as the current market-leading cells, which are made from crystalline silicon, thin films are nevertheless lighter and cheaper and can be made transparent; some industry observers believe they could kick-start a new chapter in the story of solar power.

It is a fast-growing sector, especially in Europe. Worth around €143m (£126m) in 2007, growth rates are accelerating in Germany, France and Italy as their governments set up subsidies for homeowners to install solar systems. With similar subsidies set to become available in the UK next year, the sector is expecting to see demand take off.

Solarcentury's experience with BIPV is extensive; among its projects is the roof of a new and striking education centre at the Eden Project in Cornwall. South explained that, in order to offer BIPV, the company had to develop its own range of products. 'We were forced into that, really, because the laboratory's thinking of a solar wafer doesn't work so well with the construction industry's thinking of the materials you need to put up a building,' he said.

However, South also considers that the concept of BIPV is a slippery one. 'If you imagine a field of solar panels, a solar farm, that's one thing,' he said. 'But if you imagine a large industrial installation, with many panels all tilted up at 10° to catch the maximum amount of sunlight, you might think that it was just a bolt-on. But a considerable amount of integration has to be done, in engineering terms; you have a massive aerodynamic load from all those panels and it had to be well integrated with the building's structure, otherwise the panels will fly off or they'll pull the building down.'

For Solarcentury's installations, there are two further levels of integration, said South. 'The second type is architectural integration, where the solar panels look more like part of the building, but still have to be installed by specialists; solar cladding is a good example of that,' he explained. 'And the third is what we call process integration, where the panels are not only an integral part of the building, but they can be installed by someone without specific qualifications or experience. Our solar roof tiles are an example of that; they can be installed by a roofer on the same battens as a standard tile and you just have to screw them down and connect two plugs.'

Integrating renewable generation into buildings is contentious. The government is calling for increasingly ambitious targets for renewables generation and for buildings to generate their own power; wind turbines are becoming more commonplace and can even be bought at DIY stores. However, there is some debate over how effective such measures are. Payback times for wind turbines, especially domestic ones, are long and many measures are dismissed as 'greenwash'.

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Solar, however, is different, at least in terms of its potential. Imperial College photovoltaics expert Ned Ekins-Daukes claims that the UK has sufficient roof space to generate a large amount of power. 'The most efficient solar modules right now, which use crystalline silicon, have a 19 per cent energy conversion rate; that is, they convert 19 per cent of the solar energy that hits them into electricity,' he said. 'And if you covered every roof in the UK with those, you'd have 35GW of generating capacity, but the capacity doubles in the summer and it dives in winter because of the difference in day length and the intensity of the sun. We'll get huge amounts of electricity in the summer, when we use less of it, and much less in the winter — and that brings us into the discussions of how we can manage demand, rather than just meeting it.'

For a household connected to the National Grid, BIPV could make a lot of sense, according to Ekins-Daukes. 'If you assume an average of $40m^2$ of roof area per household and if that house doesn't have any unusual energy demands, then if you install a 3–4kW peak BIPV system, they'll break even over the year, selling electricity to the grid in the summer and buying it during the winter. But the crucial issue here is the cost of the electricity.'

South added: 'The acid test is grid parity — if the energy you make is the same cost or cheaper than what you get off the grid and that depends a lot on the cost of the system.' Countries such as Germany have 'feed-in tariffs', government grants that subsidise renewable power so that it attains grid parity. The UK will bring one in this year.

**The government is calling for increasingly ambitious targets for renewables generation and for buildings to generate their own power**

Ekins-Daukes said that this has been very successful in Germany. 'The way the Germans see it is like it's purchasing a government bond,' he explained. 'You make an investment, you get your money back in a guaranteed time and then you're in profit. The banks have been very cooperative in providing the finance to buy and install the systems, so it's a very safe investment. And if that happens here, then I think people will be very happy to generate their own electricity, especially in new-builds. But it depends very much on how the feed-in tariff is adopted and presented, whether the banks support it and what non-economic barriers there are, such as the availability of reliable, competent installers.'

So can developing technology help? Crystalline silicon is still the leading product, mainly because of its efficiency. Thin films tend to be less than 10 per cent efficient, with the highest efficiencies, from amorphous silicon cells and rare-earth metal mixtures, approaching 12 per cent. Indeed, a recent project to install BIPV on a model sustainable home at the UK's Building Research Establishment specified crystalline-silicon roof panels for just this reason. Katherine Holden of Arup, which built the house, said: 'The design was heavily influenced by the solar panels. We had to opt for a monopitched roof, with the entire roof south facing, and it had to overhang the building to get enough photovoltaics and a suitable output.'

However, other thin-film technologies are knocking on the door, or rather the window; organic-based photovoltaics, with efficiencies of up to eight per cent, are a possibility for surfaces that crystalline silicon cannot reach.

'The research on crystalline silicon is concentrating on reducing cost rather than increasing efficiency,' said South. 'The physical limit — the highest efficiency possible — for a silicon solar cell is 29 per cent; the units we offer are 21 per cent. My strong belief is that we aren't going to get better efficiency in my lifetime, but there are huge efforts going in to maximise the output per pound of capital investment, rather than the output per unit area.'

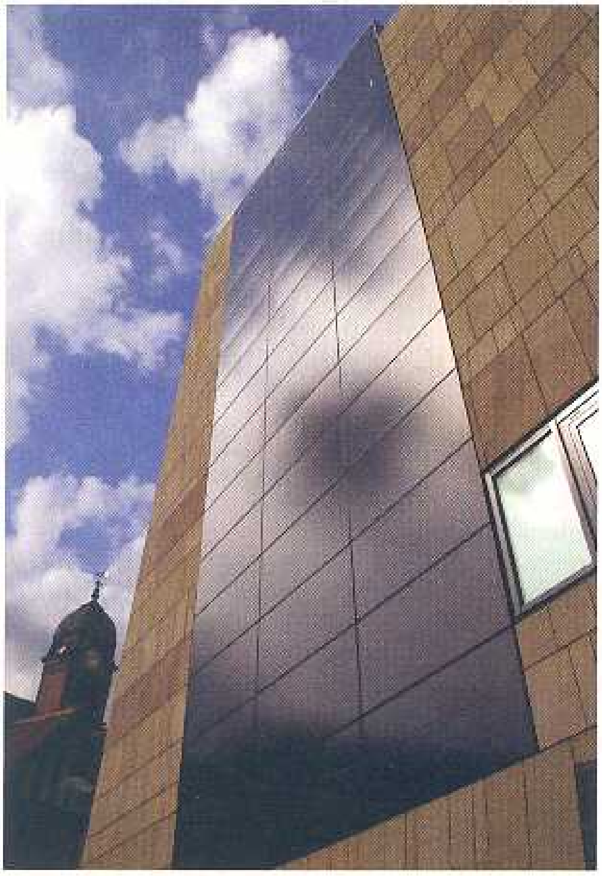
In part, this is because organic thin-film photovoltaics is inherently cheaper than silicon, which requires a large amount of energy to refine the element from sand. 'Organic photovoltaics is going to win on cost — there's no doubt about that,' said Ekins-Daukes. 'Its problem is that it's lower efficiency and, therefore in the case of BIPV, not so architecturally useful as silicon.'

Massachusetts-based organic solar pioneer Konarka is trying to address this with a particularly low-cost, low-energy product that it calls Power Plastic. Capable of being made transparent and in large volumes, Power Plastic can make any surface a solar energy converter, even windows.

**Organic-based photovoltaics, with efficiencies of up to eight per cent, are a possibility for surfaces that crystalline silicon cannot reach**

The technology, originally developed as a material to provide solar power for troops in the field, works by mimicking the structure of a semiconductor with organic materials. 'We work with polymer organic photovoltaics, using a conducting polymer,' explained Srini Balasubramanian, co-founder and research and development director of Konarka. 'Into this, we put donor and acceptor species,' he said. 'The donor would typically be something like polythiophene and the acceptor would

**BIPV technology developed by London based Solar Century have appeared on buildings in, clockwise from below: Derby, Cambridge and Manchester**



## FLUORESCENCE CONCENTRATORS

While crystalline silicon and thin-film photovoltaics fight it out in the market, a new type of photovoltaics cell, currently under development, could prove to be particularly effective. Known as fluorescent solar concentrators, they use significantly less photovoltaic material, but can still generate useful amounts of electricity.

In a normal photovoltaics cell, the active material faces the sun, but in a fluorescent solar concentrator the sun-facing component is a polymer sheet about 5mm thick doped with a material that fluoresces when hit by sunlight. Around three quarters of this emitted light — which, due to the properties of fluorescence, is all of the same wavelength — cannot escape from the polymer sheet; instead, it bounces around in the same way a light beam bounces inside an optical fibre. When the light reaches the edge of the sheet, it is absorbed by thin strips of photovoltaics cells, the same width as the thickness of the sheet, mounted perpendicular to the sun-facing surface.

'Photovoltaics cells are most efficient at certain wavelengths and, because we generate a common wavelength by fluorescence, we can tune that so we produce the optimum wavelength for the cells,' said Amanda Chatten, a physicist at Imperial College who is working on fluorescence concentrators with researchers from the Netherlands, Germany, Switzerland and Ireland. 'The fluorescent material can be a dye, which was originally used when this technology was first developed in the 1970s, but they tend to degrade when they're exposed to ultraviolet. We're now looking at quantum dots, which are much more stable, re-emit virtually all the light they absorb and can be tuned quite simply.'

Fluorescent concentrators are particularly suitable for building-integrated photovoltaics as they are both lighter and cheaper than conventional solar panels, she said. 'The polymer sheet is essentially transparent, so you can use them as a window; the photovoltaics cells are part of the frame,' said Chatten. 'The sheet would be tinted and we could tune the colour.'

She added that these panels would be ideal for use in the UK and elsewhere in northern Europe as they concentrate diffused light on a cloudy day just as well as direct sunlight. The angle of the light on the panel makes no difference.

be a fullerene-based material. We mix that into the polymer and coat them onto the base sheet in layers. When light hits these blends, we have charge transfer from donor to acceptor. We finish the device by putting blocking contacts on the interface, so electrons can go through one side and positive charges through the other.'

This approach allows the company to build its photovoltaics material by using a simple coating technique. 'We've formulated these semiconductor materials as a fluid, so you can think of it as an ink, so we can use a printing technology,' said business development director Stuart Spitzer. 'The temperature is never higher than boiling water and, with a wide enough machine, you can make great quantities very quickly.' Other organic photovoltaics techniques involve vacuum deposition or crystal growth, which require far more energy, time and expensive equipment, he claimed.

The conversion efficiency of Konarka's material is 6.4 per cent, according to Balasubramanian, although there is a trade-off between the thickness of the coatings and the amount of electricity that can be produced. This is an important point, because one of the most interesting applications of Power Plastic for BIPV applications is to make the coating thin enough to be transparent so that the material can be bonded to glass to make a solar window.

**Konarka's Power Plastic is capable of being made transparent and can make any surface a solar energy convertor, including a large window**

'Because we're using organic materials, we can tune the energy absorption spectrum of the polymers to get different colours; red, green and blue,' said Balasubramanian. 'And we can also have different intensities and saturations of the colour.'

Spitzer added: 'We're planning to launch these products this year, selling to window manufacturers, and they would then supply solar-collecting window systems.'

As transparency is important, output will be limited and this means that the systems will be best suited to buildings with very large areas of glass: commercial and office buildings, in particular, according to Balasubramanian. 'My assumption would be that these would provide supplemental power, although, for a roofing installation, we can produce an opaque version that produces more power,' he said.

However, Balasubramanian's ambition is to produce a totally transparent, yet still high-output, system. 'It's not possible yet, but we could conceivably fine-tune the polymers to absorb in the long-wavelength region and not in the visible region at all,' he said. 'It would look transparent, but it would still generate a lot of power from the solar light you can't see.'

Ekins-Daukes sounds a note of caution, however; in terms of reducing the carbon emissions from power generation, solar can never be the full answer. 'You have to keep it in perspective,' he said. 'The average family doesn't actually use that much electricity, in comparison to the gas central-heating boiler, the fuel for their car, the energy that goes into producing their food or the fuel burned to get them on their holiday to Spain. We can provide the present electricity needs of domestic buildings and some commercial buildings through BIPV and that's an important potential, but that's just a fraction of our energy use. As with all energy questions at the moment, there is no single silver bullet.'