The **solar** sell

Will solar power make a significant contribution to the world's energy needs? By **Graham Pitcher**.

Consensus amongst the scientific community is that the world's climate is changing. Those with what may be seen as a dissenting opinion claim this is part of the natural cycle. However, the majority apportion blame for climate change to our seemingly insatiable appetite for energy.

Whether it's electricity to power the array of devices in our homes or the various forms of energy which power our vehicles, CO_2 generation is contributing to – or even creating – the 'greenhouse effect'. The more CO_2 we generate, the worse things become and a section of the scientific world is raising the spectre of a 'tipping point', beyond which the Earth will be unable to recover.

So it's no surprise to discover that scientists and engineers alike are looking urgently for new ways to provide the power which we all desire. One option being presented is a return to nuclear power. While this might reduce CO_2 emissions – and opponents are not convinced about this – the approach creates another problem: disposing of radioactive waste.

Research sites around the world are working on developing solar cell technology, aiming to increase efficiency and reduce manufacturing costs.

Another strand of research is looking to capitalise on renewable energy resources. Here, developers hope to capture the energy available in the wind, the tides and the Earth itself. But a major theme in renewable energy is to harness the power of the Sun.

And it will be no surprise to learn that hundreds of research sites around the world are working on solar power – some on developing the fundamental technology required; others are more concerned with the production aspects.

One of the latter companies is G24 Innovations (G24i), which is about to go into production at its 18,000ft² plant on the outskirts of Cardiff. G24i's technical director is Martin Bellamy. He is keen to highlight solar power as a solution. "It's not about putting solar panels on buildings," he believed. "It's about providing power for people who don't have energy; there's no point in extending the mobile phone network to the developing world if there's no mains electricity to plug the chargers into."

G24i has licensed dye sensitised thin film solar technology from US company Konarka. It's been working on taking the technology from the lab to the point of production. Although the plant is about to start manufacture, the company is planning what it says is 'significant expansion' in capacity next year.

The fundamental technology is the Graetzel cell, invented 1988 by Dr Michael Graetzel and colleagues at the Ecole Polytechnique Federal de Lausanne.

"It's an organic solar technology," Bellamy observed, "although it's actually two technologies: the organic substrate and the inorganic dye."

G24i sees the technology being special for two reasons. "Firstly, it's a low light technology," said Bellamy, "and very few solar technologies do anything in low light. Secondly, it has the potential to scale."

Bringing the price down

The latter observation is crucial. Bellamy believes many solar developers have gone for the performance aspect first, then tried to scale their process. "The challenge," he believes, "is to bring the price down to $1/W and you can only do that with volume." And G24i is using a roll to roll process.

"Traditional modules are units and therefore manufactured in a batch process. Our process allows modules to be 'churned out' just like newspapers."

Jef Poortmans, director of the Solar + programme at Belgian research centre IMEC, says the organisation is using its semiconductor expertise to boost sustainable energy generation. It has two main areas of interest: crystalline silicon solar cells; and organic semiconductor based devices.

And he sees good prospects for photovoltaics (PV). "The PV market is booming," he claimed, pointing to a recent PV event held in Milan. "There were 500 companies exhibiting and 30,000m² of exhibition space," he claimed.

IMEC's involvement – and that of similar organisations – is seen by Poortmans as obvious. "Semiconductor device expertise and processing equipment expertise is an asset; particularly for crystalline silicon. In fact, many microelectronics companies are building their PV activities."

IMEC is participating in a broader European PV approach. Poortmans explained: "The European PV technology platform was established in 2005 to create a strategic research agenda. The first version of this is now available."

The European PV effort is intended to promote the rapid development of a world class cost competitive industry in Europe for sustainable electricity production. An important part of the work is to create strong links between industry, research and the market.

Cost competitive target

The plan lays out targets for PV technology in terms of €/W. A typical turnkey system is expected to cost €1/W in 2030, compared to at least €5/W today. In the longer term, this is expected to drop to €0.5/W. Solar generated electricity is predicted to cost €0.06/W in 2030 and to be broadly cost competitive with wholesale electricity.

Because of the relatively high cost of electricity in Italy, solar power is already at cost parity. But projections claim that, by 2030, solar power will be as cheap as conventionally generated electricity in most of Europe – even in the north of Norway. However, for solar power to be competitive at northern latitudes, efficiencies must increase substantially.

G24i's technology is relatively simple. The module comprises an negative electrode made from titanium foil and a transparent conductor layer. Titanium dioxide powder is painted onto the Ti foil and this acts as a support system for the ruthenium based dye. When light hits the dye, electrons are generated and collected by the conductor layer.

"The TiO_2 particles are very fine and very porous," said Bellamy, "which maximises the surface area."

G24i produces cells on a 305mm wide flexible substrate which can be up to 1000m long. The 305mm allows 24 of the 12.5mm wide cells to be placed alongside each other. Voltage is produced across the width of the substrate, whilst current is proportional to length.

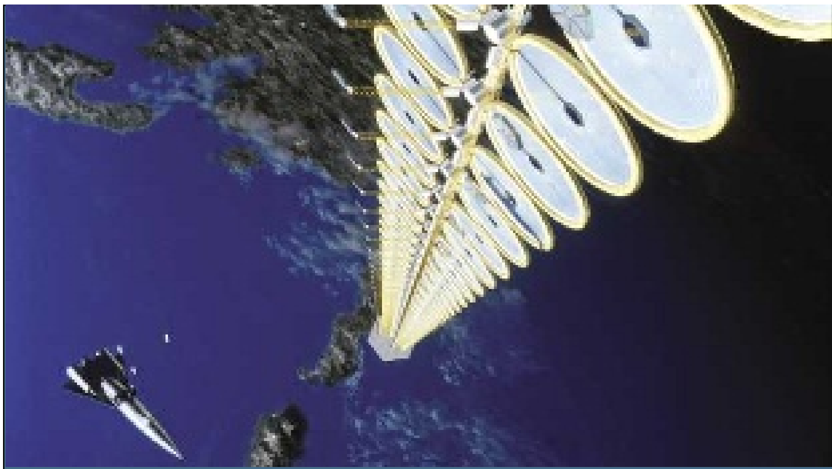
"We can then configure modules," Bellamy continued. "If you want to charge a lithium battery, you need 5V, so we split the substrate to make two 12 cell wide modules."

IMEC fellow Paul Heremans is leading organic solar cell development work at the research centre and admits this work is furthest away from industrialisation of IMEC's current solar projects. Amongst the challenges he sees is the need to reduce the cost of solar to $1/W, or €0.5/W. "Organics can meet this goal," he believes.

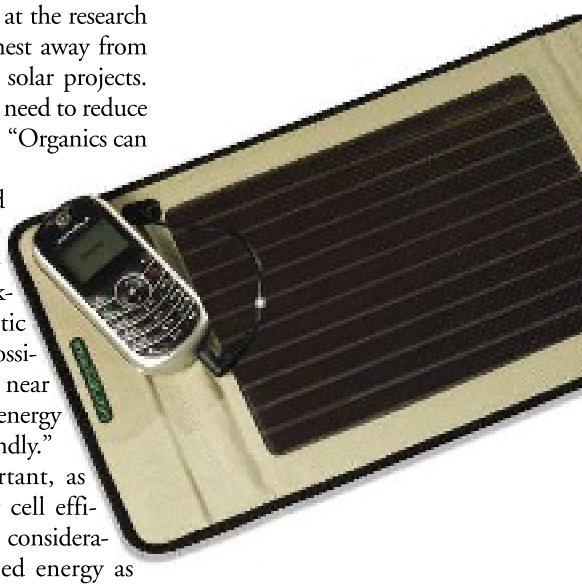
However, the processes required to make organic solar cells are very different to those used to make 'traditional' semiconductors. "We're looking at using substrates such as plastic foil," he remarked, "and paper is possible. But most processes take place near room temperature, so have a small energy budget and are environmentally friendly."

The latter point is important, as some observers see solar cell efficiency as a secondary consideration, with embodied energy as the primary one.

If you take a 20% efficient solar cell, which needed 400kWh for manufacture, and a 15% efficient cell which needed only 50kWh, observers say the latter is the better bet, because it produces net energy more quickly and thus has a better EROEI figure – energy returned on energy invested. So the solar PV industry is not only being challenged to boost the efficiency of its products, but also to make them



For some years, the concept of using a space based solar array to capture energy, then transmit it back to Earth, has been considered, such as the Sun Tower concept developed some years ago by NASA and pictured here.
A number of schemes have been put forward, with arrays of various sizes. Energy would be transmitted by microwave or laser to a receiving station on the surface and converted there into electricity.



Above: G24i believes solar cell technology will enable solutions, such as the mobile phone charger example shown here.

The Almaden solar project in Spain, being built by energy company Solucar, is aiming to generate 20MW of electricity, enough to power 12,000 homes.

The project will use 1255 heliostats with a surface area of 152,000m². These will concentrate solar radiation on to a receiver positioned on top of a 155m tower.

Above: Belgian research centre IMEC is looking at a range of organic semiconductors for use in solar cells. **Below:** G24i has built an 18,000ft² plant to manufacture organic solar cells on a 1000m long substrate. The roll to roll process is set to enter volume production next year.

more efficiently. For that reason, projects such as the solar tower in Spain (see panel above) are seen as more attractive – at least for the near future.

Two potential solutions

IMEC is looking at two ways of making organic solar cells. In the first approach, polymers are dissolved in a solvent and the solution applied to a foil substrate. The solvent is evaporated, leaving a semiconductor film. The result, said Heremans, is a bulk heterojunction. However, one electrode would need to be evaporated in a vacuum, which means the process is not yet continuous.

The other approach uses small molecules evaporated on a foil. "These form dense films and are more reliable," Heremans believed. Multiple layers are more easily formed with this approach, but it does not allow the creation of a true bulk heterojunction.

"The best efficiency with this approach is less than 5%," Heremans noted, "but we need to reach 8 to 10% before productisation and we expect major improvements from new materials."

Bellamy is keen to point out that G24i is not interested in developing the basic science; its focus is on manufacturing and production. "And that's where most research falls over," he claimed. "In many cases, the effort is making the solar cells more efficient, rather than making the process commercially viable. Although there are lots of dye sensitive research sites, nobody is doing it with a view to mass production."

Bellamy's observation about pursuing manufacturability rather than performance is underlined by the fact that G24i's modules are only 4% efficient. "But, because they produce energy all day," he contended, "they produce more energy per peak Watt than any other approach."

Although G24i's products will help address climate change, Bellamy says it's more about personalising energy 'just like the mobile phone personalised communications'. "We can provide a solution for those need energy, but you need to step back and look at why we all use energy. In the developing world, it's enabling technology; here, it's plug into the wall and that means burning oil, generating CO_2 and so on."

Bellamy sees solar power as a solution. "The end user isn't concerned with $/W, it's how much energy is produced. Solutions are about providing communications, security and so on. People don't buy solar on its own, just like you don't buy a battery; you buy a battery to put into something. Bringing the end user into the energy equation is essential."

Bellamy believes some 1.5billion people don't have access to a reliable source of power and the solution is organic solar cells, rather than their crystalline silicon based relatives. "It doesn't matter how cheap you make crystalline silicon, you can't make enough of it. There's no point in making, say, 10,000 parts; the market will want millions and we have the potential to make this volume," he concluded.