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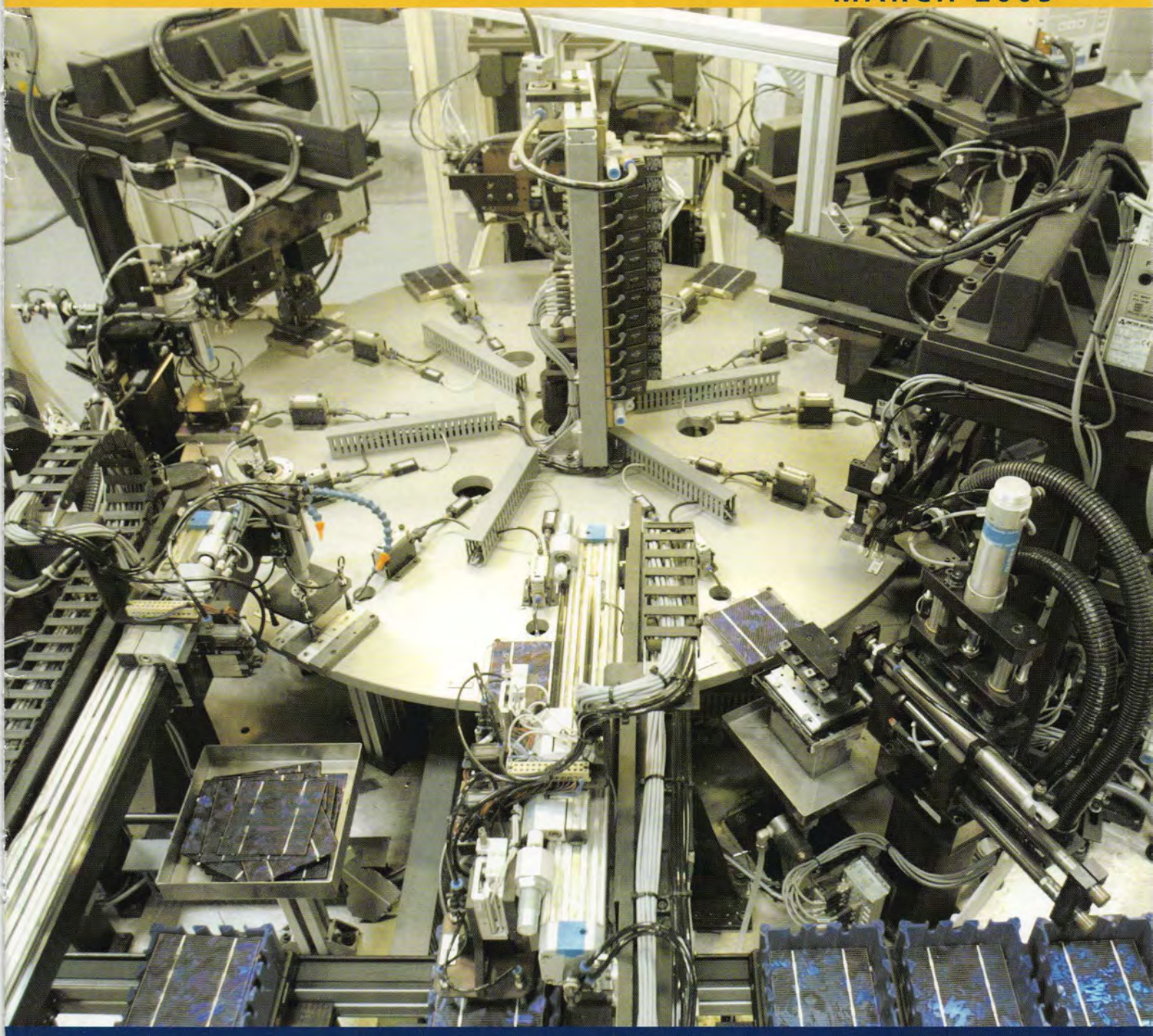

The future for solar photovoltaic power

Prospects for carbon dioxide capture and storage

Towards an effective motor management policy

published by

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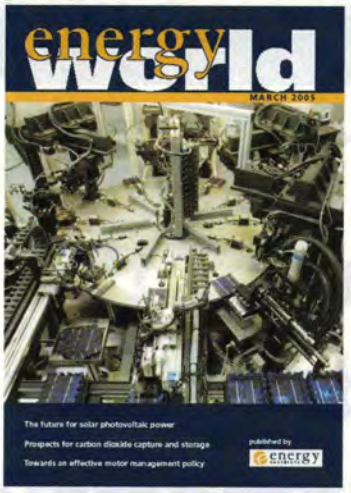
March 2005 **No. 327**

Cover

Manufacturing solar photovoltaic cells – the machinery pictured is making the electrical connections to the cells. In this issue, we take a look, courtesy of the European Photovoltaic Industry Association, into the future of solar power to 2020 and beyond.

Elsewhere, a range of other technologies which will help the fight against climate change are featured – carbon dioxide capture and storage, gasification of waste, high efficiency motors and district cooling using ammonia as a refrigerant.



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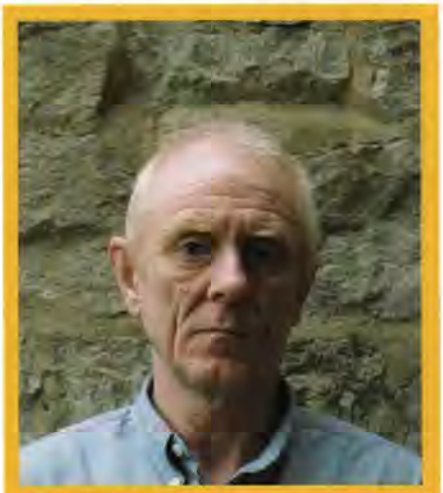
The day after the day after tomorrow



Steve Hodgson
Editor, *Energy World*

I saw the Hollywood movie *The Day After Tomorrow* at the weekend – later than most people, I know. But, at this time of intense activity around the world on methods to tackle climate change (particularly the coming into force of the Kyoto Protocol and the switch of attention to what happens after 2008/12), one of the threads of the movie plotline struck me.

In the movie, our climatologist hero has worked out that, at some time in the past, the earth suffered at massive, but also very sudden, shift in its climate into an ice age. He suggests that this could happen again and, when British colleagues report that several of their sea temperature monitoring buoys in the Atlantic show dramatic temperature falls, he thinks that we might be about to see a similar event. Melting ice caps have changed the salinity of the ocean, which in turn has caused the enormous flows of warm waters north from the equator, including the Gulf Stream, to cease. He tries to warn the US government, which doesn't listen. And then the sudden switch to a new ice age in the northern hemisphere arrives in a series of very violent storms.

Now the science in *The Day After Tomorrow* is not supposed to be real or convincing, but it did popularise the concept of a sudden switch, a 'tipping point', at which a very slow, gradual, trend can suddenly become a rollercoaster ride.

The latest contribution to the debate on how to tackle climate change, from the International Climate Change Task Force (see also page 3 opposite), also talks of a tipping point which they set at an average temperature rise of 2°C. To quote from this new organisation's report: "We propose a long-term objective of preventing average global surface temperature from rising by more than 2°C above its pre-industrial (1750) level. Beyond the 2°C level, the risks to human societies and ecosystems grow significantly. It is likely, for example, that average temperature increases larger than this will entail substantial agricultural losses, greatly increased numbers of people at risk of water shortages, and widespread adverse health impacts. Exceeding a global average increase of more than 2°C could also imperil a very high proportion of the world's coral reefs and cause irreversible damage to important terrestrial ecosystems, including the Amazon rainforest. Above the 2°C level, the risks of abrupt, accelerated, or runaway climate change also increase. The possibilities include reaching climatic tipping points leading, for example, to the loss of the West Antarctic and Greenland ice sheets (which, between them, could raise sea levels more than 10 m over the space of a few centuries), the shutdown of the thermohaline ocean circulation (and, with it, the Gulf Stream), and the transformation of the planet's forests and soils from a net sink of carbon to a net source of carbon".

Not quite as dramatic as *The Day After Tomorrow*, but a similar thesis, and one that has been expressed by many other scientists and groups. And, while governments around the world are listening to climatologists and beginning to take at least some action to slow the release of carbon dioxide into the atmosphere, the world has yet to take decisive action. Even if successful, the Kyoto Protocol will only check global carbon emissions. Reducing them is all for the future.

Climate change is the ultimate global problem – the actions of some countries will count for nothing unless the great majority of major emitters are brought into emissions-limiting agreements. Post-Kyoto, this will have to involve the major developing nations, particularly China and India, as well as the developed countries currently obliged under Kyoto to curb emissions. And the Kyoto-refuseniks, the US and Australia.

The principal objection from industry in the US and elsewhere to Kyoto is that the treaty lets China and India do nothing while developing countries force their own industries to alter their ways. New taxes, levies and regulations damage competitiveness, they say, and the cost of complying is significant.

Yet, says the International Climate Change Task Force again: "The cost of failing to mobilise in the face of this threat is likely to be extremely high. The economic costs alone will be very large: as extreme weather events such as droughts and floods become more destructive and frequent; communities, cities, and island nations are damaged or inundated as sea level rises; and agricultural output is disrupted. The social and human costs are likely to be even greater, encompassing mass loss of life, the spread or exacerbation of diseases, dislocation of populations, geopolitical instability, and a pronounced decrease in the quality of life. Impacts on ecosystems and biodiversity are also likely to be devastating. Preventing dangerous climate change, therefore, must be seen as a precondition for prosperity and a public good, like national security and public health."

The science of climate change is well-established and believed. Globally, governments have begun to recognise the problem and many have taken the first tiny steps on a road to tackling it. Now we are approaching the point of having to agree something much more substantial in terms of action.

But this is where the climate change conundrum comes in. Climate change is said, by many well-respected people, to be the most important challenge facing the world today. But it is also rather abstract in nature: we can't blame individual weather events on it; it lacks immediacy to the point where we are always taking about the future, often decades hence; and the actions of any one group are destined to have no effect unless everyone else joins in. Have we seen enough of the future yet to take climate change seriously – enough to prevent sudden, damaging change? ●

'G8-Plus Group' needed to bring in the US and developing countries to tackle climate change

High level representatives from Kyoto-rejecting countries the US and Australia have joined with Britain's Institute for Public Policy Research (ippr) to campaign for international action to tackle climate change. The international task force, established by the Center for American Progress and the Australia Institute along with the ippr, has called on the G8 group of countries to create a 'G8-Plus Climate Group' to engage the US and major developing countries in action to reduce greenhouse gas emissions.

The task force says that such a group would provide a way for G8 countries and other major economies – including India and China – to take action that would lead to large-scale reductions in emissions. The Group could pursue partnerships to achieve immediate deployment of existing low-carbon energy technologies, including agreements to shift agricultural subsidies from food crops to biofuels and promote sales of highly efficient cars.

The report also argues that all G8 countries should set a lead by adopting national targets to generate at least 25% of electricity from renewable energy sources by 2025 and mandatory cap-and-trade schemes for emissions, like the EU scheme. In the US, this could happen through the Climate Stewardship Act, proposed by Republican Senator John McCain and Democratic Senator Joseph Lieberman, and could provide a path for US re-entry into a global climate change agreement after the Kyoto Protocol's first phase ends in 2012.

The task force also calls on governments to agree to a long-term objective of preventing global temperatures from rising by more than 2°C above pre-industrial levels. And the report talks of the need for a step-change in financial and technical assistance for developing countries to adapt to climate change.

UK MP Stephen Byers, co-chair of the task force with US Republican Senator Olympia Snowe, said: "Our planet is at risk. With climate change, there is an ecological time-bomb ticking away, and people are becoming increasingly concerned by the changes and extreme weather events they are already seeing. Urgent action is required if we are to win the battle against this problem. That can only happen with strong political leadership. I appreciate that tackling climate change is politically difficult. First, there is a mismatch between the potentially unpopular decisions that need to be taken now and the benefits that will come in the medium and long term. Secondly, no country acting on its own can resolve the issue. Strong international action is vital."

"The task force, with its diverse membership, has been able to find common ground. Our recommendations are practical, realistic but also challenging. World leaders need to recognise that climate change is the single most important long term issue that the planet faces and to discharge their responsibilities to the people they represent by agreeing to concerted international action to tackle climate change."

Recommendations of the task force include:

- the G8-Plus Climate Group agree to shift their agricultural subsidies from food crops to biofuels, especially those derived from cellulosic materials, while implementing appropriate safeguards to ensure sustainable farming methods are encouraged, culturally and ecologically sensitive land preserved, and biodiversity protected;
- G8 governments establish national renewable portfolio standards to generate at least 25% of electricity from renewable energy sources by 2025, with higher targets needed for some G8 governments;
- G8 governments increase their spending on research, development, and demonstration of advanced technologies for energy efficiency and low and zero-carbon energy supply by two-fold or more by 2010;
- all industrialised countries introduce national mandatory cap-and-trade systems for carbon emissions, and construct them to allow for their future integration into a single global market; and
- a global framework be adopted that builds on the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, and enables all countries to be part of concerted action on climate change at the global level in the post-2012 period, on the basis of equity and common but differentiated responsibilities.

The largest above-ground station on the New York Metro is being renovated to include the installation of a 7000 m² roof constructed of RWE Schott solar panels, which will generate around 250 MWh of renewable electricity per year.

When renovation of the 86 year old station on Coney Island is complete, it will offer its 160,000 daily commuters a comfortable, shaded environment – the panels allow 20–25% light transmission. Before being selected for the project, the solar panels were subjected to stringent structural and maintenance analysis, including a hurricane test.

IEA commends Canada's energy markets; calls for more co-ordination on emissions and security

"Competition in the Canadian energy markets is well advanced, benefiting the consumers of Canadian oil, gas and electricity in Canada, the US and outside North America," according to Claude Mandil, Executive Director of the International Energy Agency (IEA) at the January launch of: *Energy Policies of IEA Countries – Canada 2004 Review*. However, Mandil added that: "The IEA recommends the federal government to strengthen its efforts in building consensus on important energy policy issues. Climate change mitigation remains a big challenge for Canadian energy policy in the coming years."

The energy sector is a major driver of Canada's economic growth and well-being and, as a large exporter of energy, the country is an important contributor to North American and global energy security. Canada has demonstrated a strong determination in implementing reforms to improve the performance of its energy sector and it is a leader in several fields of energy technology. But Canada's constitution provides for provincial jurisdiction over energy matters within their borders. Hence, it is a challenge to reach the compromises which satisfy all interests on topics such as climate change mitigation, regulatory regimes for new investment in energy infrastructure, expansion of inter-provincial electricity interconnections and electricity market reforms, says the IEA.

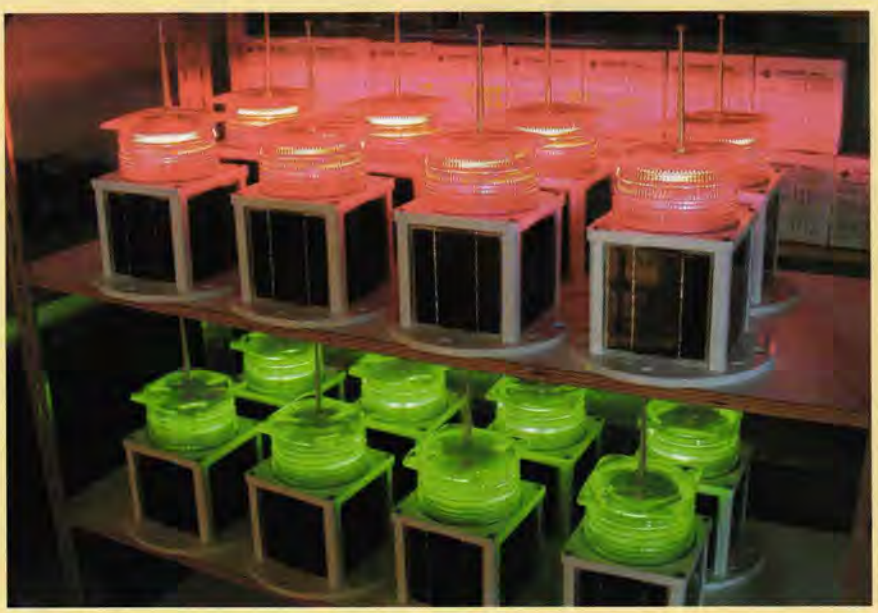
The Agency commends the federal government for its efforts and achievements in formulating the Climate Change Plan for Canada in November 2002. Although the country still displays a high level of energy consumption per unit of GDP produced, the country has to be commended for its efficiency improvement over the past few years. Canada's excellent measuring and monitoring of energy efficiency should now lead to more ambitious sectoral efficiency goals for transport and other sectors, as a solution to reducing emissions, says the IEA.

Electricity in Canada is under provincial and territorial jurisdiction, except for inter-provincial trade and international trade with the US. With growing interconnection between Canada and the US, more co-ordination and joint actions between the federal governments, provinces and their counterparts in the US is imperative with a view to ensuring reliability of electricity supply, says the IEA. The grid failure of August 2003 demonstrates such need, irrespective of the origins of the failure.

Canada's nuclear power programme is at a critical point in its history. Whilst newer plants are performing well, some of the older plants are experiencing significant problems in refurbishment. For example, the refurbishment of Pickering A Unit 4 resulted in significant costs and schedule overruns, says the IEA. Canada should not forego potentially attractive nuclear generation – the federal government should explore barriers to the attainment of maximum economic generation from existing nuclear plants, consistent with safety considerations, adds the Agency.

To further tap the potential of domestic oil and gas resources, exploration of areas under moratorium should be examined, taking the relevant measures to protect the environment. The production of unconventional oil from oil sands offers significant potential, whilst its environmental impacts need to be minimised through technology developments. Although the regulatory environment in Canadian gas sector has been stable, streamlining of the pipeline approval process should be explored, concludes the IEA.

Energy Policies of IEA Countries – Canada – 2004 Review may be ordered from IEA Books at **www.iea.org/books**



Solar-powered LED marine navigation lights from Carmanah Technologies Inc have won an award for 'best new marine safety product' from the Canadian Safe Boating Council.

The LED lights made it possible for the Canadian coast guard to complete the world's first fully illuminated marine navigation system in 2002, comprising 1,650 lighted buoys along the 23,000 km coast of Newfoundland and Labrador. The lights require zero maintenance during their five-year lifespan, and none of the regular battery or bulb changes of conventional lights.

Spain, UK best for renewables investment

Britain and Spain provide the most attractive national environments for investment in renewable energy projects among 20 countries surveyed across the globe, according to the latest 'renewable energy country attractiveness' indices published by Ernst & Young. Spain had held the top spot alone, previously, but is currently experiencing a slight increase in market risk, whilst the UK's pricing regime is becoming more attractive, says Ernst & Young. Meanwhile, the sheer size and resources of the US market, the volatility of gas and increasing coal prices and the proposed introduction of the 'production tax credit' (PTC) there have all combined to improve the potential for renewables investment in the US. That said, there is still some way to go, as the PTC expires at the end of 2005 and the adoption of renewables targets at a state level is still patchy, says Ernst & Young.

Germany held onto its fourth place, and with an estimated installed wind capacity in 2004 of just under 2 GW, clearly remains a major force in the sector, says the survey. Improving European markets include France and Portugal.

China pioneers supercritical 'clean coal' technology

UK-based Mitsui Babcock has fired the first in a new generation of supercritical power plant boilers, which deliver significant efficiency improvements for coal-fired power stations, at the Changshu power plant in China, close to Shanghai.

Power plants operating at cycle pressures above the so called 'critical' pressure are capable of reducing emissions by at least 20% compared to sub-critical plant of a similar output, says Mitsui Babcock, and the introduction of biomass co-firing, can reduce the emissions still further.

Mitsui Babcock is working on a number of projects across Asia with the Harbin Boiler Company (HBC), its partner in the region and China's largest utility boiler manufacturer.

The supercritical technology at Changshu achieved the hydraulic test milestone in record time – 22 months rather than a typical programme of 30 months. The test involves the water in the boiler being pumped to 1.5 times working pressure, thus proving the manufacturing and construction of pressure parts. Commissioning of the new supercritical boiler with the full load of 600 MW is anticipated within the next two months.

John Prosser, Managing Director of Asia Pacific said: "Demand for electricity in China is rising by 15% a year, and ordered power generating capacity is at record levels. China represents a major export opportunity for environmentally cleaner technologies such as this."

2004 the 'fourth warmest on record'

World-wide, 2004 was the fourth warmest year on record, according to the US National Oceanic and Atmospheric Administration (NOAA). The average global temperature was 0.53°C above the long-term average established since record keeping began in 1880. The mean temperature in the northern hemisphere was the second warmest on record, while the southern hemisphere experienced its sixth warmest mean temperature on record, says the NOAA.

Last year fell just behind 2003 and 2002, which tied for the second warmest year on record at 0.56°C above the long-term average. The warmest year on record was 1998, at 0.63°C above the long-term average, in part because a significant El Nino event occurred that year, adds the NOAA.

Germany's Siemens Power generation has completed construction of the 384 MW combined cycle plant in Tahaddart, about 30 km south of Tangier for Energie Electrique de Tahaddart S.A. of Tangier, which is 48% owned by the Moroccan power utility Office Nationale de l'Electricité. Tahaddart is one of the first projects implemented as the national power market is opened to foreign investors.

Siemens' scope of work also included the installation of the 13 km connection to the Maghreb-Europe gas pipeline, which supplies the power plant with natural gas. The plant is scheduled to begin commercial operation in April, from when it will provide nearly 17% of Morocco's electrical energy.

Banks to serve Spain's 'climate change sector'

Spanish bank Grupo Santander and the specialist merchant banking group Climate Change Capital (CCC) have signed an agreement to jointly develop a financial advisory business serving Spain's 'climate change sector', worth an estimated €1.3 billion this year.

The two firms say they will focus on serving companies affected by new legislation aimed at reducing greenhouse gas emissions, which includes the Kyoto Protocol and the recently introduced European Trading Scheme. Businesses affected by this legislation include Spanish utilities; refineries and gas companies; cement, paper, and ceramics companies; the renewable energy sector; and small to medium size businesses that offer services related to new technologies. In addition, Grupo Santander and CCC also intend to develop products and solutions to support the public sector in Spain, including regional governments, town halls, and development agencies with interests in energy efficiency. They will also advise Spanish savings banks and private equity firms on investing in the climate change sector.

Grupo Santander estimates that the sector across Europe was worth around €30 billion in 2004, and predicts it to grow to more than €200 billion by 2010.

Dutch chlorine plant develops hydrogen fuel cell

NedStack Fuel Cell Technology and Holland's Akzo Nobel Base Chemicals have started operation of a pilot PEM fuel cell system in Akzo Nobel's chlorine electrolysis plant as part of the eventual development of a 50 MW fuel cell power plant for the Rotterdam facility. Measured electrical efficiency of the pilot cells in this 'real life' situation is 61.8%, says NedStack.

The Akzo Nobel pilot plant produces chlorine through a membrane electrolysis process which generates chlorine and caustic soda lye as main products, and hydrogen as a by-product. NedStack has installed proton exchange membrane fuel cells that consume hydrogen produced in the plant, and convert this hydrogen to electrical power for use in the electrolysis process.

NedStack has also started the production of a second fuel cell power module, to be rated at 200 kW, which will be installed in the Rotterdam plant this year to test reliability, and design the full-scale fuel cell power plant. The Dutch Ministry of Economic Affairs is supporting the development within its 'energy saving through innovation' programme.

New support for wave and tidal power could mean offshore farms within three years

The UK's first large-scale wave and tidal power generation farms could be contributing to the national grid within three years, helped by a new Government support scheme worth £42 million, says Energy Minister Mike O'Brien. The scheme will be funded from the Government's £50 million Marine Research Deployment Fund (see *Energy World* February 05) and will support the UK's world-leading wave and tidal industry to construct demonstration farms around the UK.

Support under the scheme will be a combination of capital grant and revenue support, ie an additional payment for electricity generated.

Announcing the scheme, O'Brien said: "The marine renewables sector is at a critical point in its development from pipe dream, through R&D, to commercial viability. The UK is already by far the most attractive place to develop these emerging technologies. The Government has invested £15 million in R&D, and it's now clear that there are a number of exciting wave and tidal projects on the verge of pre-commercial operation. This new £42 million scheme marks a watershed. It will kick start construction of large-scale demonstration farms and will for the first time see wave and tidal power feeding into the national grid."

The UK's wave and tidal energy companies welcomed the package to support the next stage of development. Confusingly, both the Renewable Power Association (RPA), through its Ocean Energy Group and the British Wind Energy Association (BWEA), which 'champions the UK wind, wave and tidal sectors', claim to represent the industry.

The RPA's John Griffiths said, "We are pleased that the DTI has worked so closely with the industry and other stakeholders in developing this scheme. In particular, they have included support for each megawatt hour of output, which rewards efficient designs and fast installation. The best companies should be the major winners under this scheme."

The BWEA said, "By proposing a combination of revenue based support equivalent to 15 p/kWh and 25% capital grants, this announcement will provide these emerging power sources with a significant boost over the next few years."

Michael Hay, Marine Renewables Development Manger at BWEA, added: "Well done to Government. This is great news for the emerging wave and tidal sector. They have listened to the industry and put in place proposals for a world leading support fund to kick-start these essential carbon-free power sources. The challenge now is to get the first projects consented and in the water as soon as is practically possible. While this fund is a great step forward for devices in more advanced stages of development, the Government must ensure this marine fund has life beyond the current three year term to provide equal reassurance to the many projects at earlier stages of development."

Trust asks business to take responsibility for emissions

Readers can not have missed the latest – and largest yet – advertising and communications campaign to persuade businesses to take responsibility for their carbon emissions and impact on climate change.

The Carbon Trust says that its campaign calls on businesses to join the new industrial revolution. According to Chief Executive Tom Delay, "Climate change is the biggest environmental threat faced by the UK and action is needed now. Our industrial society is responsible for climate change and, looking to the future, we now have to create a new, low carbon economy. This is a commercial, business opportunity – one which we call all businesses to act upon. We all need to understand and take responsibility for our actions and their impact on the climate."

Delay added: "Some UK businesses have chosen to act already – but more need to do so. Businesses need to understand that there is a real commercial benefit to be gained. We can help them find practical ways to act that will benefit both their business and the environment. Whether it is the strategic energy review and efficiency audits for large energy users, or more straightforward actions such as reminding employees to switch their computers and lights off at the end of the day; all of these are practical solutions to tackle the issue of climate change."

Supporting the launch of the campaign, John Cridland, CBI Deputy Director General, said: "The business community is often unfairly blamed as being solely responsible for climate change, when in fact we have already done more than most to cut emissions. More action is needed, though and, as organisations in the UK become increasingly aware of the impact of climate change, many are already taking action."

Many thanks to readers who responded to the recent questionnaire on the future of *Energy World* and *Petroleum Review* magazines. Winners of the Red Letter Day prizes were Doug Harris of Portsmouth; Robert Cohen of Corsham, Wiltshire; Roy Kelly of Henley on Thames; and Denis Morgan and E Spearman, both of Aberdeen.

We are currently studying the results of the survey, which are both very positive about the two EI monthly publications yet also point to one or two areas of possible improvement. We will announce any changes in publication policy later this year.

UK oil and gas industry invests to check production decline

Efforts to check the decline in UK oil and gas production appear to be paying off, as investment in the North Sea continues to recover from the 'unexpected tax hit' in 2002, according to the UK Offshore Operators Association (UKOOA). However, rising costs in the UK continue to undermine global competitiveness, adds the Association.

Figures released by UKOOA show that investment in Britain's offshore oil and gas industry rose in 2004 and will continue to rise in 2005 and beyond. The outlook on production is also optimistic with UKOOA projecting a 2% increase in oil and gas volumes out to 2010, compared with previous forecasts.

"Confidence is returning to the North Sea," said UKOOA chief executive Malcolm Webb. "There has been a re-appraisal of the opportunities available in the UK continental shelf (UKCS) and this is being translated by the producers into new plans for more exploration, developments and incremental production from and near existing fields. If these plans are realised, the rate of decline in UK oil and gas production is likely to be halved to 7% per annum, extending the life of the North Sea, protecting jobs, revenues and the primary source of Britain's energy supply. This is very encouraging and a positive change in the industry's outlook after four rather troubling years."

"However, while the report shows that the industry is continuing to close the gap on its 2010 production 'vision' of 3 million barrels of oil equivalent per day (boepd), success is not guaranteed and rising costs could easily erode UKCS competitiveness. To extend the life of UK oil and gas production will require not only massive further investment from the industry but also constructive engagement from all other stakeholders, including, very importantly, the Government in the form of a stable and predictable fiscal regime and apt regulation."

Key findings of the UKOOA *2004 Activity Survey* are:

- total expenditure in 2004, including operational, exploration and capital costs, is an estimated £8.9 billion, up £0.5 billion on 2003;
- total expenditure for 2005 is expected to exceed £9 billion; total spend over the next five years is £35 billion;
- capital investment picked up significantly in the second half of 2004, and is projected to remain strong in 2005 at £4.31 billion (up 11% on 2004);
- however, operating costs rose sharply last year, by £0.5 billion to £5 billion; unit operating costs in 2005 are predicted to rise by 18% compared with last year's survey, reflecting the increased costs of extending the life of ageing assets and infrastructure;
- oil and gas production in 2004 is estimated at 3.8 million boepd – or 1.38 billion barrels of oil equivalent (boe) over the year;
- the production forecast out to 2010 is up 2% on last year's projections, halving the rate of decline in UK oil and gas production to 7% per annum; for oil/liquids the survey shows a 4% increase over recent forecasts;
- total production between now and 2010 is forecast at 7 billion boe; and
- total remaining reserves are estimated to be up to 28 billion boe.

Meanwhile, detailed negotiations have been concluded on the UK/Norway Framework Treaty, paving the way for unprecedented co-operation on North Sea projects between the two states. UK Energy Minister Mike O'Brien said that the conclusion of negotiations: "marks a real milestone in the relationship between the two states. Two years of hard work and amicable and constructive negotiation has laid the foundation for decades of mutually beneficial trade and exploitation of North Sea reserves between our two countries. The UK will not only benefit from the new Langeled pipeline project which can supply up to 20% of our future gas needs but Norway can be confident that it has a stable, long-term partner and outlet for its gas. Oil and gas companies in both the UK and Norway can now develop further lucrative cross-boundary oil and gas deals on a much clearer and faster basis."

If London wins the competition to host the 2012 Olympic and Paralympic Games, all the sailing events will be held at the Weymouth and Portland National Sailing Academy, where the new Osprey Quay development includes a photovoltaic system to capture solar power. London 2012, the organisation bidding to host the 2012 Olympics, has made a commitment to a 'low carbon Games'. Working with PV company solarcentury, the Sailing Academy has led the way.

Solarcentury, which designed and managed the installation, helped the Academy to apply for a 60% government grant for the project under the DTI's Major Photovoltaic Demonstration Programme. The roof-mounted panels will generate around 19 MWh of power each year.

A large electronic display in the foyer of the Sailing Academy shows the instant electricity being generated, the total amount generated and the cumulative savings in carbon dioxide emissions. As the project is used by large numbers of people, particularly children, it is hoped that the display will heighten awareness of the need for energy conservation.

Shell Chairman urges stronger government action on climate change

Support for more determined government action to limit emissions of carbon dioxide into the atmosphere has been voiced by an unlikely source, Lord Ron Oxburgh, Chairman of the UK arm of Shell, while delivering the fourth annual Greenpeace Business Lecture in January. Warning against the "angry beast" of climate change, Oxburgh said that the Shell Group has nothing to fear from the taxation and regulatory changes that are needed to avoid the potentially disastrous consequences of climate change.

He said, "Governments in developed countries need to introduce taxes, regulations or plans such as the European Union carbon trading scheme to increase the cost of emitting carbon dioxide." This is the only way that technologies such as biofuel, carbon sequestration, the use of hydrogen as a fuel and wave, tidal, wind and solar power would displace the use of oil, coal and gas. "None of this is going to happen if the market is left to itself," he added.

In his 50 minute address, Oxburgh outlined Shell's strategy for coping with tougher laws and taxes on using oil and gas by gaining expertise in the various environmentally-friendly technologies that may play a role in meeting future energy needs. He focused on the need for more research into marine renewables – particularly wave and tidal power which he said were "under researched and under resourced" and into better ways of storing renewable energy. He also highlighted the important role that biofuels and biomass could play in producing energy for transport, electricity and heating, says Greenpeace.

On transport he said that, in addition to biofuels, hybrid cars were a cost and fuel-efficient way of bridging the gap into a possible future energy economy based on hydrogen. He also acknowledged the need for aviation growth to be curbed, either by bringing it into the emissions trading scheme or instituting an aviation tax.

Lord Oxburgh also said that the highest priority in the western world is to find ways for emerging countries to meet their energy needs in a clean way. None of the emerging industrial giants of the future – Russia, Brazil, India and China – will accept a lower standard of living, and history has shown that as countries become more prosperous their demand for energy increases. According to Oxburgh, we need to work with them to help them leapfrog existing polluting technologies.

New energy-saving lighting controls for Carbon Trust HQ

The offices of the Carbon Trust are to benefit from an energy-saving automatic lighting control system installed by Ex-Or Ltd. The company installed its 'LightSpot' system on the 8th, 9th and 10th floors of the Carbon Trust office in Clement's Inn, London.

The system switches the lights on and off by monitoring the presence of occupants and by measuring the amount of natural light available. Open plan office areas, smaller cellular offices and also meeting rooms are controlled by the system. Around the perimeter of the open plan area, the lights remain off when levels of daylight are sufficiently high. In meeting rooms, which are used irregularly, lights are automatically switched off when LightSpot detects the rooms are no longer occupied.

Peter Hambly, Director of Marketing and Communications at the Carbon Trust said: "We do exactly what all small and medium sized enterprises can do to cut carbon emissions. We have an environment policy and an action plan where we look at and review all our systems as a business and work out ways where we can become more energy efficient. Automatic lighting control can dramatically cut the unnecessary use of lighting. We estimate that, following this installation, we are cutting the amount of electricity used by at least a quarter. It also helps create a better working environment for us as it means everyone is working in the correct levels of light."

Carbon Trust lights will be switched according to occupancy and ambient lighting levels

Half of new homes 'fail to meet energy standards'

The first ever survey of new homes in occupation has shown that almost half of all new houses in England are failing even to meet minimum Building Regulations requirements.

Researchers from the Building Research Establishment visited 100 new homes built under the 2002 Regulations. They examined boiler installations, loft and pipe insulation, lighting and glazing, seeking to compare these items with those promised to the local council when it gave Building Regulations approval. For practical reasons, they were unable to check the correct appliance of either floor or wall insulation.

The results were startling. The more expensive the home, the more corners had been cut. The assessors' task was complicated by the substantial latitude afforded housebuilders in how homes are deemed to comply, with many trade-offs between different energy saving measures permitted.

The results have been presented both to government officials and their advisory committee on Building Regulations, as well as to building control officers. Whilst it has long been acknowledged that there was always some cheating on implementation, most observers are genuinely shocked at how poor the rates of compliance are, says the Association for the Conservation of Energy.

One simple check is to measure the number of air changes, a concept long opposed as a mandatory requirement under the Regulations by the House Builders Federation. But this survey may have increased the likelihood of their being forced to permit random testing, when further revisions are introduced later this year.

Nissan, GSK opt for used wind turbine for on-site power

Nissan Motors – soon to be home to seven wind turbines

Car manufacturer Nissan Motors is to have seven 750 kW wind turbines erected at its Washington, Tyne and Wear, site. The turbines will add up to a 5.2 MW generation facility, and will provide around 10% of the plant's electricity needs.

Nissan's move follows a decision by GlaxoSmithKline to introduce wind energy at its base in Teesdale – here two refurbished 250 kW turbines are being installed.

Both companies were advised by TNEI Services, part of The Northern Energy Initiative based in Newcastle upon Tyne. The company says it is involved in advanced negotiations about on-site wind energy with several other household names from the retail and automotive sectors.

At Nissan, which occupies a 750 acre site and is the UK's largest car manufacturer employing 4,000 people, the wind farm is scheduled to be operational next year – subject to a favourable planning decision by the City of Sunderland Council. As with GSK, TNEI Services has provided all on-site studies and will source second hand wind turbines from European suppliers.

The prospects for soaring energy costs has led to an increase in enquiries at TNEI over recent months, with interest being shown in biomass ground heat and photovoltaic systems, as well as wind. The company is networking with European suppliers to import second hand and new wind turbines into the UK that substantially reduce project costs – in some cases to as little as £125,000 for 250 kW installed.

- Meanwhile, Siemens Power Generation has secured an order from npower renewables to supply 40 wind turbines to the Farr Wind Farm, located 10 km south of Inverness in northern Scotland. The order value for the turnkey project, with a total capacity of 92 MW, is approximately €90 million. The project is scheduled to go online in spring of 2006 and will be npower renewables' largest wind farm measured by installed capacity.

Alarming rise in new business rates for renewables schemes

The Government is sabotaging the fragile growth of the UK's renewable energy industry by setting new business rates that will raise bills for green generators by up to 700%, while rates for nuclear and fossil fuel plants are set to fall. So say the trade associations representing the renewables sector.

The extraordinary situation arises from the way in which new rates will be calculated for a five year period from April. The formula used by the Valuation Office (VO) makes rates proportional to the receipts of each plant. In the case of renewable generators this includes the incentive payments for sustainable energy sources. Since 2002 all electricity consumers have been paying a small proportion of their bills to support renewable power. Now the Government will effectively be taxing these incentive payments through the rating system, say the associations.

Rates are assessed for generating stations on a site-by-site basis and the rises therefore vary. Based on the preliminary assessments issued by the VO, the maximum increase for wind generation stations was 708% and the average about 100%. The maximum increase for biomass plants was 145%, while hydropower suffered one increase over 1000%.

"This is another nail in the coffin of the Government's renewable energy targets," said Philip Wolfe of the Renewable Power Association. "We have been urging the DTI, which is responsible for renewables, to work with the Office of the Deputy Prime Minister's business rates department to find a sensible solution."

Marcus Rand of the British Wind Industry Association put it another way, "This seems a classic case of un-joined-up Government. We will be seeing a ridiculous situation where, with one hand the Government is giving financial support to renewables, while with the other it is taking some of that support away", he said.

Green power for Wembley

Operators of the new Wembley Stadium have chosen npower business to supply 100% certifiable green energy to operate the facility. The £1.8 million a year contract will run until 2010 and the stadium's annual energy usage is predicted to be 38 GWh. Renewable energy will be used to power the whole stadium, including 688 food and drink service points, the heating, the retractable roof, 30 escalators, the media centre and two giant video screens.

In addition to supplying energy, npower will also provide a half-hourly online service, which will allow the stadium to closely monitor its electricity, gas and water usage.

Meanwhile, insurance giant Zurich has switched to using renewable electricity to heat and light its buildings across the UK.

The future for solar power – a view from the industry

The dramatic recent growth of wind power in certain countries of the world has rather pushed the solar power story into the background. But the industry is projecting that, given proper government support, solar power could meet around 1% of global electricity demand by 2020, with much greater things to follow. Here, in an edited version of the summary to its new Solar Generation *report, the European Photovoltaic Industry Association (EPIA) and Greenpeace explain how.*

The solar electricity market is booming. In the year 2003, the cumulative installed capacity of solar photovoltaic (PV) systems around the world passed 2,400 MWp. Global shipments of PV cells and modules have been growing at an average annual rate of more than 35% for the past few years.

Such has been the growth in the solar electricity industry that it is now worth more than an annual €3 billion.

Competition among the major manufacturers has become increasingly intense, with new players entering the market as the potential for PV opens up. The world wide photovoltaics industry, particularly in Europe and Japan, is investing heavily in new production facilities and technologies. At the same time, political support for the development of solar electricity has led to far reaching promotion frameworks being put in place in a number of countries, notably Germany and Japan.

Since the first edition of *Solar Generation* was produced in 2001, the global market has continued to expand at the rate then predicted. While some countries, such as the United States, have lagged behind their expected development, others such as Germany have exceeded expectations. There is also evidence of new enthusiasm for solar power in some of its most promising potential world markets, such as China.

This clear commercial and political commitment to the expansion of the PV industry means that the current surge of activity in the solar electricity sector represents merely a foretaste of the massive transformation and expansion expected to occur over the coming decades.

A projection to 2020

Numerous analyses about the potential market development of solar photovoltaics have been published in the past. The aim here has been to compile a detailed quantitative knowledge base, coupled with clearly defined and realistic assumptions from which extrapolations could be made on the likely development of the solar electricity market up to 2020 and beyond. The results which have emerged from this extensive analysis point to a technology that will make a major impact on the everyday adult lives of the population born today.

Clearly, this transformation will not happen by itself. It will require the far reaching commitment of both consumers and industry, as well as significant political will. The level of commitment needed, however, has already been demonstrated in those countries which show the greatest growth in their solar electricity industries. We must learn from those lessons and adapt and deploy the corresponding catalysts on a global level if solar electricity is to play a major role in the lives of the next generation.

Taking its lead from success stories like those in Japan and Germany, this EPIA/Greenpeace report looks forward to what solar power could achieve – given the right market conditions and an anticipated fall in costs – over the first two decades of the twenty first century. As well as projections for installed capacity and energy output it makes assessments of the level of investment required, the number of jobs which would be created and the crucial effect which an increased input from solar electricity will have on greenhouse gas emissions.

This scenario for the year 2020, together with an extended projection forwards to 2040, is based on the following core inputs:

- PV market development over recent years both globally and in specific regions;
- national and regional market support programmes;
- national targets for PV installations and manufacturing capacity; and
- the potential for PV in terms of solar irradiation, the availability of suitable roof space and the demand for electricity in areas not connected to the grid.

The following assumptions have been employed.

Market growth rates: the average annual growth rate of the worldwide PV market up to 2009 is projected to be 27%, then rising to 34% between 2010 and 2020. Although initial growth is expected to be fastest in the grid-connected sector, by 2010 the off-grid sector will play a steadily increasing role.

Electricity generation: figures for the growth in global electricity demand up to 2020 (on which comparisons with expect-

PV systems capacity	205 GWp
Grid-connected consumers	93 million world wide[1] 31 million in Europe
Off-grid consumers	950 million world wide[2]
Employment potential	2.25 million full-time jobs world wide
Investment value	€62 billion per annum
Prices for grid connected PV systems	Reduction to €2 per Wp
Cumulative carbon savings	730 million tonnes of carbon dioxide

1. Based on 2.5 persons per household, with an annual consumption of 3,800 kWh
2. A 100 W solar system will cover the basic energy needs of 3–4 people

Table 1. Detailed projections for 2020

ed PV development are based) are taken from projections by the International Energy Agency (IEA). These show total world power demand increasing to 25,600 Terawatt hours (TWh) by 2020.

Carbon dioxide savings: over the whole scenario period it is estimated that an average of 0.6 kg of carbon dioxide would be saved per kWh of output from a solar generator.

Projection to 2040: For the period 2020–2040 a moderate annual growth rate of 15% has been assumed, as well as a very conservative lifetime of 25 years for PV modules.

The scenario is also divided in two ways – into the four main global market divisions (consumer applications, grid-connected, remote industrial and off-grid rural), and into the regions of the world as defined in projections of future electricity demand made by the IEA.

Key results of the analysis

The key results of the EPIA/Greenpeace scenario clearly show that, even from a relatively low baseline, solar electricity has the potential to make a major contribution to both future global electricity supply and the mitigation of climate change.

These key results are:

- global solar electricity output in 2020: 282 TWh, equivalent to 10% of EU-25 electricity demand in 2003. This is also equivalent to 1.1% of global electricity demand; and
- global solar electricity output in 2040: 7442 TWh, equivalent to 21% of global electricity demand.

Detailed projections for 2020 are shown in Table 1.

The EPIA/Greenpeace scenario shows that by the year 2020, PV systems could be generating approximately 282 TWh of electricity around the world. This means that enough solar power would be produced globally in twenty years' time to satisfy the electricity needs of 10% of the entire EU-25 (2003 figure). Put another way, this would represent the annual output from 76 coal-fired power plants.

Global installed capacity of solar power systems would reach 205 GWp by 2020. About half of this would be in the grid-connected market, mainly in industrialised countries. Assuming that 80% of these systems are installed on residential buildings, and their average size is 3 kWp, the total number of people by then generating their own electricity from a grid-connected solar system would reach 93 million. In Europe alone there would be roughly 31 million people receiving their supply from solar electricity generation.

Although the key markets are located now mainly in the industrialised world, a global shift will result in a significant share – 30 GWp – being taken by the developing world in 2020.

Since system sizes are much smaller and the population density greater, this means that up to a billion people in developing countries would by then be using solar electricity. This would represent a major breakthrough for the technology from its present emerging status.

PV power in Europe – a new-build solar canopy

By 2040, the penetration of solar generation would be even greater. Assuming that overall global power consumption had by then increased from 25,600 to 36,000 TWh, the solar contribution would equal 21% of the world's electricity output. This would place solar power firmly on the map as an established energy source.

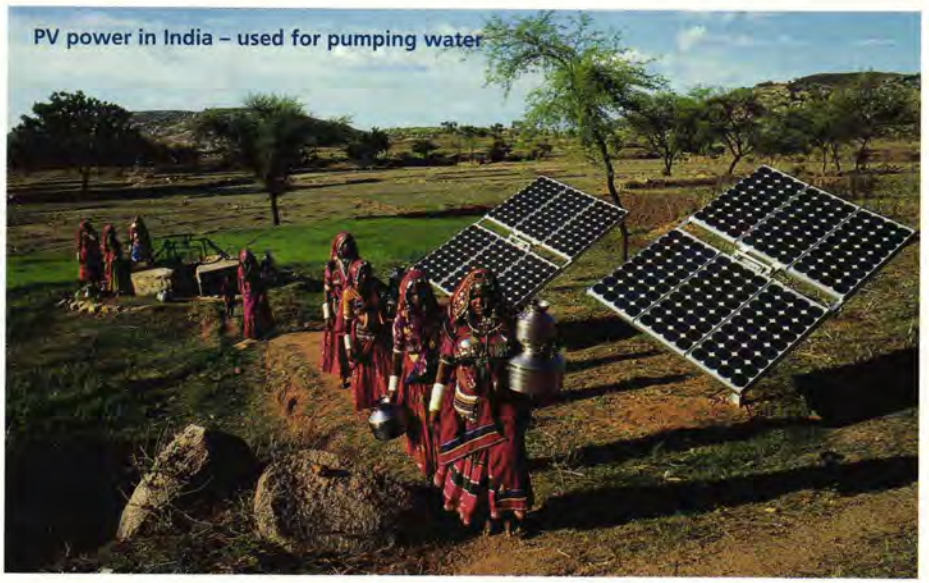
For the solar production industry, global annual shipments of PV modules will rise from 750 MWp in 2003 to more than 48,000 MWp in 2020. This represents an increase by a factor of 64.

For the job seekers of the 2020 generation, this would represent a major contribution towards their employment prospects. On the assumption that more jobs are created in the installation and servicing of PV systems than in their manufacture, the result is that by 2020, more than 2.25 million full time jobs would have been created by the development of solar power around the world. The majority of those would be in installation and marketing.

By 2020 solar PV would also have had one other important effect. In environmental terms, it would have reduced annual carbon dioxide emissions by 169 million tonnes. This reduction is equivalent to the emissions from all 45 million cars currently operating in Germany, or 76 coal-fired power plants. Cumulative carbon dioxide savings from solar electricity generation between 2003 and 2020 will have reached a level of more than 730 million tonnes.

Policy recommendations

In order to supply up to a billion people with solar electricity by the year 2020, and go on to achieve a global electricity share of 21% by 2040, a major shift in energy policy will be needed. Experience over the past few years has demonstrated the effectiveness of joint industrial and political commitment to achieving greater penetration of



PV power in India – used for pumping water

solar electricity into the energy mix at local, national, regional and global levels.

A number of key political actions are required.

- An annual world PV market growth of 3.7 GWp+ by 2010 will only be achieved through the extension of best practice support schemes, appropriately adapted to local circumstances, to encourage the uptake of solar electricity amongst consumers. The German and Japanese experiences highlight the impact which such actions can have on the global photovoltaics industry.
- The inherent barriers to the take-up of solar power – and the subsidies available to fossil and nuclear fuels which currently penalise renewable sources – must be removed.
- A variety of legally enforced mechanisms must be implemented which secure and accelerate the new market for solar photovoltaics. Particularly in industrialised and emerging economies, the introduction or expansion of premium feed-in tariffs with guaranteed lifetimes must be a cornerstone of all future promotion mechanisms for solar electricity.

Our goal now must be to mobilise the necessary industrial, political and end-user commitment to this technology and, more importantly, the service it provides. We must redouble our efforts to ensure that the generation born today benefits from all the socio-economic and environmental benefits that solar electricity offers. ●

Contact the European Photovoltaic Industry Association (EPIA) at **www.epia.org**

How Germany took the lead in Europe

Germany is the European leader in solar energy. Having already developed the world's largest installed capacity of wind turbines, Europe's most populous state is now looking to push photovoltaics into an equally prominent position.

In terms of installed capacity, Germany overtook the USA in 2001 to achieve second position globally behind Japan. At the end of 2003, total capacity had reached 416 MWp, with 130 MWp installed in 2003 alone. In the 2001 edition of *Solar Generation* it was ambitiously estimated that the country could achieve a figure of 438 MWp by 2004. This has in fact been almost reached by the end of 2003, and with the expectation that more than 650 MWp will be installed by the end of 2004.

In the background to this success is the German Social Democrat/Green government's Kyoto-led commitment to reduce its emissions of greenhouse gases by 21% over the period 1990 to 2008-12. This will be achieved by a mixture of shifting energy production towards cleaner sources and a programme of energy efficiency. Two successive pieces of legislation have been crucially important in supporting the first of these aims – the 100,000 roofs programme started in 1999 and the 2000 Renewable Energy Law, updated in 2004. One result is that the wind energy industry has seen a capacity of over 15,000 MW installed, representing roughly 5% of electricity supply, and an estimated 45,000 jobs created in less than a decade. The German solar industry has now started a similar boom for PV.

The rooftop programmes

Germany has been a pioneer in grid-connected PV, with an extremely effective '1,000 Rooftop Programme' running from 1990 to 1995. More than 2,250 rooftop installations were connected to the grid during this period, with an average capacity of 2.6 kW per roof. In 1995, total system costs averaged €12.27/W and produced an average 700 kWh per kW installed over the year.

At the end of this programme the German PV market suffered a significant breakdown, however, and Greenpeace and other organisations started extensive lobbying work to encourage a follow-up. Greenpeace launched a solar pioneer programme in 1995 and has continued since then with extensive information work in favour of solar PV. Between 1995 and 1999 about 40 cities and towns also implemented their own 'rate based' incentive schemes. These allowed residential customers to sell electricity from their rooftop PV systems to the utility for up to €1.02/kWh. The purchase price was usually supported by a 1% levy on electricity sales, mostly introduced after a vote among local electricity customers. This support was eventually superseded by the national Renewable Energy Law.

In 1999, a new five year programme was launched to promote the installation of PV on 100,000 German roofs, with a budget of €460 million. The aim was to develop a total generating capacity of 300 MWp. For both private households and businesses the incentive came through a guaranteed ten year low interest loan (1.9% per annum), and with no repayments in the first two years. Such loans were considered a proven method of avoiding PV's currently high start-up investment costs.

Although initial reaction to the '100,000 Roofs' programme was disappointing, the new Renewable Energy Law (REL) introduced in April 2000 accelerated the market dramatically. Under the REL, anyone who installed a solar generation system received a buy-back rate of €0.5 per kWh over 20 years. This payment then reduced by 5% each year from 2001 onwards for newly installed systems, a fall intended to mirror the anticipated reduction in the price of PV.

This combination of the solar roof programme and the REL has proved a potent mix. Such was the overwhelming response that the 2000 PV loans budget of €92 million was already used up by the almost 4,000 applications approved during the first quarter of the year. Thousands more applications had to be postponed due to lack of funds. During 2000 alone more than 8,000 systems were approved, with a total capacity of 41.66 MW. The average size also increased to 5.18 kWp, with over 100 plants in the 50 to 120 kWp range – a sign that the market was moving into the business/industrial sector. With the ending of the 100,000 roofs programme the Renewable Energy Law was revised, but it is still possible to receive a low interest rate loan for investment in a PV system, for example under the carbon dioxide abatement programme.

The outcome of the 100,000 roofs programme (1999-2003) with support from the 2000 Renewable Energy Law is impressive:

- 345.5 MWp installed;
- total investment by customers €1.77 billion;
- market volume increase from 12 MWp in 1999 to 130 MWp in 2003;
- PV system price reduction of 20%; and
- investment by the PV industry of €1 billion.

Future prospects

The German government, strongly supported by public opinion, clearly considers PV to be a viable long term option for bulk production of carbon-free power. Public funding of R&D, about €17 million in 2003, is therefore likely to continue. Its focus will be on reducing the costs of solar cell and module production, and improving the efficiency and reliability of systems.

Most importantly, the Renewable Energy Law has provided a secure, medium-term planning base for investment, at the same time helping to move the technology forward from small-scale manufacturing for niche markets to mass production for a broad range of applications. ●

- PV capacity end 2003: 416MWp; and
- Support system: premium price per kWh, financing opportunities from the German Bank for Reconstruction

Security of supplies becoming significant concern for European utilities

Fundamental market forces are still pushing prices up in the European utility sector, but the advent of competition in some markets is constraining price rises overall, according to the latest set of figures from Capgemini's *European Energy Markets Deregulation Observatory*. One conclusion of the *Observatory* is that market fundamentals, particularly the balance between supply and demand, are exerting a stronger influence on prices in a number of markets. Whereas deregulation initiated competition based on price, and therefore resulted in reductions in price, markets are evolving to the point where forces of supply and demand are also beginning to establish prices.

Increased competition in the European utility market was triggered by the auctions of virtual power plants, gas release programmes and continued merger and acquisition activity. This activity allowed incumbent utilities to gain access to physical assets, develop a regional presence and deliver dual gas and electricity offerings, says CapGemini.

Overall, substantial progress on utility market deregulation was seen on two fronts in 2004: the complete opening of the non-residential market and the unbundling of distribution utilities. But, despite this progress, security of supply continues to be a major concern for utilities and regulators. Governments and utilities have launched initiatives to increase infrastructure capacities, notably the building of nuclear reactors in Finland and France and new investments in gas infrastructure projects in the UK.

Colette Lewiner, senior vice president, energy, utilities and chemicals at Capgemini explains: "Real generation capacity margins remained tight in several countries, including new EU joiners. Several initiatives were taken to increase the cross-border capacities and exchanges in Europe. However the electricity exchange levels remained too modest to significantly decrease the threat of new black-outs in the coming years. Wholesale spot electricity prices were increasingly volatile and subject to big price spikes related to events such as changing weather conditions, outages of major power plants or transmission line congestion. As a consequence, the security of electricity and gas supplies in the coming years is becoming a significant concern that deserves proper treatment."

CapGemini's report also found that there has been notable growth in renewable generation, since the last EEMDO was published, particularly of wind power and particularly in Spain and Denmark. Expansion in other countries is more modest, but planning applications indicate that we should see substantial growth in other countries such as the UK.

Other findings include:

- *interconnector activity:* while there has been no significant activity this year the picture is changing rapidly. There are a number of initiatives underway to establish new interconnectors or create additional capacity on existing ones.
- *wholesale markets:* the number of wholesale markets has grown quickly and there are now 11 regulated power exchanges in Europe. However the real issue is that wholesale markets are facing a lack of liquidity. More liquid exchanges would allow a real European electricity market.
- *retail switching:* competition is progressing in all countries and, after July 2004, all EU members have opened to competition their industrial and commercial market. The client's switch rates evolve following the stages of deregulation: when competition begins to develop, consumer awareness grows and mobility rates increase, they could drop as markets mature.

Europe 'should meet' its Kyoto target, but progress is patchy

The European Union will reduce its greenhouse gas emissions by slightly more than required under the Kyoto Protocol, provided that Member States implement all the policies, measures and third-country projects they are planning, and provided that several countries cut emissions by more than they have to. This is according to latest projections compiled by the European Environment Agency (EAA), which show that the 15 pre-2004 EU Member States (the EU-15) should cut their total emissions to 7.7% below 1990 levels by 2010 on the basis of existing domestic policies and measures already being implemented and, more importantly, additional policies and measures currently planned.

Plans by six EU-15 Member States to use credits from emissions-saving projects in third countries, through the Kyoto Protocol's flexible mechanisms, would contribute a further reduction of around 1.1%, taking the total to 8.8%, says the EAA. This is more than the 8% decrease from 1990 levels that the EU-15 has committed itself to achieving by 2008-2012.

Each of the EU-15 countries also has an agreed legally binding target for limiting or cutting its own emissions to ensure the overall 8% reduction is met.

But the projections also show that, at present, Denmark, Italy, Portugal and Spain are on course for above target emissions, some by a wide margin, even with use of the Kyoto mechanisms and additional measures planned. Germany is in danger of slightly exceeding its emission limit on the basis of existing policies and measures.

This means that the EU-15 may reach its 8% reduction target only if the projected failure of these Member States to respect their targets is compensated by others making bigger emission cuts than required, adds the EAA.

Competition in conventional European power 'is a myth'

Effective competition in the European power markets is just a myth: there is no real competition on more than 90% of the EU electricity market. And, unless the current distortions in the emerging internal electricity market are overcome, there will be no effective internal renewable electricity market for renewables to compete in, according to a briefing from EREC, the European Renewable Energy Council.

The briefing rather goes against findings from CapGemini reported above.

"While other players in the conventional European power sector ask for competition amongst renewable energy producers, it should be recalled that effective competition in the more than 90% of the market that is based on conventional electricity is a far cry from reality," said EREC's Oliver Schäfer. ●

Prospects for CO_2 capture and storage

The International Energy Agency's World Energy Outlook reference scenario projects that, based on policies already in place, by 2030 carbon dioxide emissions will have increased by 63% from today's level. Even in the 'world alternative policy' scenario – which analyses the impact of additional mitigation policies up to 2030 – global emissions would increase by 40% on today's level, putting them 62% higher than in 1990. Hence, says the Agency, to avoid substantial increases over the next few decades, stronger actions than those currently being considered by governments must be taken.

One technology option is to capture the carbon dioxide produced from fuel use at major point sources and prevent it from reaching the atmosphere by storing it. Here, in an edited version of the overview of its new publication on the subject, the IEA speculates on the prospects for carbon dioxide capture and storage.

The IEA study shows that carbon dioxide capture and storage (CCS) is a promising emission reduction option with potentially important environmental, economic and energy supply security benefits. But more research and investment into carbon dioxide capture and storage is required. The study highlights the fact that large-scale uptake of capture and storage technologies is probably 10 years off and that, without a major increase in RD&D investment, the technology will not be in place to realise its full potential as an emissions mitigation tool from 2030 onwards.

Carbon dioxide capture and storage (CCS) involves three distinct processes: first, capturing carbon dioxide from the gas streams emitted during electricity production, industrial processes or fuel processing; second, transporting the captured carbon dioxide by pipeline or in tankers; and third storing carbon dioxide underground in deep saline aquifers, depleted oil and gas reservoirs or unmineable coal seams. All three processes have been in use for decades, albeit not with the purpose of storing carbon dioxide. Further development is needed, especially on the capture and storage of carbon dioxide. While pipeline transport is an established technology, the siting of CCS projects can reduce the need for an extensive transportation system. The challenge, cost and environmental impact of such a carbon dioxide pipeline system should not be underestimated.

Current and planned CCS projects

An overview of CCS projects is provided in Table 1. In most carbon dioxide capture demonstration projects, existing technologies are applied; however, various small-scale pilot plants based on new capture technologies are in operation around the world. Only one power plant demonstration project on a megatonne scale has so far been announced: the FutureGen project in the US. This is a coal-fired advanced power plant for cogeneration of electricity and hydrogen. Its construction is planned to start in 2007. Other demonstration projects are planned in Canada, Europe, and Australia.

There are one hundred ongoing and proposed geologic storage projects. Two of these projects deserve special mentioning because of their scale. Storage in deep saline aquifers has been demonstrated in one commercial-scale project, at the Sleipner site in Norway (sub-sea storage). About 1 Mt of carbon dioxide per year has been stored since 1996. This project is important as it proves that storage in aquifers can work in practice. No leakage has so far been detected. Using carbon dioxide to enhance oil recovery and carbon dioxide storage underground have been demonstrated at the Weyburn project in Canada. About 2 Mt of carbon dioxide per year has been stored since 2001. In both projects the behaviour of the carbon dioxide underground has corresponded to what models had predicted, and important progress was achieved in the monitoring of carbon dioxide underground.

Pilot projects suggest that carbon dioxide-enhanced coalbed methane (ECBM) and enhanced gas recovery (EGR) may be viable but the experience so far is not sufficient to consider these two as proven options. Encouraged by these promising results, many more storage demonstration projects have been started or are planned.

In principle, carbon dioxide can be captured from all installations used to combust fossil fuels and biomass, provided that the scale of the emissions source is large enough. In practice, only three areas are suitable: electricity generation (including district heating and industrial CHP generation), industrial processes, and fuels processing. Emissions from other sources – such as the transport, agriculture, service and residential sectors – are too dispersed to make capture viable. Alternative measures, such as enhancing energy efficiency, renewables, CHP and increased use of hydrogen produced at centralised facilities fitted with carbon dioxide capture technology, may be better options for these sectors.

Since power production is responsible for over 29% of global carbon dioxide emissions, capturing from electricity plants offers the best initial potential for capturing the carbon dioxide generated from fossil-fuel use. To a lesser extent, carbon dioxide can also be captured during the production of iron, steel, cement, chemicals and pulp, and from oil refining,

Type of project	Number of projects
Carbon dioxide capture demonstration	11
Carbon dioxide capture R&D	35
Geologic storage	26
Geologic storage R&D	74
Ocean storage R&D	9

Table 1: Overview of worldwide CCS projects

natural gas processing and the production of synthetic fuels (such as hydrogen and liquid transportation fuels from natural gas, coal or biomass).

Which capture technologies are most promising?

Carbon dioxide can be captured either before or after combustion using a range of existing and emerging technologies. In conventional processes, carbon dioxide is captured from the flue gases produced during combustion (post-combustion capture). It is also possible to convert the hydrocarbon fuel into carbon dioxide and hydrogen, remove the carbon dioxide from the fuel gas and combust the hydrogen (pre-combustion capture).

In pre-combustion, physical absorption of carbon dioxide is the most promising capture option. In post-combustion capture, options include processes based on chemical absorption or oxyfueling (combustion using oxygen separated from air, which generates nearly pure carbon dioxide flue gas). Chemical and physical absorption are proven technologies. Longer-term, gas separation membranes and other new technologies may be used for both pre- and post-combustion capture.

In electricity generation, carbon dioxide capture is most effective when used in combination with large-scale, high-efficiency power plants. Indeed, the success of a CCS strategy could depend on the use of such plants. For coal-fired plants, integrated gasification combined cycle (IGCC) fitted with physical absorption technology to capture carbon dioxide at the pre-combustion stage is considered to be promising. Coal-fired ultra supercritical steam cycles (USCSC) fitted with post-combustion capture technologies or various types of oxyfueling technology (including chemical looping, where the oxygen is supplied through a chemical reaction), may emerge as alternatives. For natural gas-fired plants, oxyfueling (including chemical looping), pre-combustion gas shifting and physical absorption in combination with hydrogen turbines, or post-combustion chemical absorption are promising options.

At a later stage, fuel cells may be integrated into high-efficiency coal- and gas-fired power plants fitted with CCS. Capturing carbon dioxide from plants which cogenerate electricity and synthetic fuels could have additional cost savings compared to stand-alone power production with carbon dioxide capture.

Advances in capture technology are needed to reduce the cost of carbon dioxide capture from power generation. Given the range of ongoing R&D efforts, it is not yet possible to pick a 'winning' capture technology. It is likely that several will be used in future. All require further improvements to cut costs and improve capture efficiency before they can be applied on a commercial scale, a process which is likely to take years. RD&D must be accelerated if CCS is to play a substantial role in the coming decades and have a significant impact on emissions.

How much carbon dioxide storage capacity is available?

Deep saline aquifers, depleted oil and gas reservoirs and unmineable coal seams offer the best option for underground carbon dioxide storage. This includes subsea reservoirs. Oceanic storage (i.e., carbon dioxide storage in the water column) is problematic given the unknown environmental impacts. Surface mineralisation is still at a conceptual stage.

In underground reservoirs, carbon dioxide is stored as a bubble under an impermeable caprock at a depth of more than 800 m, in the top part of a water-filled reservoir rock. Deep saline aquifers offer potentially decades or hundreds of years' worth of storage capacity with between 1,000 and 10,000 Gt of capacity available, possibly even more. This is the single most important underground storage potential. Around 920 Gt of carbon dioxide could be stored in depleted oil and gas fields. The storage capacity of unmineable coal seams, where carbon dioxide is absorbed on the coal surface, is an order of magnitude smaller. While the absolute value of the potentials are uncertain as of yet, it is clear that they are large. Carbon dioxide storage may be combined with enhanced oil recovery (EOR), enhanced coalbed methane recovery (ECBM), and enhanced gas recovery (EGR). Such combinations could create revenues that may offset part or even all of the capture and transportation cost.

Many storage sites are far from large emission sources. Coupled with the fact that long-range intercontinental transportation of carbon dioxide would incur significant additional cost, this means that the economic storage potential is country and region specific and smaller than the total geologic storage potential. However, in most world regions storage capacities do not pose a constraint for widespread CCS use for decades to come.

What is the risk of leakage back into the atmosphere?

All three storage options – deep saline aquifers, depleted oil and gas reserves and unmineable coal seams – need more proof on a large scale. The technology to store carbon dioxide underground should be considered proven technology. The problem is whether the carbon dioxide will leak from underground storage sites back into the atmosphere. The leakage discussion can be split into two parts: the question to what extent leakage can reduce the emissions reduction effectiveness of CCS, and public concerns that carbon dioxide leakage can be dangerous.

Small leakages of carbon dioxide may occur over a long period of time, which could reduce the effectiveness of CCS as an emission mitigation option. This so-called permanence problem is currently dealt with through field tests and through modelling studies. Depleted oil and gas fields have contained hydrocarbons for millions of years. This makes them a relatively safe place to store carbon dioxide. The problem for such reservoirs is mainly if the extraction activity has created leakage pathways, and if abandoned boreholes can be plugged properly so the carbon dioxide cannot escape.

The only existing large-scale aquifer storage demonstration project has shown no leakage since it started eight years ago. Many projects for natural gas storage and acid gas storage have worked well. Progress in modelling allows increasingly accurate forecasts of the long-term fate of the carbon dioxide, which cannot be tested in practice. Several natural phenomena, such as carbon dioxide dissolution in the aquifer water, will reduce the long-term risk of leakage. The understanding of these phenomena is improving gradually.

Carbon dioxide is not toxic, but it can be dangerous in high concentrations as it can cause suffocation due to lack of oxygen. Accidents where significant amounts of carbon dioxide are released from underground reservoirs, with potential risk for local residents, are highly unlikely. The storage under more than 800 m of sediment excludes sudden eruptions of massive amounts of carbon dioxide. However, there are cases where natural carbon dioxide emissions from underground have created locally dangerous situations. Proper carbon dioxide monitoring systems and remediation measures can prevent such problems.

While the RD&D results are encouraging, more pilot projects are needed to better understand and validate the permanence of underground storage in various geological formations and develop criteria to rank appropriate sites. Too strict

criteria for leakage could unnecessarily reduce the potential for aquifer storage.

What is the cost of CCS?

The future cost of capturing, transporting and storing carbon dioxide depends on which capture technologies are used, how they are applied, how far costs fall as a result of RD&D (innovation) and market uptake (learning-by-doing), and fuel prices. Since applying capture requires more energy use and leads to production of more carbon dioxide, the cost per tonne of carbon dioxide emission mitigation is higher than the per tonne cost of capturing and storing carbon dioxide. The gap between the two narrows as capture energy efficiency increases.

At this stage, the total cost of CCS could range from US$50 to $100 per tonne of carbon dioxide. This could drop significantly in future. In most cases, using CCS would cost $25–50 per tonne of carbon dioxide by 2030, compared to the same process without. Certain early opportunities exist with substantially lower cost, but their potential is limited.

The cost for CCS can be split into cost of capture, transportation and storage. Current estimates for large-scale capture systems (including carbon dioxide pressurisation, excluding transportation and storage) are $25–50 per tonne of carbon dioxide but are expected to improve as the technology is developed and deployed. If future efficiency gains are taken into account, costs could fall to $10–25/t carbon dioxide for coal-fired plants and to $25–30/t carbon dioxide for gas-fired plants over the next 25 years.

With carbon dioxide transportation, pipeline costs depend strongly on the volumes being transported and, to a lesser extent, on the distances involved. Large-scale pipeline transportation costs range from $1–5/t carbon dioxide per 100 km. If carbon dioxide is shipped over long distances rather than transported in pipelines, the cost falls to around $15–25/t carbon dioxide for a distance of 5,000 km.

The cost of carbon dioxide storage depends on the site, its location and method of injection chosen. In general, at around $1–2 per tonne of carbon dioxide, storage costs are marginal compared to capture and transportation costs. Revenues from using carbon dioxide to enhance oil production (EOR) could be substantial (up to $55/t carbon dioxide), and enable the cost of CCS to be offset. However, such potential is highly site specific and would not apply to most CCS projects. Longer-term costs for monitoring and verification of storage sites are of secondary importance.

Using CCS with new coal- and gas-fired power plants would increase electricity production costs by 2-3 cents/kWh. By 2030, CCS cost could fall to 1-2 cents per kWh (including capture, transportation and storage).

The relevance of CCS differs by region. Model analysis suggests that CCS can become an important option in North America, Australia and parts of Europe. While the CCS potentials in China and India are important as well, the realisation of these potentials will depend on the extent of global efforts to reduce carbon dioxide emissions. If carbon dioxide policies are limited to industrialized countries, the role of CCS is significantly reduced on a global scale. This finding emphasises the importance of technology transfer and international co-operation on both technology and policy.

Given that long-range transportation of carbon dioxide seems an unlikely option due to its high cost, for countries without sufficient storage potential close to their emission sources, it may be more cost effective to consider alternative emission reduction strategies. While having CCS in a carbon dioxide policy portfolio is certainly attractive, the issue of its application will require a careful case-by-case project evaluation. This evaluation must account for the energy system characteristics on the continental, the country and the local scale.

What will it take to bring CCS to market?

There is a 'window of opportunity' for CCS to compete as a technology option, starting from around 2020 and peaking in the second half of the 21st century. Beyond that, carbon dioxide-free alternatives would make CCS redundant. In other words, CCS should be considered an essential 'transition technology' to a sustainable energy system for the next 50 to 100 years.

The single most important hurdle which CCS must overcome is public acceptance of storing carbon dioxide underground. Unless it can be proven that carbon dioxide can be permanently and safely stored over the long term, the option will be untenable, whatever its additional benefits.

The potential for 2030 is two to three orders of magnitude greater than the projected Mt-scale demonstration projects for 2015. This indicates the need for significantly increasing both investment in RD&D and the scope of projects, if a CCS strategy is to succeed. Taken together, all the planned CCS projects in the coming decade will barely reach the 10 Mt per year scale. If the full emission mitigation potential of CCS is to be realised, RD&D activities need to be scaled up and accelerated significantly.

Achieving this will require increasing the number of commercial scale storage pilot projects over the next 10 years and ensuring that the general public is consulted throughout. RD&D should initially focus on storage projects which enhance fossil-fuel production and those which advance knowledge on sub-sea underground storage, and aquifer storage in locations with low population density, in order to minimise planning hurdles. Processes which consult, review, comment and address stakeholder concerns should be built into all pilot projects. Procedures for independently verifying and monitoring storage and related activities should also be established. Finally, a regulatory and legal framework for carbon dioxide storage projects must be developed to address issues around liability, licensing, leakage, landowner, royalty and citizens rights.

Governments must address the present shortage of sizeable RD&D projects in order to advance technological understanding, increase efficiency and drive down costs. This will require increasing RD&D, investment into CCS demonstration projects, and power-plant efficiency improvements. By 2015 at least 10 major power plants fitted with capture technology need to be operating. These plants would cost between $500 million and $1 billion each, half of which would be additional cost for CCS. The current CCS budget is over $100 million per year. The needed RD&D would represent a fivefold increase. While the amount required is challenging, it is not insurmountable given the scale of past energy RD&D budgets. It would represent a 30% increase of the current total RD&D budget for fossil fuels and power and storage technologies. Leveraging the funds in private/public partnerships is essential.

Creation of an enabling environment to ensure technology development must be accompanied by the simultaneous development of legal and regulatory frameworks. In the interests of time, and given the diversity of institutional arrangements and policy processes between countries, working at the national level using existing frameworks may be the best short-term option.

Finally, countries should create a level-playing field for CCS alongside other climate change mitigation technologies. This includes ensuring that various climate change mitigation instruments, including market-oriented trading schemes, are adapted to include CCS. The future role of CCS depends critically on sufficiently ambitious carbon dioxide policies in non-OECD countries. Therefore, outreach programmes to developing countries and transition economies and international commitment to reduce carbon dioxide emissions are a prerequisite. The maturation of a global emissions-trading scheme, a meaningful price for carbon dioxide and a predictable return on investment are important factors that could stimulate the timely deployment of CCS.

Copies of the full IEA report: *Prospects for CO_2 capture and storage* are available at the IEA online bookshop at **www.iea.org**

Energy recovery alternative to landfill

New gasification-based technology from ENER.G Natural Power can help to both cut the use of fossil fuels and provide an alternative waste disposal option, writes Nick Dawber, *managing director of the company.*

Based in Norway, ENERGOS, the ENER.G Group's specialist in gasification technology has successfully developed an advanced conversion technology for the recovery of energy from pre-sorted household and other wastes, as defined under the UK's Renewable Obligation Order. The process involves the gasification of the waste derived fuel and is characterised by its low emissions and high rate of energy recovery.

The technology has already been proven commercially with the construction and operation of six plants around Europe. Together, these plants have accumulated over 100,000 hours of operational experience.

The technology could be of crucial importance for local authorities as plants are sized for local communities, converting between 30,000 and 80,000 tonnes of post recycled waste residue per year into green electricity and/or heat – delivered for local use. In combination with a local recycling facility, the ENERGOS plant receives only waste that cannot be effectively recycled and which would otherwise go to landfill.

The small-scale plants offer a number of benefits:

- the small size of the building (1,500–2,300m^2) is designed to minimise visual impact;
- transport of waste is minimized – because the energy-from-waste plant is sited adjacent to an existing local authority recycling facility; and
- inherently low emissions – at a fraction of EU permitted levels (thanks to the patented technology and advanced control of the two-stage process).

Energy is recovered from pre-sorted household and other wastes through ENERGOS' patented design for the thermal conversion of waste, controlled by proprietary software. This thermal conversion process reduces the need to invest in high-cost flue gas cleaning systems.

Commissioned in 2002, the Forus waste-to-energy plant in Norway turns up to 38,000 tonnes of wastes into 100 GWh of thermal energy per year

The two-stage thermal treatment process comprises gasification and high temperature oxidation. This converts local waste streams into thermal energy for process steam, district heating, and/or electricity generation.

The design makes it possible to achieve simultaneously:

- low carbon content in slag (less than 3% TOC);
- CO stability at a low level;
- a high degree of cracking of organic substances;
- low and stable NOx emissions; and
- qualification as renewable energy in UK.

Fuel used in the plant is pre-treated waste. The required pre-treatment consists of shredding to ensure a sufficiently high surface-to-volume ratio, as well as separation of ferrous metals. The plant is equipped with a fuel bunker.

Fuel is delivered to the energy plant by trucks in closed containers and unloaded in the fuel bunker. The bunker hall is operated slightly below atmospheric pressure (to reduce the risk of odour), by drawing air through the reception area into the thermal process. Fuel is unloaded from the fuel bunker by use of an overhead crane and delivered to the thermal conversion unit.

The drying, pyrolysis and gasification of the pre-treated waste is carried out in the plant's primary chamber under substoichiometric conditions. High temperature oxidation of syngas delivered from the primary chamber takes place in the secondary chamber, where secondary air and re-circulated flue-gas is added at several additional points in order to achieve the right temperature trajectory. The primary chamber is equipped with a fixed horizontal oil-cooled grate that is divided into several separate sections, each with a separate primary air supply.

The bottom ash is discharged from the primary chamber at the end of the grate. The discharged bottom ash (now at less than 3% TOC) is cooled in a water-basin and transported to a suitable landfill site at regular intervals.

The syngas generated in the primary chamber is transferred to a separate secondary chamber where final high-temperature oxidation takes place. Recovered energy is then converted into hot water or steam and the flue gas is passed through a dry flue gas cleaning system with injection of lime and active carbon.

Six purpose-built energy-from-waste plants, incorporating this technology, are already in operation across Scandinavia and Germany. One of these plants is the Hurum Plant in Norway, which was successfully commissioned in 2001 and is currently achieving a fuel capacity of 36,000 tonnes per year, with an energy production rate of 90 GWh (thermal) per year. ●

Contact ENER.G at **www.energ.co.uk**

Towards an effective motor management policy

The humble electric motor is responsible for two-thirds of the electricity bill of an average industrial plant. Too easily taken for granted, this workhorse of industry could save money in a number of ways. A company that prides itself on knowing where to buy motors cheaply and quickly may be surprised to find that focusing on price alone could be costing more in running expenses than they are saving in capital costs. The Carbon Trust offers advice.

While the principles of motor operation have not changed over the years, advances in materials, computer-aided design and manufacturing capability mean that today's motors are smaller, cheaper and more efficient than earlier models. Motors are now available 'off the shelf' with efficiencies exceeding 95% (ie they lose only 5% of the energy they consume as heat, friction, etc). Consider a 55 kW motor that is only 2% less efficient than the best in class. It will lose an extra 1 kW of energy – that is a lot of heat to dissipate and is likely to cost a further £250 or more in running costs each year and over £2,500 during the motor's ten-year lifetime. Multiplying this saving across all the motors in a plant would lead to significant financial benefits that go straight to the bottom line.

Rather than shopping around to save a few tens of pounds on the purchase price of a motor, experienced buyers consider efficiency and life-cycle costs first, and the price second. Fortunately identifying high efficiency motors is easy. The European motor efficiency classification scheme designates motors as one of three classes – EFF1, EFF2 and EFF3. EFF2 motors are normally the default standard offered to industry, but EFF1 is the best. (When purchased as part of a capital investment, companies may be able to claim an Enhanced Capital Allowance on EFF1 rated motors – for more information, visit **www.eca.gov.uk**).

EFF3 motors are the least efficient, but they have largely been phased out. Purchasers should be careful to specify EFF1 motors – the small premium charged for such motors is usually recouped within the first year of operation.

Always specify EFF1 motors, even in equipment that comes with an integral motor

Because EFF1 motors have lower energy losses, they will run cooler and should, therefore, last longer before requiring maintenance or replacement. Each additional year of life reduces the effective annual cost of a motor.

A well maintained motor should last for ten years or more, although it could need bearings changed or to be rewound during this period. Changing the bearings is a sim-

Motor size (kW)	New motor cost (£)	Rewind cost (£)	Running cost of EFF1 motor (£/year)	Running cost after rewind (£/year)	Cost differential after one year (£)	Rewind or replace?
5.5	260	400	1,249	1,307	199	Replace
11	490	600	2,448	2,531	193	Replace
22	850	800	4,811	4,945	83	Replace
30	1,100	950	6,518	6,698	30	Replace
55	2,240	2,000	11,823	12,080	16	Replace
75	2,850	2,200	16,037	16,383	–304	Rewind
110	5,100	3,500	23,423	23,926	–1,097	Rewind

Example based on electricity cost of 4.5 pence/kWh, motor duty of 6,000 hours/year at 75% load, and a loss of efficiency of 1% following rewind. This table is an example only, the costs and hence payback will vary from site to site.

Table 1. Examples of rewind versus replacement costs

Effect of unplanned breakdown	Related energy cost
Start-up losses	A lot of energy is lost during the warm up time of high temperature processes.
Alternative methods for regaining production used	Less efficient methods of production may be used (eg use of older equipment or one involving additional transport costs).
Loss of product during warm-up period	Some processes produce product while they are warming up that has to be scrapped.
Energy used in part-processing the product is lost	Considerable energy may have been expended in adding value to the product; this energy will be wasted.
Disposal of damaged product	There may be energy costs involved in the handling, treatment and disposal of scrap product.
Rework costs	Additional energy used in reworking spoiled product.

Table 2. Hidden energy costs of motor failure

ple operation for trained personnel and should not affect the motor's performance. Rewinding the motor is a more difficult operation, and a poor-quality repair has major implications for efficiency and motor life. Getting it right should keep any reduction in efficiency to 0.5% or less, but getting it wrong could mean that the efficiency falls by 2% or more. Therefore, it is important to use a high quality repair shop.

When a motor fails and an equivalent replacement is available 'off the shelf', it is often easier to buy this replacement. But now may be the time to replace it with an EFF1 motor – and hence gain the benefits of this more efficient motor for just the relatively small capital cost premium (a new motor is being purchased anyhow).

An EFF1 motor could be 3% more efficient than the old motor, which will lose, say, 0.5% in efficiency after rewinding. The net gain of 3.5% from replacement rather than repair becomes financially attractive. The actual cost savings will depend on the running hours and the motor load. With knowledge of the costs of buying new motors and repairing failed ones, it is possible to create a simple spreadsheet as shown in Table 1. This can be used to determine whether it makes sense to replace or repair a motor. Many companies are surprised to find that it makes more sense to replace all failed motors rated up to 55 kW, but it all depends on the circumstances at individual sites.

Use a quality motor repair shop and devise a policy on failed motors

Motor failure offers the opportunity to save energy by fitting a new and more efficient model. But how much lost production and expensive downtime could be prevented if it could be predicted when a motor was going to fail? The failure of a critical motor in a steel works could cost £250,000, while that in the glass industry over £150,000. The cost of such an occurrence in an average plant will be much lower, but still sufficient for an expected motor failure to be given high priority.

Machine operators are often good at reporting when a motor 'doesn't sound or feel right'. However, condition monitoring techniques that give advance warning of all but a few random failures offer a more methodological approach. Companies that undertake periodic condition monitoring of critical motors report that it is highly cost-effective and reduces the uncertainty in their operations.

Monitor important motors to avoid the costs of unexpected failure

Table 2 lists some of the energy costs associated with unplanned breakdowns. A comprehensive policy on motor management would help to minimise the energy and production costs relating to motor failure. All sizes and types of company can benefit from thinking about the priorities and then devising a suitable approach. It is not necessary to do everything in-house – motor suppliers, repairers and condition monitoring specialists can help. It is recommended that, within a company, everyone concerned with motors is consulted – they may have useful ideas to contribute and the success of the policy will depend on their commitment.

On an average industrial site, the potential energy savings from electric motors and the systems they power are greater than most other sources of energy savings put together. The modern motor may be quiet, reliable and actually quite efficient, but it should not be overlooked when searching for energy savings.

The Carbon Trust offers free advice and support on how to achieve energy efficiency in motor-driven systems.

Call the Helpline on 0800 585794 or visit the Carbon Trust's website at **www.thecarbontrust.co.uk/energy**

EfW operator saves £90,000 a year

Renewable energy producer SITA UK Ltd is saving electricity worth over £90,000 of a year at its Teesside facility, thanks to the installation of motor control equipment from Telemecanique, a brand of Schneider Electric.

A routine production project being undertaken by PPT Drive Systems Limited, one of Schneider's partners, revealed that large centrifugal fans used in the power generation process were running continuously at full duty with air flow being controlled by mechanical vane dampers. SITA Tees Valley agreed to PPT completing a free energy audit to make recommendations for energy savings. PPT developed a model, using six Telemecanique AC sensorless flux vector inverters from 30 kW to 110 kW. The model showed a possible reduction in energy consumption from 320 kW to just 50 kW.

PPT Drive Systems was able to complete the installation within three days, which comfortably fitted the timescale for one of the plant's annual week-long shut downs.

Although the SITA Tees Valley site is 50% exempted from the effects of the Climate Change Levy, the installation still qualifies for the Government's Enhanced Capital Allowance scheme. The bottom line is that payback on the drives installation was less than six months, even before any capital allowances.

Contact Schneider Electric at **www. schneider.co.uk**

SITA's energy-from-waste site at Tees Valley

Car mirror maker cracks noise and energy

A plant modification at automotive mirror maker Flabeg in Birmingham to reduce noise has also led to a 65% reduction in energy consumption, which will recoup the capital outlay in 12–14 months.

Flabeg, whose mirrors are fitted to most of the leading makes of car including BMW, Ford, Porsche, Toyota, VW, Jaguar, Nissan, and Audi buys in plain flat glass and its manufacturing process ends with drying mirrors with an air knife.

The air knife was incredibly noisy. Some years ago it was enclosed to reduce the noise but it was still emitting 91 DB(A), loud enough to make ear defenders obligatory.

The suggestion from Mitsubishi Electric was to fit an inverter to slow down the fan, which would reduce the noise and had the attractive extra benefit of reducing power consumption. The inverter chosen was Mitsubishi's F700 model, which has been developed specifically to improve energy saving performance compared to other inverters.

There was an immediate cut in noise, down to 81DB(A).

Flabeg has at least three other air knifes on site where it will be replicating the success, and its sister plant in Germany also plans to follow the lead.

Contact Mitsubishi Electric at **www.industrial.meuk.co.uk**

Air knife used to dry new mirrors

District cooling and thermal storage to cut energy costs at Heathrow's Terminal 5

Heathrow's heavily-serviced new Terminal 5 building will benefit from a state-of-the-art district cooling system and thermal store designed by Parsons Brinckerhoff Ltd after a careful comparison of alternative cooling solutions. Here, PB's Paul Woods *explains how it will work and what it will deliver in terms of energy efficiency.*

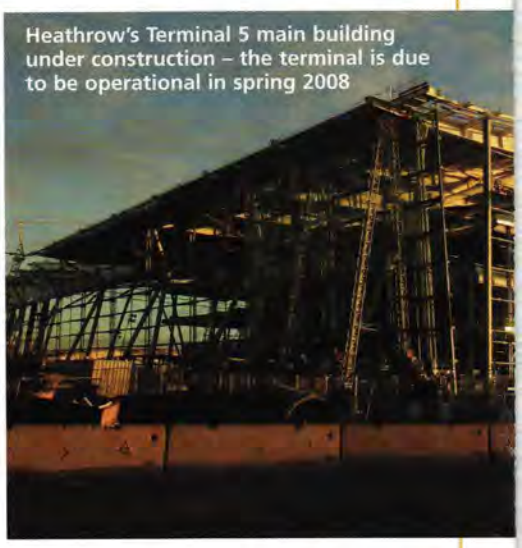
Terminal 5 at Heathrow is designed for a capacity of 30 million passengers a year, making it equivalent to a major international airport (Gatwick handles 27 million). The terminal building has a large floor area with substantial internal spaces. This floor plan, combined with the harsh environment of an airport, means that a sealed building with mechanical cooling is essential. There are high internal heat gains from people, lighting and equipment such as baggage-handling machinery. In addition to the main building, there is a second satellite terminal building and a hotel, as well as several smaller buildings for support activities. The total peak cooling demand for the campus was estimated at around 30 MW.

BAA had set a tough energy target for the development and the efficiency of the chiller system was an important factor in achieving this goal. Measures were also taken to reduce cooling demands within the building, such as improved lighting control and control of fresh air rates according to occupancy levels in the building.

PB's initial designs of the cooling system compared distributed and centralised cooling. The centralised option was selected and a new energy centre is currently under construction as a separate building just to the south of the main terminal building. This article describes the development of the design of the centralised chiller plant and the chilled water distribution network which together demonstrate the concept and benefits of large-scale or district cooling.

Chiller plant

PB's design team evaluated a number of refrigeration systems by calculating the 'total equivalent warming impact' (TEWI). This takes account of the global warming emissions associated with both the energy used to drive the chillers and also the emissions from refrigerant leakage.



Heathrow's Terminal 5 main building under construction – the terminal is due to be operational in spring 2008

The analysis revealed that the indirect production of carbon dioxide from electricity consumption was the main influence in determining the total warming impact. The solution with the lowest TWEI was to use screw compressors utilising ammonia (R717) refrigerant. Ammonia has the advantage of having zero global warming potential if a leak occurs.

One of the options considered used chillers with twin compressors, which not only improved the system resilience, but also resulted in excellent part-load performance. Typical coefficients of performance (CoPs) quoted are shown in Figure 1. This performance is due to the machines being able to run one compressor against a condenser and evaporator heat exchange area designed for two compressors. Utilising the compressor economiser connection has increased full-load performance. Each compressor is driven by an 11 kV motor which is directly energised from the main electricity incomer. The high voltage motors have eliminated costly transformers and their associated electrical losses.

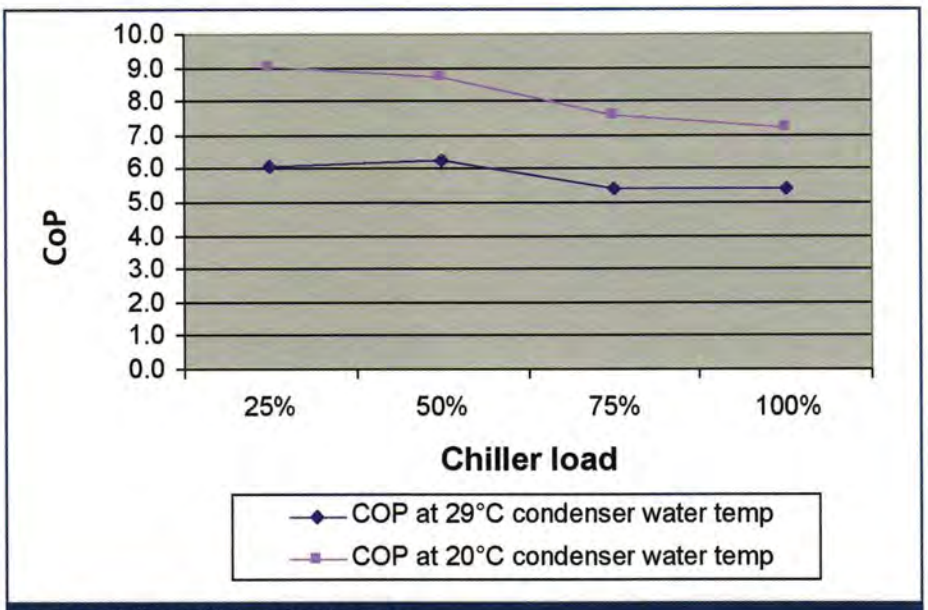


Figure 1: Chiller coefficient of performance

For most of the year, the chillers will run at part load and the external wet bulb temperature will be lower than design, giving lower condenser temperatures than under design conditions. In more average weather and during part-load operation, a CoP of about 7 to 8 can be achieved.

Evaporative cooling towers have been used which can produce the lowest condenser water temperature and hence a higher chiller CoP. Cooling towers are more suited to a central system where good maintenance regimes can be established.

A free cooling system has been installed so that up to 4.8 MW of cooling is achieved by using the cooling tower water to pre-cool the chilled water return through a plate heat exchanger. The design of the system ensures the lowest practical cooling tower water temperatures by isolating a number of cooling towers from those rejecting heat from the condenser water system. This system will be used to meet cooling demands in winter and at night.

Hydraulic design of district cooling network

The energy centre includes the pumps to distribute the chilled water around the campus. The hydraulic design investigated the pump head requirements, system temperature differential and system control philosophy.

In order to optimise the pumping design the central facility was located as near as practical to the chilled water users. There were two distinctive groups of buildings: the main terminal building, which is closest to the energy centre, and the satellite buildings further away. The distribution system was therefore split into two pumped circuits depending on the required pumping head. The resulting design consists of a low-head circuit for the main terminal building, and a high-head circuit to supply the satellite buildings at the extremes of the network. The two circuits ensure that the distribution pumps only generate the pressure head required, with a consequent reduction in electricity use.

The main disadvantage of a centralised chiller system is the capital cost of the chilled water distribution pipe network. The main determinant of cost is the volume of water to be supplied, which is calculated from the temperature difference between flow and return. This system temperature differential was optimised by avoiding heat exchangers in the system and by specifying air handling unit cooling coils with relatively high return temperatures. The additional cost for greater air handling unit heat exchange area was offset by reduced network pipe sizes and pumping energy due to lower system flow rates. The chilled water system design temperature differential is 5.5°C flow and 14°C return.

A further design optimisation involved determining the optimum pipe sizes that minimised, on a life cycle cost basis, the capital cost, pumping energy cost and heat gain cost.

The variable volume controls and variable speed drives result in a reduction in the energy consumption of the distribution pumps. Base load pumps have been installed, sized for both reduced flow rates and also correspondingly lower heads. This has ensured that high flow and head pumps are not operated at a reduced efficiency during periods of low demand. Volume flow rate is controlled to maintain a fixed differential pressure at the network index points.

Thermal energy storage

The production of chilled water at the airport is primarily for comfort cooling. Passenger numbers and ambient weather conditions determine the chilled water demand. This results in highly variable annual and daily profiles. The high peak demands only occur for a few hours on the hottest days of the year. A number of different thermal storage technologies were investigated to determine if storage could achieve the following:

- reduction in installed chiller capacity;
- reduction in energy consumption; and
- reduced operating costs by producing cooling at night.

Both chilled water and ice storage were evaluated. The analysis showed that the higher pressure differential across the compressors caused by the lower evaporating temperatures needed to make ice increased energy consumption. Although a chilled water store needs substantially more volume for the same energy storage effect, chilled water was preferred on energy efficiency grounds.

As a result of the analysis a chilled water store has been incorporated into the district cooling system. The storage facility has the following modes of operation: demand levelling – to reduce operating costs by generating chilled water at night; and peak lopping – to ensure peak demand can be met (as the installed chiller capacity is less than the peak demand).

For the majority of the year the store operates in the demand levelling mode. This allows some of the production of chilled water to be moved from the day period to the night period when electricity prices are lower. The lower night ambient temperatures result in a lower condenser water temperature. This offers two energy efficiency advantages: an increased chiller CoP and the opportunity to make more use of the free cooling system. The potential to manage electrical demand will also be beneficial when negotiating electricity prices with suppliers.

By varying the rate of storing or discharging energy the load on the chiller can be managed, reducing the number of starts and optimising further the CoP.

During periods of high demand the store operates in the peak-lopping mode. Chilled water is discharged from the store when the demand exceeds the capacity of the chillers. The peak-lopping mode has resulted in the installed chiller and heat rejection capacity being reduced by 4.4 MW, and the consequent cost saving was sufficient to pay for the store.

In summary the store offers five benefits:

- reduced chiller capacity and associated heat rejection and power supply capacity;
- generating cooling at night leading to lower electricity costs;
- higher CoP whilst operating at night with lower condenser water temperatures;
- increased utilisation of the free cooling system; and

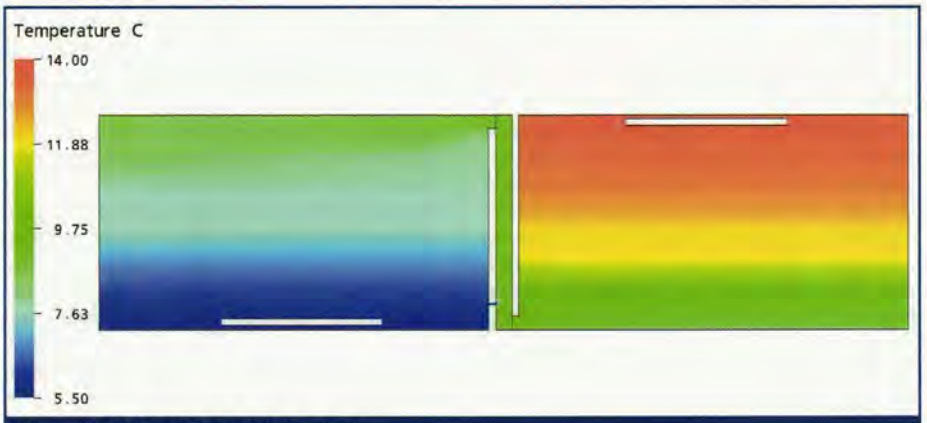


Figure 2: CFD model graphical output

- load management to maximise chiller efficiency.

Detailed design of the store

The chilled water store consists of a 3,600m³ buried concrete tank that operates at atmospheric pressure.

A computational fluid dynamics (CFD) software package (CFX 5.5) was used to determine the optimal design of diffusers within the store, and to determine the maximum storage capacity and discharge rates. Figure 2 shows the graphical output from the CFD model: a cross section through the store with water temperature represented by different colours.

The diffusers are designed to produce low water velocities to minimise mixing of the water during charging and discharging. This design has encouraged thermal stratification of the water to increase the useful stored energy. The CFD modelling showed that the addition of a baffle wall to partition the tank maximised the useful energy storage to 22,000 kWh(th). Figure 3 shows the relationship of store discharge temperature against time with and without the baffle wall.

Safety issues with ammonia refrigerant

Specifying ammonia refrigerant has resulted in additional expenditure for ammonia leak detection and extract ventilation systems. The controlled environment of a centralised facility has enabled the cost-effective implementation of these systems. The installed safety systems have been specified to protect both the public and operators in the event of an ammonia release.

To reduce the potential risk, the refrigerant charge has been kept to a minimum by specifying plate heat exchangers for both evaporators and condensers. Specifying direct expansion machines can further reduce the charge of refrigerant. However, in this application flooded evaporators with surge drums were specified as the additional superheat required for direct expansion compromised efficiency. The installed machines have a refrigerant charge of 0.15 kg of ammonia per kW of chilling.

In accordance with European standards each chiller is located within a dedicated special machinery room. An ammonia leak detection system is installed within each room to activate an extract ventilation system, and to isolate the room from any electrical supplies that could provide a source of ignition. Electrical panels are all located outside the chiller room. This compartmentation of chillers enables the remaining machines to continue to operate even if one is leaking ammonia. The extract system is designed such that in the event of a 'worst case' liquid release the concentration of ammonia within the room will not exceed 25% of the lower flammability limit (37,000 ppm).

The requirement of an ammonia scrubber has been avoided by designing fresh air dilution into the extract system. The fresh air dilution ensures that the concentration of ammonia discharging from the extract system is reduced by 75%. Pollution dispersion software was used to establish that this concentration of ammonia discharging from the extract system would not result in a risk to the environment and would not be noticed by the public.

District cooling		Distributed chillers	
MWh(e) per year		MWh(e) per year	
Network pumping	1,173	Local pumping	440
Ammonia screw chillers	12,848	HFC centrifugal chillers	18,823
Wet cooling towers	778	Dry coolers	946
Free cooling	-385	Free cooling	0
Transformer losses	20	Transformer losses	212
TOTAL	**14,434**	**TOTAL**	**20,421**

Table 1. Calculated system electricity consumption

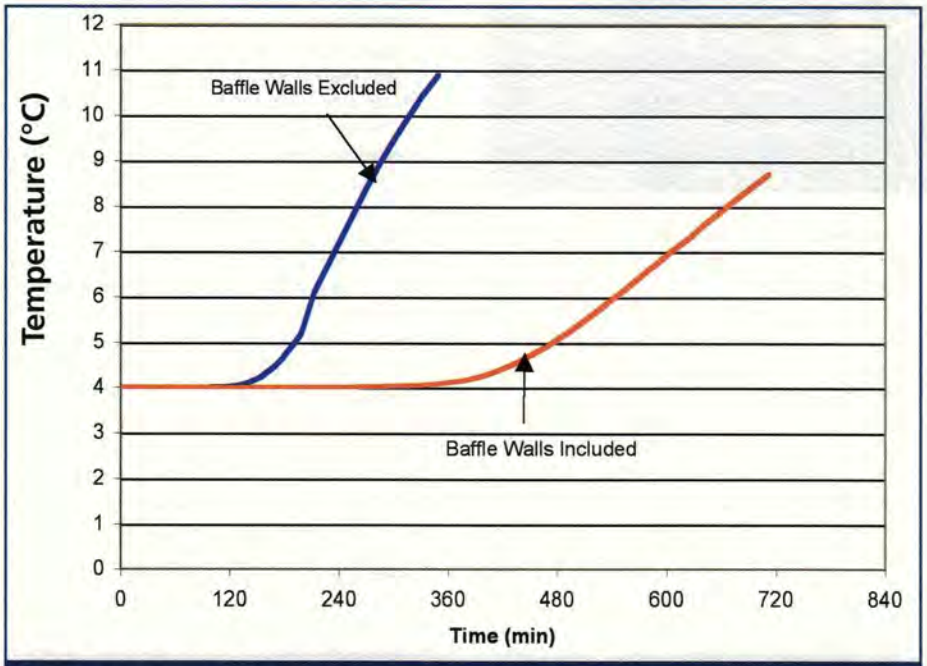


Figure 3: Chilled water discharge temperature

System efficiency

PB's design of the Terminal 5 district cooling system with central chilling facility has resulted in increased system efficiency when compared with a notional distributed cooling system. Table 1 shows the total electricity used for the two systems.

The calculated figures in Table 1 indicate that the district cooling system requires additional pumping energy for the distribution of chilled water. However, this additional energy requirement is more than offset by the increased efficiency of the centralised chiller plant utilising evaporative cooling towers and ammonia refrigerant. The free cooling capability in the district cooling option provides a small additional benefit by removing the requirement for cooling for a small proportion of the year. The loss in efficiency due to electrical transformers has been reduced in the district cooling system by running the chillers at the main incomer voltage, in this case 11 kV. It is expected that the thermal store will also produce further energy savings as well as reducing operating costs.

As illustrated at Terminal 5, the benefits of a district cooling system can be summarised as:

- 30% reduction in electricity use compared to distributed chillers;
- centralised chillers deliver higher efficiencies than smaller local chillers even taking account of energy for chilled water distribution pumping;
- open-circuit evaporative cooling towers, ammonia refrigerant, free cooling and chilled water storage are features that can be included cost-effectively in a centralised facility; and
- the chilled water store reduces chiller capacity and takes advantage of night electricity rates as well as offering some energy efficiency advantage.

In large, high-density commercial building developments where cooling demands are significant there is a case for considering a district cooling system similar to that designed for Terminal 5.

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Adapting buildings for a warming climate

New research commissioned by the DTI analyses the impact of increasingly hot summers on UK buildings and identifies how different types of building can best be adapted. The research was carried out by Arup and is published by CIBSE in a new publication: Climate change and the indoor environment: impacts and adaptation. *By* Dr Jake Hacker *and* Professor Michael Holmes, *both of Arup.*

There is compelling scientific evidence that the climate is changing and it is probable that average temperatures will increase by several degrees over the coming century. These increases in temperature are expected to have a major impact on the indoor environment, especially since even today many buildings are unable cope with hot summer weather. The starting point for the research is the set of 'UKCIP02 Climate Change Scenarios' for the UK, which provides the best currently available scientific projections for UK climate over the coming century.

Key questions are:

- To what extent will climate change increase the occurrence of summertime thermal discomfort and overheating in different types of UK buildings?
- To what extent will passive measures be able to improve summertime thermal comfort and ameliorate the increased tendency for overheating?
- How effective will different approaches to comfort cooling be under the changing climate?
- What are the energy use implications of the various strategies?

Historically most buildings in the UK have relied upon outside air for cooling in summer. This approach is becoming increasingly unreliable for several reasons. First, summer temperatures have increased, particularly since the late 1980s. Second, building usage in offices has changed with increased occupancy levels, longer working hours, use of desktop computers, photocopiers and laser printers and deeper floor plans – factors that have led to greater internal heat loads.

Using UKCIP02, the research studied 13 different types of building, including houses, apartments, offices and schools to determine how well they will cope with higher outside air temperatures. The research went on to outline ways in which those buildings can be adapted to improve comfort levels for people who have to work or live in them. Particular emphasis was given to energy efficient solutions rather than relying on the simple expedient of air conditioning.

The main benefit vis-à-vis energy use is that with less cold weather during the heating season, space heating costs will be reduced accordingly. For example, in the case study of an advanced, naturally-ventilated school, the amount of energy use by the boilers in the 2080s would be about 40% of what it was in the 1980s. Generally, heating energy use would decrease between 25 and 40% for all the types of building studied for the same period.

Although both residential and non-residential buildings are affected, adaptation methods will be particular to each type of building. Even within similar types of building the solutions will differ according to factors such as how the building is used and the preferences of the owners/occupiers. Overall, buildings with the ability to limit unnecessary heat gains (eg from the sun, lighting and electrical equipment) and control ventilation rates will be fare the best. Buildings with high thermal mass will also be less affected and easier to adapt than lightweight structures without the use of mechanical cooling.

A key concern with respect to the internal environment of buildings is the potential for significant increases in building energy use due to mechanical comfort cooling systems. This increased use of mechanical systems will itself hamper efforts to reduce greenhouse gas emissions and limit climate change.

The quantitative dynamic thermal modelling focussed on London and made use of the present-day CIBSE design summer year (1989) and synthetic future years under the UKCIP02 Medium-High climate change scenario. The results for this location and climate change scenario indicate the following:

- For schools, the high internal heat gain from classroom occupants together with the high fresh air ventilation rates required to maintain good air quality mean that, as the external air temperature increases, it becomes increasingly difficult to achieve comfort standards through use of passive systems alone. Even in very well designed passive school buildings, the results suggest that a move to a mixed-mode approach, in which mechanical systems are available at times of peak cooling need, may be warranted.
- For offices, a range of buildings have been considered. As for school buildings, the modelling suggests it would be difficult as the climate warms to meet present day comfort expectations in offices by adopting a purely passive approach, again suggesting that the mixed mode approach may provide the most practical way forward.
- The effects of climate change are projected to be largest in south east England and effects will be less severe in other parts of the country. However, significant climate impacts are expected in other regions as well.
- In all the case studies, the warmer climate conditions point to the need to limit summertime heat gains to spaces as far as possible as the first and most energy efficient measure to reduce the need for mechanical comfort cooling. This means employing solar shading, reducing the density or power output of lights, machines and possibly the density of occupants, and providing the ability to reduce ventilation to minimum levels during hot periods of the day. For buildings with exposed thermal mass it also means enabling ability to purge spaces with cool air at night and during periods of cooler weather to maximise the capacity for passive heat absorption by the building fabric.

TM 36: Climate change and the indoor environment: impacts and adaptation, is available from CIBSE at **www.cibse.org/publications**

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	Region	Nov 2004	Dec 2004	Jan 2005
1	Thames Valley	198	289	263
2	South East England	228	327	297
3	South Coast	194	265	265
4	South West England	164	235	238
5	Severn Valley	216	285	268
6	Midlands	232	300	298
7	West Pennines	235	315	296
8	North West England	223	308	291
9	Borders	226	306	278
10	North East England	244	319	290
11	East Pennines	235	305	295
12	East Anglia	244	327	307
13	West Scotland	236	306	306
14	East Scotland	250	325	298
15	North East Scotland	253	325	302
16	Wales	194	267	262
17	Northern Ireland	215	291	295
18	North West Scotland	235	286	303

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To book a table at the ceremony please contact Arabella Dick,
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All EI Awards 2004 photos: Jim Four.

Top: *EI Awards statues*

Middle: *EI Awards 2004 Guest speaker and presenter, Matthew Pinsent, CBE*

Bottom: *EI Awards 2004 winners on stage with Matthew Pinsent (centre).*

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