MODERN ENERGY

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Rush is on to develop smarter power

Sylvia Pfeifer considers the range of technologies starting to attract serious investment

On the banks of the Elbe in northern Germany, a giant turbine looms over the city of Magdeburg. It is the world's most powerful, taller than St Paul's Cathedral and capable of producing 7.5MW of power – enough for 7,500 homes.

The windmill, an Enercon E-126, has a power that would have been unthinkable even a few years ago. It is an example, however, of how tough carbon reduction targets and new technologies are combining to drive remarkable innovation in energy. The world's appetite for energy shows no signs of abating, putting pressure on the industry to deliver.

Price is the added stimulant; without the constant innovation and investment in renewable and traditional forms of power, such as fossil fuels, politicians fear a rapid and unpopular rise in consumer and industrial bills.

Simon Luby, associate director at SgurrEnergy, a renewables consultancy, compares the recent rush of change to the evolution in the aerospace industry from the original jumbo, Boeing's 747, which first flew in 1969, to the Airbus A380, which went into commercial service 40 years later.

"The sort of scale-up we've seen in aerospace has taken 40 years, but the wind industry has scaled up by a greater factor in half the time – critical for maximising production but also bringing technology challenges with it," he says.

Simon Currie, global head of energy at Norton Rose Group, says: "We expect to be able to run before we can walk, but the engineering challenges are huge.

"However, the industrial logic of this sector [offshore wind] is encouraging manufacturers to build the capacity. If renewable energy can achieve a cost of energy that is close to that of traditional forms of generation, suddenly the market has a choice," he adds.

The Magdeburg giant may already be about to be surpassed. In Norway, plans are well advanced for a 10MW plant, one-quarter as powerful again.

In oil and gas, new, techniques for "fracking" – fracturing rock formations with a combination of high-pressure water and chemicals – hold out the hope for opening vast new fields without the environmental damage caused by earlier types.

In North America, new production from tight oil reserves has helped reverse the decline in US oil output.

Injection technologies are also giving new life to mature oilfields, while in provinces such as the Atlantic waters off Brazil, pioneering drillers are finding oil and gas in depths of water that would have been thought prohibitive in the recent past. New, ultra-deepwater rigs can operate in depths of up to 7,500 feet.

Even in the conservative field of nuclear power, where designs have typically taken a generation to come into service, new ideas are coming through.

Several companies, from industry stalwarts such as Westinghouse and General Atomics to relative newcomers such as Hyperion Power, are working on schemes for mini power stations.

These "community nukes" would be small enough to power a village or factory, and simple enough to be switched on, sealed and buried underground without further maintenance.

Another option is to join groups of them together to generate greater amounts of power, or to use them to augment the output of existing nuclear facilities.

One of the first practical applications is likely to be in the isolated village of Galena in Alaska, where the local authority has agreed to tackle crippling energy bills – the 675 inhabitants are cut off by river ice for eight months of the year – by installing a Toshiba 4S reactor (super-safe, small and simple).

This will generate 10MW of power, and according to the manufacturer, could run for 30 years without refuelling. If the plans go according to schedule, Toshiba will install

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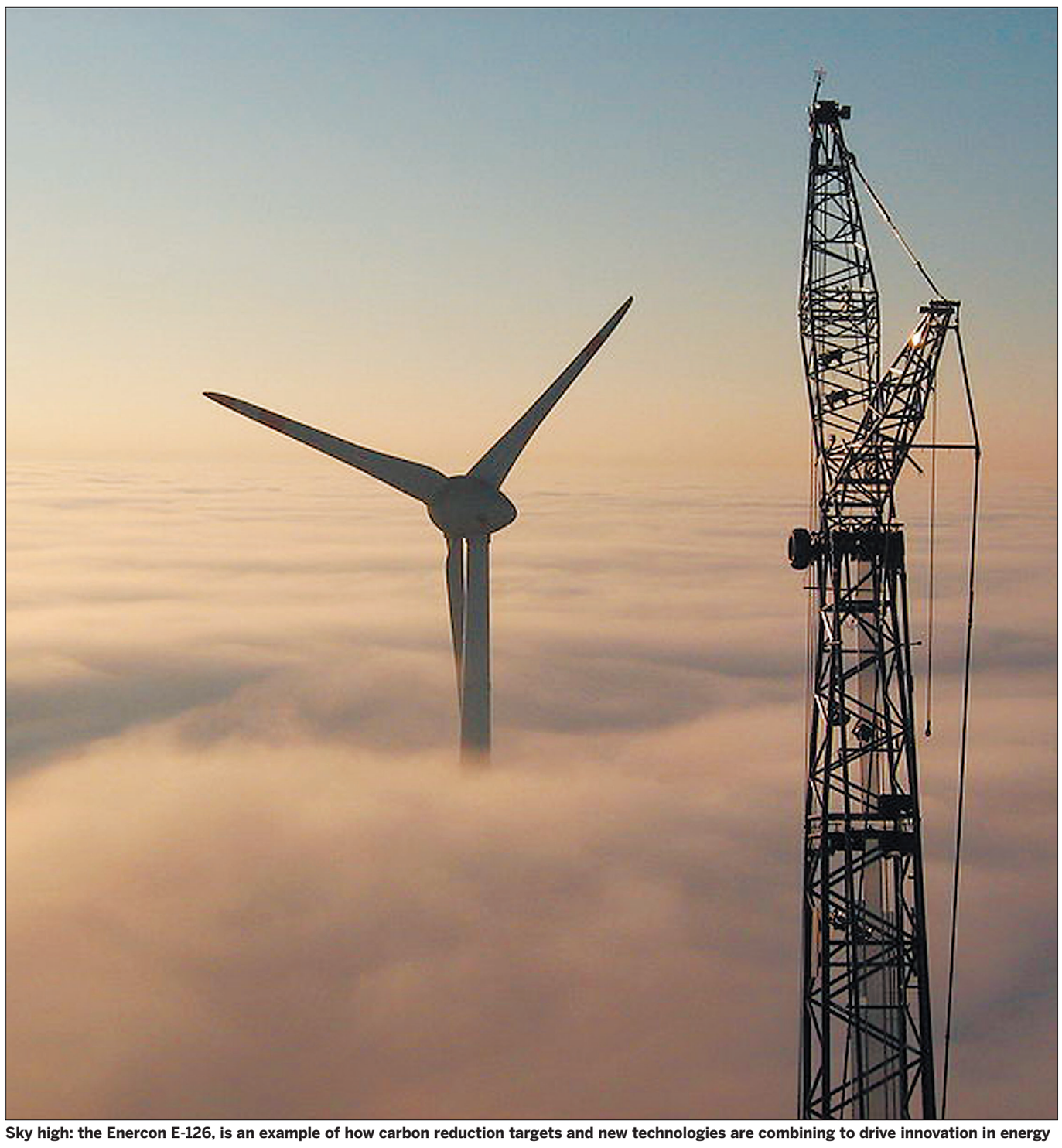


Sky high: the Enercon E-126, is an example of how carbon reduction targets and new technologies are combining to drive innovation in energy

Protesters win first round of PR battle

Fracking

Sheila McNulty on a process, in use for years, that is now being fought over in the courts

Dave Lesar, Halliburton's chief executive, sought last month to ease environmentalists' fears about the chemicals used in producing oil and gas from shale by demonstrating that they were consumable.

Only the demonstration – at the Colorado Oil and Gas Association conference – was not as comforting as some might have hoped.

Mr Lesar did not consume the fracking fluids himself but called up a fellow employee to do the honours.

"My first thought was, 'if this stuff was so benign, why wouldn't he drink it himself?'," says Mark Brownstein, chief counsel to the Environmental Defense Fund's national energy programme. "There was definitely a Mr Burns-and-his-loyal-assistant-Smithers quality to it."

Even those who have never watched *The Simpsons* can imagine that reference is unflattering.

And yet Halliburton has refused to explain why Mr Lesar did not drink the fluid, only offering that, at a September conference, he drank a small amount himself.

Mr Brownstein's take on the episode was positive, however. "That the folks at Halliburton are looking at concerns over the safety of its fluids shows that the way pressure is being brought to bear on the industry is having an effect."

The industry acknowledges that environmentalists have won the initial public relations battle against fracking.

Although the technique has used for decades, campaigners have years gained ground by questioning the impacts of the process that involves pushing water laced with chemicals under the ground at high pressures to fracture rocks and release oil and gas.

Amid claims of groundwater contamination, companies have found themselves shut out of certain parts of the US and elsewhere.

New York State, for example, issued a moratorium on fracking. New Jersey's state legislature passed a bill in June to bar fracking permanently, although the governor, Chris Christie, has recommended it be for one year.

The process is being questioned by other jurisdictions and is being fought over in courts.

But perhaps the biggest threat is from the US Environmental Protection Agency. Richard Stoll, who has followed the controversy for the law firm Foley & Lardner, says that the EPA issued "guidance"' on its website last year that said no company could frack with diesel in the mixture without a permit. He says the EPA skipped the standard "rule making" process for issuing regulations with this website posting, surprising the industry.

The problem is, he says, that over the years, many companies have used diesel. They are moving away from the fuel, but are still using fluids that may contain some compounds found in it. The EPA is expected to issue more "guidance", Mr Stoll says, that "may define diesel quite broadly to mean fluids that contain compounds found in diesel even if the fluid really isn't diesel".

If the EPA defines its guidance so broadly and retroactively, many could be deemed in violation of the law. The ensuing law suits and attempts to clean up fluids will slow production, he says. The industry is taking the EPA to court for what it says was illegally changing the law without public comment or other normal parts of the process.

Dave Lesar, CEO at Halliburton, has tried to allay critics' safety fears

On another front, the EPA has sued Range Resources for allegedly contaminating the water supply in Texas – a charge the state and the company deny. The speculation is, Mr Stoll says, that the EPA is conducting investigations that may lead to similar suits in other parts of the US. "There are little brush fires going on everywhere," Mr Stoll says.

The industry is rushing to put them out by explaining how many jobs fracking provides at a time when unemployment is high and the economy sluggish.

Jim Mulva, chief executive of ConocoPhillips, says natural gas sustains 2.8m jobs in the US alone. Most are linked to fracking across at least 15 states.

"The record is in our favour – those millions of wells safely fractured since the 1940s," Mr Mulva says. "There have been some problems, but they are rare. And they were caused not by fracturing but faulty drilling and well completion work or improper handling of fluids on the surface."

He notes that fracking occurs far below drinking-water aquifers, with the wells cemented to seal them off from any water supplies.

The industry hopes all this will enable it to win battles – and eventually the war – to develop US natural gas supplies.

Gary Adams, US oil and gas expert at Deloitte, the consultancy, says natural gas meets 25 per cent of US energy demand, heats 50 per cent of US homes and powers more than 120,000 natural gas vehicles. "It's to the US's advantage to look for ways to leverage the use of natural gas."

Chesapeake Energy is leading the way on that front, converting 100 of its rigs, all its hydraulic fracturing equipment and almost 5,000 of its fleet vehicles to run on natural gas.

Henry Hood, Chesapeake's general counsel, says that, in the past five years, the US's second biggest natural gas producer has paid 1m mineral owners $9bn in leases and bonuses, $5bn in royalty payments and $2bn on government taxes to fuel jobs growth.

Yet there are hundreds of gas producers adding to those numbers. The industry insists it could continue to expand supply, and the economy, if the government allows fracking to continue.

It is the job growth borne by fracking that has the industry convinced this will be an important issue in the upcoming campaign.

"Any politician who opposes responsible natural gas development in the US does so at their peril," says Peter Robertson, former vice-chairman of Chevron's board and senior adviser at Deloitte. "I think Democrats and Republicans are all supportive of jobs."

Bigger role for extraction technology

Enhanced recovery

Two-thirds of oil well reserves stay where they are, says **Sheila McNulty**

Chevron first began producing oil in the Permian Basin of Texas in the 1920s. That it has never left is a testament to the vast resources in the US's largest oil region, as well as the technology that continues to help the company find ways to extract more of it from the ground.

The industry routinely notes that two-thirds of the world's oil remains trapped in known oilfields – either because the it does not have the technology to recover it or it is so deeply embedded that it is not economic to do so.

Indeed, in the Permian, where 30bn barrels of oil have been produced, Chevron estimates there are another 60bn barrels in place.

"There is a huge target there," says Mitch Mamoulides, Chevron's manager for the Permian south. "We just need the technology to get it out."

Technological advances, in the form of what the industry calls enhanced oil recovery (EOR), have played a big role in the Permian's production.

Mr Mamoulides says three-quarters of Chevron's Permian production is through EOR. The first 15 to 20 per cent of oil from a well flows with conventional pumping. The next 15 to 20 per cent is produced by flooding wells with water at high pressure, and the next 8 to 12 per cent is the result of pumping in carbon dioxide, which reduces the bond that oil has with rock.

That leaves some 50 per cent of the oil in each well.

"One of the misconceptions many people have is that we are drilling into a big pool of oil," Mr Mamoulides says. "We're producing out of solid rock that is denser than the concrete on your driveway."

The next stage of extracting still more oil from the Permian will involve what Chevron calls the "I Field", or the intelligent oilfield. This will involve using the latest technology to see thousands of feet underground to where the oil remains stuck, so as to pinpoint and target a specific zone for further recovery.

"There will be other technologies," Mr Mamoulides says, and they will not only be used in the Permian.

Trevor Wallace, president of PetroMark Energy, a small exploration and production company, has made a career out of buying old wells from big companies, such as Chevron, or from larger independents, which considered them too small to bother with.

He goes in with the latest technology, hoping to produce many thousands of barrels that would otherwise be left for dead. These days, he is concentrating on a field in California, as well as some under-developed Texas properties.

"We want to put together a precisely tailored programme," Mr Wallace says. On the California field, he is looking at targeted fracturing of the rock for certain formations, and applying a chemical "wash" that loosens oil from rock for others.

"You can really go in and make the most of the opportunity," he says.

It is something other major oil companies, are doing globally.

"Energy demand is expected to double over the next 40 years," says Val Brock, Royal Dutch Shell's manager of improved and enhanced oil recovery. At the same time, the International Energy Agency projects production will decline by two-thirds over the next 20 years.

"There is no alternative but to pursue EOR," Mr Brock says.

In addition to the EOR methods that Chevron uses in the Permian, Shell has had success with thermal (heating the oil to help it flow) and polymer use (that helps lift oil off rocks).

Mr Brock says 4 per cent of global oil production is now based on EOR. Even a 1 per cent improvement is significant, he notes, explaining that that translates to 88bn barrels of oil – enough to fuel the world for three years.

The potential for EOR is huge, given efforts have long focused on onshore oilfields and the industry can begin applying some of these technologies to fields offshore. How fast it finds a way to apply new technologies depends on the oil price.

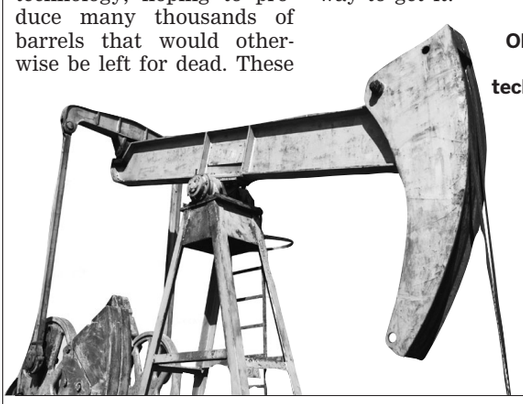
Dallas Parker, partner at Mayer Brown, the energy-focused law firm, says the industry is always investing in EOR, but focuses more intently on it when research becomes more affordable.

"Every time the oil price goes up, people find a way to get more oil out," Mr Parker says. "It's all a function of the price of oil and the technology."

It is not an area reserved only for the big oil and gas companies. Mr Parker points out that the boom in shale oil and gas was created by the US's small independents, which discovered it was economic to extract fuel from shale rock by combining multi-staged fracturing of the rock with water at high pressures, drilling horizontally under the ground.

"It was the entrepreneurs who kept trying to crack the code to extract gas trapped in the tight shales," Mr Parker says. "There's still scope for entrepreneurs to try their hand at EOR."

He believes such efforts will continue. "With that much oil being left in the ground, if the price is right, people are going to find a way to get it."



Old wells, new technology

How to get brass from a variety of muck

Waste

Sylvia Pfeifer discusses scientific advances that have a role to play in alternative energy

On a 750-hectare site near Nottingham, in the English Midlands, one of Britain's biggest water utilities has been planting maize.

Severn Trent, the owner of the land, has not diversified into farming but has been using the crop to generate electricity in what is the UK's first commercial scale dedicated crop digestion plant.

Severn Trent, which serves more than 8m customers, faces an increasing need for energy. Each year, about 35,000 tonnes of maize silage is fed into a 2MW energy crop anaerobic digestion plant which generates biogas which in turn is used to help run the company's adjacent sewage treatment works.

The land has been used for safe recycling of sewage sludge for many years and so cannot be used for food crops.

For Severn Trent, the project is an important part of its renewable energy expansion programme – by March 2013, it aims to be generating 30 per cent of the power its business requires from renewables, including wind turbines, as well as sewage gas combined heat and power (CHP) plants.

The company's CHP plant not only generates enough electricity to run the sewage works but also produces about 1MW of surplus electricity which is fed into the national grid.

The project, which began operation last October, also has wider significance. It is testament to the fact that waste – from food to municipal sewage – has a role to play in the evolution of the energy industry.

In the UK, the government's review of waste policies, published in June 2011, recognised the important part that energy from waste can help play in meeting the country's renewable energy targets, to diversify supply, and to provide economic opportunities.

The review suggested renewable electricity generated from waste through combustion technologies could almost treble from the current 1.2TWh to between 3.1TWh and 3.6TWh by 2020.

At present, waste accounts for 1.5 per cent of energy produced in the UK, from two principal technologies: various combustion processes and landfill gas. Some companies estimate that waste could account for as much as 6 per cent of UK electricity by 2015 – but only if planning permission to build infrastructure and facilities is improved.

David Nickols, managing director of future energy at WSP, the engineering consultants, says: "Within the water utilities sector, the vast majority of investment is in anaerobic digestion."

Outside the water utilities sector, several projects are under way by the food and beverage industry. Farmers are also among the backers of some anaerobic digestion plants, using a combination of farm waste, specially grown crops and discarded food collected by local councils.

While projects vary, depending on the country, the main driver for investment, says Mr Nickols, is of course the promise of making a commercial return.

Harvest time: the UK's first commercial scale crop digester near Nottingham converts maize silage into biogas

But that in turn is heavily influenced by regulation. Infrastructure also has a role to play; in many countries, utilities are too fragmented to make it easy to establish a viable network for biogas.

Sweden, for example, which is more advanced than many of its European neighbours in terms of multi-utility organisations, is a world leader in upgrading and use of biomethane for transport and has many "biogas vehicles", including private cars and buses.

> Waste accounts for 1.5% of energy in the UK, mainly from combustion processes and landfill gas

Another area of the waste market, landfill gas, is already a mature application in Europe. In the UK, which is the biggest landfill market in Europe, the government recognised in the 1990s that it would need to do something about the gas – mainly made up of methane and 20 times more harmful than carbon dioxide – if it was to meet its renewable energy targets.

One of the big winners from this has been Infinis, a company that was originally backed by Terra Firma, the private equity group of Guy Hands.

Eric Machiels, chairman and chief executive of Infinis, says nearly 10 per cent of Britain's renewable energy comes from electricity generated by methane from its 124 landfill sites.

One of the main attractions of landfill gas, he says, is that it provides power that is available all the time.

However, with gradual decommissioning of landfill sites, and strict incineration legislation, it is a mature business in Europe.

Mr Machiels notes that sites are predicted to release gas for the next 20 to 30 years. The group has diversified into other areas such as onshore wind and hydropower. China, however, offers potential expansion prospects in landfill gas and Infinis is considering several opportunities.

Waste water is another part of the debate and is also one of the most rapidly growing areas of the market.

A range of waste water treatment specialists has sprung up in recent years, including Bluewater Bio. The company, treats a range of municipal and commercial effluents using proprietary technology that generates water for re-use in agricultural, industrial and social applications.

People need to be re-educated about water, says Daniel Ishag, its chief executive. "There is an entitlement mentality in the west, where people feel entitled to cheap water but prices will have to go up. Technology is the only way to bridge that gap."

Rush is on to develop smarter power

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the plant, free of charge, next year.

One relatively new market that is seeing strong demand, especially in the wake of the nuclear crisis in Japan, is that for huge floating gas platforms.

Royal Dutch Shell, the Anglo-Dutch oil major, announced the go-ahead this year for its Prelude liquefied natural (LNG) gas project in Australia, the world's first floating LNG plant.

The company has not disclosed the cost of developing Prelude but analysts at Wood Mackenzie estimate it at about $11.5bn. When fully equipped and with its storage tanks full, Prelude will weigh about 600,000 tonnes – six times as much as the largest aircraft carrier. It expects to ship its first gas in about 2017.

For the company – and the industry – it is an important step and should allow Shell to pursue offshore gasfields that would otherwise be too costly to consider.

Analysts believe the decision to develop Prelude could have wider ramifications, acting as a boost for Australia's ambitions to expand its LNG production, adding to the debate over whether the country will overtake Qatar as a producer of LNG.

These developments would not have been viable 10 years ago. Technology is also helping the international oil majors in their quest for new resources, be that oil and gas in frontier areas such as deepwater Brazil and Angola, or unconventional gas in North America and China.

Increasingly, many are also focusing on getting more out of older fields. "Companies have a good record of getting extra hydrocarbons out of the ground. The key technology involves reservoir modelling and management," says Andy Brogan, oil and gas partner at Ernst & Young.

Cost remains a stumbling block, in particular for technologies such as new nuclear and renewables. "There are a lot of advanced technologies, but they are not always bankable," says Jim Fitzgerald, assistant director of environmental finance at Ernst & Young. "Technologies can get developed, but the initial deployment and scale-up are significant hurdles to overcome."

Many also need guarantees from governments to help underpin them but "the quid pro quo is new jobs", he adds.

The industry knows it needs to keep innovating to survive – be it a solar company trying to reduce costs or an explorer drilling for oil and gas – but driving all this is investment. Lots of it. Against a background of uncertain and volatile economic times, one of the concerns uppermost in the minds of executives is that companies will start to pull back from spending, affecting the energy supply-demand balance in the longer term.

Peter Voser, chief executive of Shell, told the Financial Times this month that oil and gas supplies will struggle to keep up with world demand growth, leading to greater volatility for energy prices in the long term.

He warned that there was still an immense challenge in meeting growing world demand for energy.

The problem was not a lack of oil and gas in the ground, he said, but inadequate investment, following cuts by many companies since the start of the financial crisis.

"While demand tends to pick up in one or two years, a typical cycle for a good big oil and gas project is six to eight years," he said.

The world needs to add the equivalent of four Saudi Arabias or 10 North Seas over the next 10 years just to keep supply level, he added.

The message is clear: the oil and gas industry, as well as the wider energy sector, will need to draw on its mental, as well as its physical resources, to survive.

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Enthusiasm for reactor investment cools

Nuclear

Ed Crooks explains why the industry faces a tricky future around the world

Fallout: a mother and child are checked for radiation exposure after the meltdown at Fukushima. Even before the accident, prospects were looking difficult Epa

In much of the world's nuclear industry today, the watchwords are "make do and mend".

Even before the Japanese earthquake and tsunami of March 11, prospects for nuclear construction were looking difficult in most of the developed world, mostly because of shaky economics. Weak power demand because of the recession, and cheaper alternatives such as gas and coal, made it difficult to justify investment in reactors.

Where projects were going ahead, they were doing so only with strong government support.

The meltdown at the Fukushima Daiichi plant, now ranked by the International Atomic Energy Agency as being as serious as the Chernobyl disaster of 1986, has further dented enthusiasm.

Around the world, countries that were in favour of new nuclear investment have had their confidence shaken. Sceptics have become more firmly opposed, while several of those on the fence have been tipped into rejecting nuclear power. The IAEA says about six countries interested in developing a civil nuclear industry have notified it that they have abandoned their plans.

No country that has committed itself to building plants has scrapped those plans. The UK and France, two of the more pro-nuclear countries in Europe, are going ahead.

China, having frozen approvals of new nuclear plants following Fukushima, has been reported as planning to give the go-ahead next year, and is set to dominate the landscape for nuclear construction.

The IAEA's most recent projection is that the world will add up to 150,000 megawatts of additional nuclear capacity by 2020, of which China plans to provide 70,000MW.

China's 2020 target of reaching 80,000MW of nuclear capacity, from 10,000MW last year, may slip a little because of the post-Fukushima delay, but its ambitions still dwarf those of any other country.

Other emerging economies, including India and the United Arab Emirates, are also planning significant investments in new reactors.

However, while the global nuclear industry is growing overall, its share of electricity generation is likely to slip, the IAEA believes, as other forms of generation grow more quickly.

In most of the developed world, the emphasis is shifting towards finding alternatives to nuclear power, and getting more out of existing reactors.

Germany and Switzerland have announced plans to shut down their reactors, and a referendum in Italy has decisively rejected new construction. In Japan, traditionally a pro-nuclear country, which derived about 30 per cent of its electricity from nuclear plants last year, opposition has been emerging as an important political issue.

Companies in the nuclear industry have been repositioning themselves for a market less attractive than it was at the start of the year.

Shaw, the US civil engineering company, has decided to exercise its option to sell its 20 per cent stake in Westinghouse, the nuclear engineering group, to Toshiba of Japan.

Toshiba is now considering selling on part of its holding – which will be 87 per cent once the Shaw deal has gone through – to another investor.

Siemens of Germany has said it is pulling out of its joint venture with Rosatom of Russia to make nuclear generating equipment, as a result of the German government's plans to close the country's 17 nuclear power stations by 2022.

In the UK – which looks set to be the west's largest market for reactors over the coming decade, if the government's plans are delivered – Scottish and Southern Energy, one of the leading power companies, announced it was dropping out of a consortium with GDF Suez of France and Iberdrola of Spain to build reactors.

General Electric, the US industrial group that is one of the world's leading nuclear engineers through its joint venture with Hitachi of Japan, has said it does not hold out much hope for market growth in the immediate future.

John Krenicki, the chief executive of GE's energy division, told analysts recently: "Nuclear for the next five years is going to look a lot like it did for the past five years: mostly fuel and service [work]."

He added that he expected nuclear power, which was about 3 per cent of his division's revenues, to decline in importance, as other parts of the business grew more rapidly.

In these conditions, the pressure is on for generators to squeeze more out of existing plants. All over the world, governments are extending the lives of ageing reactors. In the US, 60 reactors have been given approval to have their working lives extended from 40 to 60 years. France and Russia are making similar moves, and other countries such as the UK are expected to follow.

In the US, there has also been a lot of work done to increase the capacity of existing nuclear plants. Since 1977, regulators have approved 139 upgrades in the US, adding about 6,000MW to the capacity of the US reactor fleet. John Rowe, chief executive of Exelon, the largest US nuclear generator, has argued that these life extensions and modifications are a much more cost-effective way of investing in nuclear power.

Other countries, including Spain, Sweden and Finland, have also allowed significant upgrades.

However, the limits of the extra power that can be squeezed out by these modifications – mostly carried out to the steam turbine systems used for power generation, rather than in the reactors themselves – are now being reached.

One solution to pushing output even further is being proposed by Lightbridge, a US nuclear fuels company. It is offering a new type of metallic nuclear fuel, being evaluated at the US government's Idaho National Laboratory. Lightbridge says it can increase the output on an existing reactor by up to 17 per cent.

Seth Grae, the company's chief executive, says: "With our fuel, you can get a 10 per cent power uprate by spending only about $10m."

In today's difficult, highly competitive market for generators, squeezing out more electricity in the most cost-effective way possible is a highly attractive proposition.

Difficult balance of supply and demand

Innovation

Ed Crooks reports on problems posed by the 'new renewables'

As electricity systems around the world add ever-greater contributions from renewable energy to their grids, power engineers are being confronted by a challenge they have not faced before.

Almost all the generation capacity now connected to electricity grids is, broadly speaking, available at will. There are always constraints: nuclear power cannot be ramped up and down very easily; hydropower can be affected by levels in rivers and reservoirs, and any generation that uses a steam turbine – most fossil fuel and nuclear plants – can be affected by water shortages,

In general, however, today's power plants are always there when needed for the complex task of balancing supply and demand across the grid.

Recent experience in China, where periods of insufficient voltage causing shutdowns and blackouts have been a regular phenomenon, shows what can happen if the grid is allowed to fall out of balance.

That is why what are sometimes called the "new renewables" – wind and solar power – present such a challenge.

Weather forecasting can make unexpected variations less of a problem, but the essential nature of these forms of generation is that they are intermittent, their availability subject to the vagaries of wind and sun.

The scale of the problem this presents can be seen from one UK company's estimates that at times, on cold, still days, the output of its wind farms was just 10 per cent of their notional maximum output. The implication is that the company would need to keep 90 per cent of its wind capacity available in back-up generation, for use when the wind stopped.

Demand response – dialling down electricity use when supplies are short – is part of the answer, but the "smart grid" technology that would make that possible is still in its infancy, and some customers have been reluctant to embrace the idea.

Indeed, if anything demand is becoming less stable in many parts of the world because of the spread of air conditioning, which can cause surges in demand as temperatures rise.

For now, the burden of balancing the grid falls entirely on the demand side. As the output of wind and solar power rises and falls, other forms of generation will have to fall and rise to match it, to keep the grid balanced.

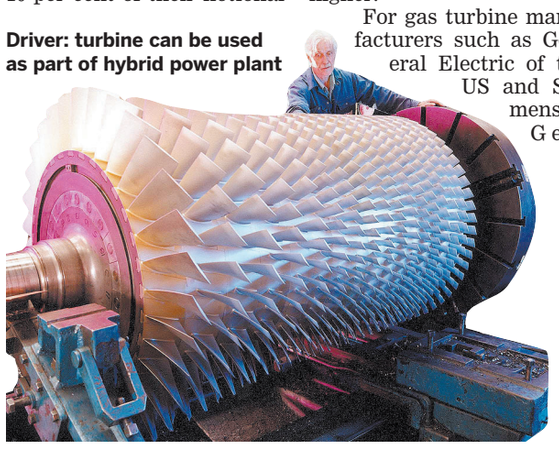
> 'Customers need to make a transition. They now need efficiency plus flexibility'

One of the big problems with that, however, is that it can greatly reduce the efficiency of the power plants that are being used to ramp up and down.

Coal and combined cycle gas turbine (CCGT) power plants are most efficient when they are running all the time. If their output is fluctuating, then their costs and greenhouse gas emissions for a set volume of electricity are likely to be higher.

There are special gas plants, sometimes known as peakers, that are much quicker to start up, and are designed for use only to meet peak demand, but their costs are always higher.

Driver: turbine can be used as part of hybrid power plant



For gas turbine manufacturers such as General Electric of the US and Siemens of Germany, the problem of balancing the grid with a much high contribution from intermittent renewables has created an incentive to develop plants that can be ramped up and down quickly, but run more efficiently than traditional peakers.

"Customers need to make a transition," says Steve Bolze, GE's head of power and water. "They now need efficiency plus flexibility."

Siemens says it has spent €500m on developing a prototype plant at Irsching in Bavaria that generates 578 megawatts with an efficiency – the ratio of the energy output from the plant to the heat created by burning the gas – of almost 61 per cent.

Just as importantly, the plant can bring 500MW online in just 30 minutes, and change its output up or down by 35MW a minute.

GE, meanwhile, has launched its FlexEfficiency 50 plant, which it says offers an even faster ramp-rate of 50MW per minute. At a similar size to the Siemens plant of 510MW, it is also claiming even higher efficiency, at "greater than 61 per cent". GE says it invested about $500m to develop the plant.

The Flex 50 has been sold to customers in Turkey and China. MetCap Energy Investments, the Turkish buyer, attracted considerable publicity for ordering the turbine as part of a "hybrid power plant", which also included wind turbines and solar water heating on the same site.

The addition of wind turbines, is something of a gimmick. There is no reason why the wind and gas generation need to be located on the same site, so long as they are connected up to the same grid. The solar technology, however, brought in when GE did a deal to invest in eSolar, a small US company, does add something to the plant's performance, helping heat the water used in the steam turbine. GE believes the technology could be attractive to other customers in sunny regions such as parts of Africa.

In the short term, Europe is the big opportunity, because of the development of renewables over the coming decade, as member states move to meet European Union targets.

As that market grows, there will be pressure on turbine suppliers to improve performance even further. "The FlexEfficiency 50 has really shaken the industry," Mr Bolze says.

A laboratory for life after fossil fuels

Geothermal power

Andrew Ward looks into Iceland's clean energy potential

All steamed up: geothermal power companies are increasing capacity to meet rising industrial demand

Iceland's President Olafur Ragnar Grímsson has only to look out his window for a reminder of his country's clean energy potential. From the white-washed presidential residence on a windswept peninsula outside Reykjavik, he can look across the capital to a volcanic mountain range behind.

It is Iceland's location on a geological hotspot in the middle of the North Atlantic that makes it one of the world's leading developers of geothermal power – electricity generated from the heat of the earth's core.

Now, as the country battles its way back from a crippling financial crisis, Mr Grímsson is promoting its geothermal resources as a driving force behind economic recovery. He has travelled the globe selling Iceland's geothermal expertise with a focus on the world's big emerging economies.

"Clean energy has become the pillar of co-operation between Iceland and China and also with India," he told the Financial Times. "These countries can see the potential of geothermal power to help meet their rising energy needs."

Chinese interest in Iceland – including a recent deal by a Chinese tycoon to buy a large swathe of Icelandic wilderness for a tourism project – has sparked fears in the west that Beijing could be seeking a strategic foothold in the North Atlantic.

But Mr Grímsson says the primary focus of bilateral relations is energy, as China looks for help in meeting its goal to produce 15 per cent of its energy needs from non-fossil fuels by 2020.

It may seem strange for a country of 1.3bn people to be seeking guidance on energy matters from a nation whose entire population, at 320,000, is smaller than most districts of Beijing. Yet, with almost all its electricity and heating needs provided by geothermal and hydro power, Iceland is a laboratory for life in a post-fossil fuel world.

Mr Grímsson has been cultivating energy ties with Beijing since taking former Chinese president Jiang Zemin to visit a geothermal plant during a stop in Reykjavík in 2002. "You could see the Chinese delegation came away seeing geothermal energy in a new light," he recalls.

Since then, the two countries have signed formal co-operation agreements to work together on geothermal projects in China and other parts of the world. Chinese engineers, meanwhile, have been sent to Iceland to study at a United Nations-run geothermal training centre.

China may not be as well known as Iceland for its volcanoes and hot springs but geothermal power is accessible in many parts of the country. An Icelandic company called Enex has been developing a geothermal heating system in Xianyang, a city in Shaanxi province, in a joint venture with Sinopec, the Chinese state-owned energy group, with plans for similar projects elsewhere. Beijing is among other cities considered to have geothermal potential.

China is one of many countries in which Icelandic geothermal companies are active, ranging from Slovakia and Hungary to Kenya and El Salvador.

> Chinese interest in Iceland has sparked fears that Beijing could be seeking a strategic foothold in the North Atlantic

The idea of Icelandic engineers spreading clean energy to the world represents an appealing contrast to the country's ill-fated flirtation with international banking over the past decade. However, it is at home where Icelanders stand to make the biggest economic gains from the bubbling hot spots beneath their feet.

With much greater supplies of power than its tiny population could ever consume, Iceland has used its surplus electricity to attract investment and jobs from the energy-intensive aluminium smelting industry. Electricity is so cheap that it makes economic sense for smelting companies, including Alcoa and Rio Tinto Alcan, to produce aluminium in Iceland, despite its isolated location. There are three smelting plants in operation, with one under construction and another two planned.

Anxious about over-reliance on aluminium, the country is seeking to diversify into other energy-hungry industries. A big data centre, for example, is under construction at the former Nato air base at Keflavík, west of Reykjavik.

Geothermal power companies are increasing capacity to meet rising industrial demand. Alterra Power, a Canadian renewable energy company, recently won approval to expand its Reykjanes geothermal plant from 100MW to 180MW.

However, not all Icelanders are happy about commercial exploitation of their country's energy reserves. Environmentalists have fought against the aluminium industry for decades and the Canadian takeover of a domestic power company by Alterra, previously known as Magma Energy, last year was deeply unpopular. Björk, the Icelandic pop star, led the protests over a deal that she claimed would give foreigners too much power over the country's natural resources.

Controversy also surrounds tentative plans to export Icelandic electricity via a 1,170km undersea cable to Scotland. The idea has been mooted for years but appeared to take a step forward in March when it emerged that Landsvirkjun, the state-owned utility that produces three-quarters of Iceland's electricity, was conducting a feasibility study.

The $2.1bn project has become more viable as technological advances make it possible to transmit electricity over longer distances through high-voltage cables.

Supporters say an Iceland-UK power link could make energy exports as valuable to the Icelandic economy as oil and gas is to Norway. For the UK, it would help cut greenhouse gas emissions and provide more reliable supplies than wind power.

Many Icelanders are cautious about letting the rest of Europe share in their energy riches. However, with an estimated three-quarters of the country's geothermal resources still undeveloped, advocates say there is more than enough to go round.

How to match oil and gas with a green reputation

Carbon capture

Andrew Ward on a pioneering project in Norway

Testing: the Mongstad demonstration plant has raised scepticism

To supporters, it is a groundbreaking project at the forefront of efforts to fight climate change. To critics, it is a cynical smokescreen to justify business as usual by western Europe's biggest oil and gas producer.

Welcome to Mongstad, Norway, home of what will soon be the world's most advanced test facility for capturing greenhouse gas emissions from fossil fuels.

Due to start operations early next year, the $1bn demonstration plant will extract carbon dioxide from the exhaust gases emitted by Norway's largest oil refinery and an adjacent gas-fired power station.

Technology Centre Mongstad, is a beacon for those who believe carbon capture and storage (CCS) will allow the world to greatly reduce its greenhouse gas emissions while continuing to burn fossil fuels.

The plant is designed to remove 100,000 tonnes of CO_2 a year and, if successful, the technology could be used on a much bigger scale at Mongstad and similar power plants and chemical facilities around the world.

The captured gas would then be stored in underground repositories, including depleted North Sea oil and gasfields, to prevent it reaching the atmosphere and contributing to global warming.

CCS has been touted as an answer to climate change for years, but Norway has moved further than most in turning it from science fiction to reality.

In addition to its work on capturing CO_2, the country is also at the forefront of storage technology. Statoil, the state-controlled petroleum group, has extracted about 13m tonnes of CO_2 directly from its Sleipner gas field since 1996 and buried it in undersea reservoirs.

Statoil is also involved in the Mongstad project as the main industrial partner to Gassnova, another state enterprise dedicated to developing CCS. Shell, the Anglo-Dutch oil major, and Sasol, the South African energy and chemical group, also have small stakes.

For Norway, CCS offers hope of a world in which its role as a big oil and gas producer can be reconciled with its self-image as a green and socially responsible nation. Put more bluntly, it wants to promote its plentiful reserves of natural gas as a cheap and reliable power source whose environmental impact can be mitigated using CCS.

Per Rune Henriksen, the state secretary for energy, says Norway supports the push to find alternatives to fossil fuels – pointing out that 96 per cent of the country's own electricity needs are met by hydropower. However, he says that renewable energy alone cannot satisfy the world's growing hunger for energy, as China and other emerging economies industrialise. If fossil fuels are here to stay, he adds, it is essential to find a cleaner way to burn them.

Mr Henriksen says CCS could contribute nearly a fifth of the emissions reduction needed to restrict the rise in average global temperatures to 2 degrees above pre-industrial levels – the limit urged by the UN's Intergovernmental Panel on Climate Change if the world is to avoid catastrophe.

Yet, despite Norway's enthusiasm for CCS, the Mongstad project has been beset by controversy from the start.

The test facility was originally intended as a first step towards full-scale carbon sequestration at the newly opened gas-fired power station at Mongstad. The power plant was a source of political controversy during the planning stage and approval was made conditional on it being equipped with CCS technology. However, in May a final investment decision on whether to go ahead with the full-scale project was delayed until 2014.

"This is a very complicated project and the difficulties turn out to be bigger than expected," says Mr Henriksen. "We had the idea that the test facility and the full-scale development could be done in parallel but now we have decided we have to go further in developing the technology before we take the investment decision."

> 'This is a very complicated project and the difficulties turn out to be bigger than expected'

Ironically, one of the causes of delay has been health concerns over possible toxic emissions from the CCS process, which involves the use of amine solvents to separate the CO_2 from other gases. Gassnova says it is confident the technology is safe but claims more testing is needed to be sure.

Supporters of CCS accuse the government and Statoil of foot-dragging. "It was not a clever idea to give responsibility to develop one of the most important climate change solutions to an oil company," says Frederic Hauge, president of the Bellona Foundation, a pro-CCS Norwegian environmental group, referring to Statoil.

Other environmentalists are more sceptical of CCS altogether. Truls Gulowsen, head of Greenpeace Norway, describes it as a "false hope" technology that risks delaying investment in more proven ways of cutting emissions. "Lots of public money is being channelled into expensive CCS projects, when we don't know if they will work and which are much more expensive than anyone will ever be willing to pay," he adds.

But Mr Hauge says that, with 80 per cent of global electricity production still coming from fossil fuels and with China opening new coal-fired power plants at a rate of almost one a week, CCS must be part of any climate change solution.

He urges Norway not to give up on a mission that Jens Stoltenberg, the prime minister, once described as the country's "moon landing".

To venture where no driller has gone before

Deep water Brazil

Sheila McNulty finds outsiders sceptical of Petrobras's ambitions

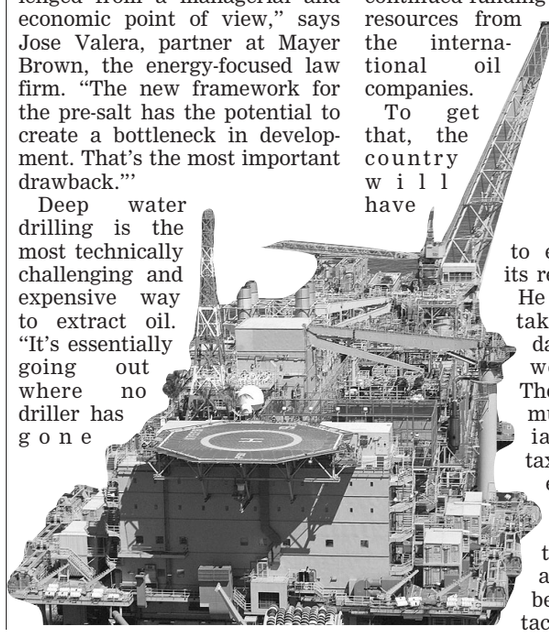
Drilling in the deep water Gulf of Mexico may have captured the public's attention since the Macondo disaster. But for those in the industry itself, which considers the explosion of a deep water rig a one-off, Brazil's deepwater fields are a far more compelling long-term story.

Brazil's offshore oil reserves, which for years remained locked under a 2km-deep salt layer under the seabed, are estimated to hold up to 50bn barrels of oil.

Petrobras, the state oil company, is the main beneficiary, given nationalist laws that mean it must hold 30 per cent of any project as well as serve as operator in the area covering this new-found source.

The company plans to invest $224.7bn over five years to exploit this technically difficult area. And while it has deep pockets and technical abilities that few other national oil companies can claim, there are concerns it is taking on too much.

"Petrobras is going to be challenged from a managerial and economic point of view," says Jose Valera, partner at Mayer Brown, the energy-focused law firm. "The new framework for the pre-salt has the potential to create a bottleneck in development. That's the most important drawback."'



Petrobras rig in the Brazil basin

Deep water drilling is the most technically challenging and expensive way to extract oil. "It's essentially going out where no driller has gone before," Mr Valera says. "In deep water, it's a true exploration effort. Now we're discovering these tremendous resources. That truly is a new frontier."

The international oil companies – along with Petrobras – are home to much of the engineering and other talent required on such projects.

Yet it is tough to get foreigners the required work permits and Brazilian legislation requires huge pay-outs to all staff on top of their salaries, according to Nick Stocker, regional director of Latin America for NES Global Talent, an energy industry head hunter.

In the past, the country's education system did not focus on science and maths, which means it has a lower number of engineering graduates than other countries focused in this area, he says.

Brazil produces about 40,000 engineers a year, compared with 80,000 in South Korea, 250,000 in India and 400,000 in China.

"You have some technical professionals and engineers – just not enough of them," Mr Stocker says. "That experience cannot be gained overnight."

For Brazil to maintain the growth it is planning for its oil industry, he says, there are some who believe it will need continued funding and technical resources from the international oil companies.

To get that, the country will have to ease some of its restrictions.

He says it can take 30 to 40 days to get a work visa. Then companies must pay myriad social taxes, covering everything from holiday to severance to maternity and paternity benefits, that tack on at least another 69 per cent to salaries.

"Clients have to plan carefully and in advance, taking into account the schedule and cost implications of bringing foreign skills into Brazil," Mr Stocker says.

The other key deep water basins are the US Gulf, as well as off Africa's west and east coasts, the North Sea and Australia. All are competing for talent and dollars.

With most of the world's conventional, large-scale onshore or near-shore oil reserves in areas guarded by national oil companies, ranging from Saudi Arabia to Mexico and Venezuela, there is little prospect for large-scale, long-term value creation for the international oil companies, according to Wood Mackenzie, the consultancy, which is why they are increasingly looking for reserve growth offshore.

"The shape of most international company portfolios has changed substantially over the past 10 years, with a relentless shift towards these more technically-challenging projects," Wood Mackenzie said in a July report on the industry.

Deep water, liquefied natural gas, unconventional oil and unconventional gas now comprise almost 50 per cent of the future upstream value of the international majors, Wood Mackenzie says.

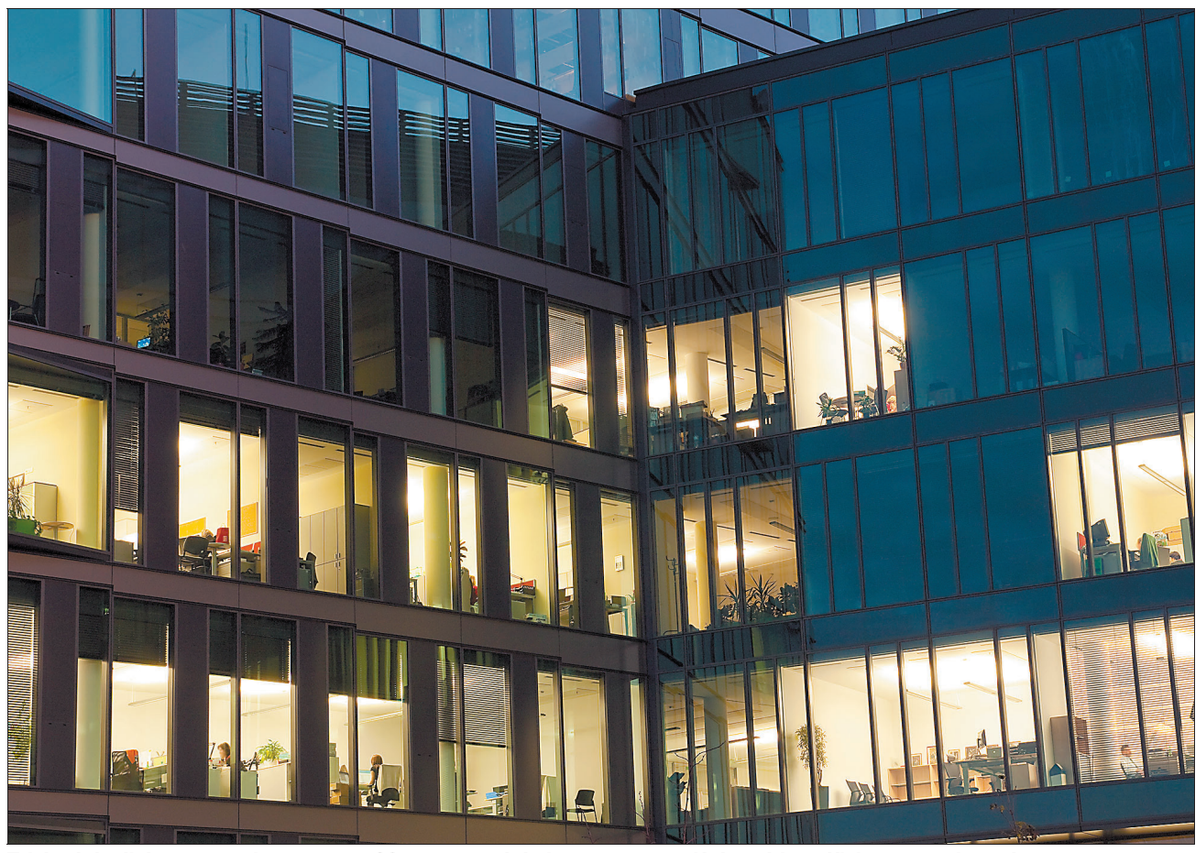
How quickly these individual areas will be developed depends on how quickly access, talent and investment dollars come through.

The technology, the industry notes, has made possible things that were unimaginable 10 years ago. In 2004, for example, drilling in 9,000 feet of water was a record, Mr Valera says. Now the industry can drill in 14,000 feet.

"Ultra deep water is so expensive and technologically demanding, it is an area the international oil companies see as a resurgence for them. They won't be crowded out by the national companies, as is the case in conventional oil development areas,"' Mr Valera says.

Whether Brazil will take enough advantage of the international oil companies' expertise in this area remains to be seen.

Rising price of power may concentrate minds



Trick of the light: companies can save 20 per cent of their energy costs if they drive efficiency consistently Dreamstime

Efficiency

Sarah Murray on why business is still failing to capitalise on potential savings

When describing the incentives for business he is putting in place, Daniel Esty, commissioner of Connecticut's department of energy and environmental protection, talks of a "market failure".

He is not referring to an oversupply of products or an industrial oligopoly. He is talking about the failure of companies to capitalise on the gains to be made from energy efficiency strategies.

"For almost every company, there are substantial opportunities that have high returns on investment for quick paybacks," he says. "Companies are making a serious error by failing to take on those investments as way to cut costs."

Collectively, the savings look large. The McKinsey Global Institute estimates that, with investment of $170bn in energy efficiency, growth in global energy demand could be cut by at least half by 2020 – equivalent to one-and-a-half times the US's current energy consumption.

Individually, too, the savings for businesses are substantial. "We're seeing companies that can take out 15 to 20 per cent of their energy costs if they drive efficiency consistently," says Matt Rogers, a San Francisco-based McKinsey director.

Yet companies are still failing to capitalise on the potential savings. This is particularly true of small and medium-sized companies. Fifty-three per cent of UK SMEs have no management systems in place, and almost 20 per cent do not know whether they reduced their consumption in the past year, according to research released in August by Npower, the energy company.

A number of barriers prevent companies from seizing these opportunities. First, becoming more efficient is a complex business. Energy use is spread across an enterprise, and companies often lack infrastructure such as metering systems to track its use. Historically, another barrier, particularly in the US, has been its low cost, providing little incentive to save.

With prices rising and business prospects remaining tough, cost savings look increasingly attractive. However, misperceptions linger about the return on investments in efficiency.

"In some cases, these are quite fast payback opportunities," says Mr Esty. "Any company that hasn't done a relighting initiative, for example, is missing a very quick two-to-three year payback."

As the price of technologies such as sensors falls, payback times are becoming shorter. Take LED lighting. When combined with sensors monitoring the amount of light in a warehouse or factory and detecting when someone has entered an aisle, lighting levels can be automatically adjusted.

"An LED system of this type used to take 36 or 40 months to pay for itself. But when you combine LED technology with software and sensors, it now pays back in about nine months," says Mr Rogers.

Yet, in a tough economy, with limited time and resources to hand, and power costs not always seen as severely damaging profitability, managers tend not to prioritise efficiency.

Promoting it therefore requires a number of strategies. First, employees need clear and accurate information on how to achieve savings.

Psychology plays a role, too. To many people, energy is invisible. Without intelligible information about the impact of powering down computers or adjusting the air-conditioning on cooler days, there is little incentive to act.

Amanda Harrison, an occupational psychologist at Arup, the design and engineering group, says one effective way of providing information is by installing devices such as dashboard systems that display the amount of energy being used in an office or manufacturing facility and its real-time cost.

She emphasises the importance of conveying information in ways employees can understand, such as equating energy savings to the numbers of homes that could be powered by that energy and for how long.

Having an executive responsible for the issue also helps. "The companies that have been most successful have a senior person making sure the tools are being applied systematically," says Mr Rogers.

Government policy can also shape behaviour. Regulatory instruments include equipment and building efficiency standards and codes.

Mr Esty believes governments should provide carrots as well as sticks. He cites Connecticut's green bank, which will help finance clean energy and efficiency projects. "Rather than waiting for them to call us, we're going to call companies as a way to help small businesses in particular," he says.

He believes shareholders will start viewing energy efficiency in a more positive light. "You get solid returns with much less risk and complexity," he says. "In an era of more cautious investing, energy efficiency looks ever more attractive."

The simplicity of an artificial leaf

Some might find nothing new in the idea of tapping into the sun as a source of renewable energy.

But Daniel Nocera, professor of energy and chemistry at Massachusetts Institute of Technology, plans to use solar power in a completely different way – by using light to split hydrogen from water to create power.

Prof Nocera is essentially replicating a process found in nature: photosynthesis. He has developed an artificial leaf – a silicon panel about the size of a playing card with cobalt and nickel catalysts on either side – that, when dipped into water and held up to sunlight, splits water to hydrogen and oxygen.

"It's doing exactly the same thing as a leaf," he says. "It's sunlight in; hydrogen and oxygen out. And you can use the hydrogen and oxygen at some later time."

This has big advantages in off-grid locations. While solar panels can be part of a distributed system, the limitations of battery technology mean it remains difficult to store the energy that panels generate.

By contrast, splitting water into hydrogen and oxygen creates a chemical fuel that can be stored.

For a domestic home, silicon shingles placed on a roof would, with small amounts of water flowing around them, use sunlight to split hydrogen and oxygen. This could be stored in a fuel cell at night to generate electricity, or the hydrogen could be burnt in a turbine to generate heat.

With India's Tata Group as his investor, Prof Nocera believes this system could provide affordable power to the millions of people in developing countries who lack access to the grid or to other sources of energy, which is why he is focusing on cost rather than efficiency.

The artificial leaf is a cost-effective solution because, unlike a solar panel, where crystal silicon has to be packaged and wired into a module, Prof Nocera's catalysts interface directly with the silicon leaf.

He believes that designing energy systems must be extremely simple and cheap prompts innovation and creativity.

"I get up in the morning saying, 'what science can I do to make this as cheaply as possible, and then I'll work on efficiency'," he explains.

"In the developed world, we focus on efficiency, and usually with higher efficiency comes higher cost."

He also believes that he can develop new sources of power more easily in countries that lack existing infrastructure than in what he calls the "legacy world", where entrenched systems and vested interests work against anything new and different.

"I always say the poor are helping me," he says. "By designing for them, they can be the early adopters because they're not beholden to some existing energy system – so in that regard the market is easier to penetrate."

Prof Nocera's real breakthrough, however, has been in developing a catalyst that will not oxidise but that continually heals itself as it is working. Here again, he believes that designing energy systems for the poor can lead to scientific discoveries that would not otherwise be made.

Designing something that could be cheaply manufactured meant using low-cost materials – but most of these materials would eventually corrode.

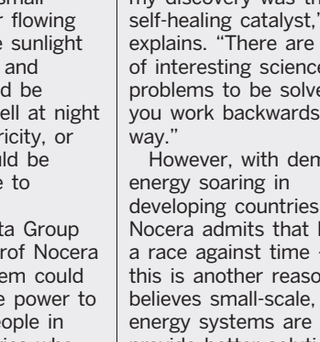
"I needed to overcome the corrosion problem and my discovery was the first self-healing catalyst," he explains. "There are masses of interesting science problems to be solved if you work backwards that way."

However, with demand for energy soaring in developing countries, Prof Nocera admits that he is in a race against time – and this is another reason he believes small-scale, cheap energy systems are likely to provide better solutions for the developing world than large, highly engineered infrastructure.

"It takes a lot of time to develop those things," he says.

"So the best strategy is to make it small-scale and simple to engineer – and then to manufacture the heck out of it."

Sarah Murray



Nocera: Tata Group of India is his big backer

Where the wind blows: even without moving overseas, the Chinese turbine industry has taken up a large share of the world's wind power. About half the turbines installed around the globe last year were in China Bloomberg

Turbine talent seeks overseas outlets

Wind power in China

Sarah Murray reports on state-sponsored success seeking low-income markets

With its voracious appetite for energy and a generous supply of wind, it is no surprise China has rapidly developed a market for wind power. Until recently the market was domestic, but now wind turbine companies are eyeing prospects in markets such as Europe and the US.

"To date, it's been about stimulating investment locally," says Ben Warren, Ernst & Young's environmental finance expert. "But it's also about getting a foothold in the future energy economy."

Already, four Chinese wind turbine makers – Sinovel, Vestas, Goldwind and Dongfang – rank among the world's top 10 turbine manufacturers. Even without moving overseas, the industry has taken up a large share of the world's wind power. "About half of the wind turbines installed around the world last year were in China," says Mr Warren.

In this rapid expansion, turbine manufacturers have had generous state support. As the government seeks to reduce its dependency on coal-based power, it has worked aggressively to develop renewable sources of energy, and the wind industry has been at the receiving end of many of the policy carrots.

Under Beijing's renewable energy law, wind generation projects have received particularly strong incentives. In addition, national targets have accelerated the development of renewable technologies while feed-in tariffs have guaranteed a rate of return for investors in wind power.

"It's a policy driven market," says Liming Qiao, China director of the Global Wind Energy Council. "The renewable energy law, which is the framework for all renewable energies, came into force in 2006. Since then, the industry has thrived."

The government has also been anxious to attract outside investors to help build technological capabilities. As in other sectors, by running pilot programmes and scaling them up, the country has built industries that are low risk and require low investment levels.

"That's what they did with wind starting around 2000," says Caitlin Pollock, senior analyst for Asia Pacific wind energy at IHS Emerging Energy Research.

"They handpicked several companies and tried making wind turbines and then encouraged a lot of companies to make components though subsidised programmes." Additional measures have included auctioning land that was permitted for wind farm installations and stimulating investment and developer interest through guaranteed supply contracts.

Through its "wind power base" initiative, China plans to build a series of 10-gigawatt wind plant sites in resource-rich parts of the country by 2015.

> Manufacturers in China are shifting their focus from volume and economies of scale to quality

"It's tremendous growth," says Ms Pollock. "And this is all because of government will and a lot of government support."

While most of this activity has been taking place at home, global ventures are starting to emerge, particularly as the domestic market starts to look crowded. "There's overcapacity, at least in terms of theoretical assembly capacity," says Ms Pollock. "Demand is surging but not at the same rate as supply."

This is partly what has driven some companies to look overseas for new business. In 2008, for example Goldwind bought into Vensys, a German turbine designer. The company also put its first wind turbines on US soil when it installed three in Minnesota.

Sinovel has also been active overseas, signing an agreement in April to develop wind power projects with the Greek Public Power Corporation. In July, it signed an agreement with Mainstream Renewable Power to install 1 gigawatt of wind turbine capacity in Ireland over the next five years, with Mainstream developing and constructing the projects and Sinovel providing turbine technology.

Another Chinese wind company, XEMC Windpower, installed a 5-megawatt offshore wind turbine prototype in the Netherlands in June. In August, it struck an agreement with Gaelectric, an Irish developer, to supply about 13.6MW of wind turbine capacity, including installations at three onshore sites in Ireland.

Expansion overseas will not come without difficulties, however. First, the companies need to meet US and European certifications. Meanwhile, perceptions about the poor quality of Chinese industrial products linger.

"It's part perception and part reality," says Faheen Allibhoy, senior investment officer at the International Finance Corporation, the private sector arm of the World Bank. "The Chinese have expanded the industry very quickly and there are always bugs when you do that."

Companies also need to satisfy the conditions of equity investors and debt providers in a world where international financiers are demanding improved quality in the projects to which they lend.

As a result, manufacturers in China are shifting their focus from volume and economies of scale to quality. For now, ventures in overseas markets remain few in number. "But it's a huge target for these Chinese turbine manufacturers," says Ms Pollock.

Moreover, since most Chinese manufacturers have focused on developing smaller wind turbines than those in the US and Europe, opportunities are likely to emerge outside western markets, particularly in lower income countries.

"We'll see turbines in smaller countries," says Ms Allibhoy. "So the whole market will develop across the world, because there are so many places that need power and wind is a very viable and cost-competitive resource."