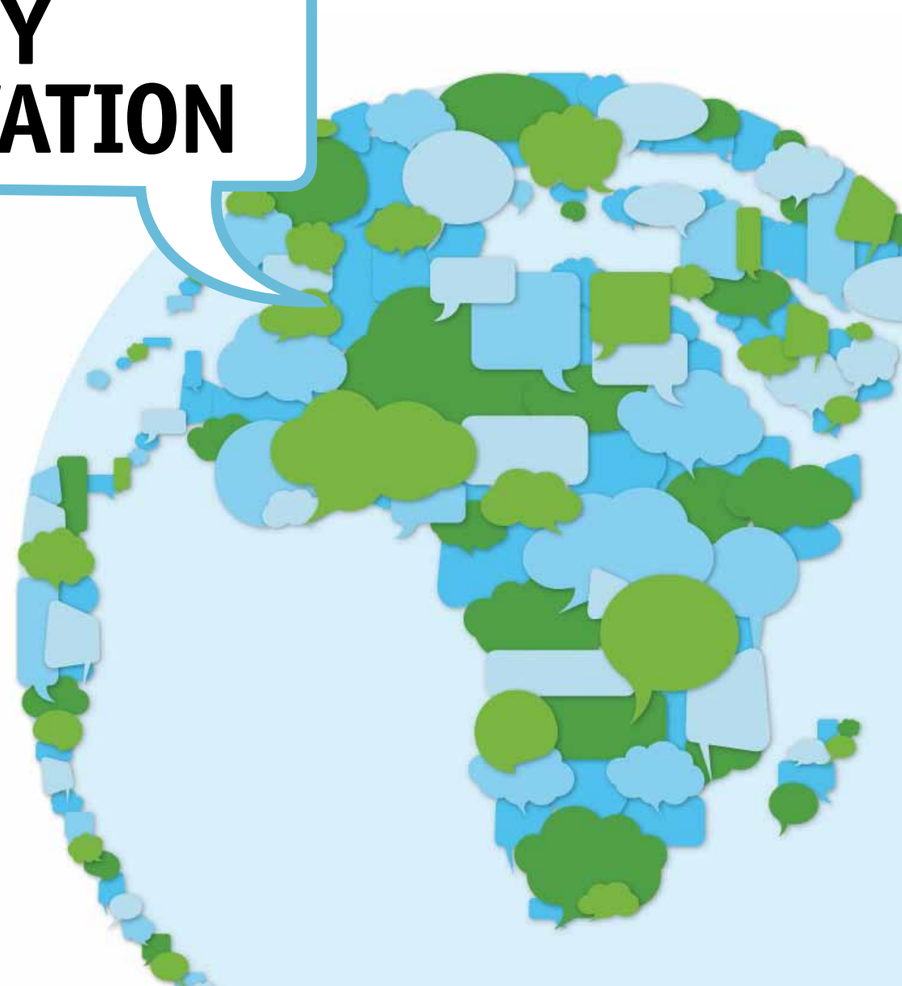
The Economist Intelligence Unit

THE GLOBAL ENERGY CONVERSATION

PART 3

NURTURING ENERGY INNOVATION



Supported by

Economist Intelligence Unit
The Economist Intelligence Unit (EIU) is the world's leading resource for economic and business research, forecasting and analysis. It provides accurate and impartial intelligence for companies, government agencies, financial institutions and academic organisations around the globe, inspiring business leaders to act with confidence since 1946.

Economist Intelligence Unit
20 Cabot Square,
London,
E14 4QW
Telephone + 44 (0) 20 7576 8181
Fax +44 (0) 207 576 8472
E-mail london@eiu.com
www.economistconferences.co.uk

CONTENTS

INTRODUCTION From the Economist Intelligence Unit

It seems apparent that innovation will be required across the energy sector in order to help it meet the twin challenges of rising energy demand and climate change. But seemingly well-meaning policies can turn out to have an adverse effect on innovation and the world's current economic woes may limit the pace of investment. In which energy sources is innovation most needed? How can governments get the policy framework right for stimulating innovation, and then put it to work?

Research carried out for this report highlights technologies and policies to meet the world's energy challenges. According to an Economist Intelligence Unit (EIU) poll of 731 business executives, most technological advance in energy will come from solar, wind and biofuels. But nine in ten respondents say the cost of renewables must come down if they are to replace fossil fuels as the major source of energy.

To facilitate this, 70% of executives think new technologies should be exonerated from trade barriers. Over three-fifths (62%) also say rewarding energy-efficient behaviour is the best way to increase energy innovation. However, just over a third of respondents (35%) think their government is doing enough to raise public awareness of energy and environmental challenges.

Against this difficult backdrop, the experts contributing to this report have been set the task of debating various energy technologies, including solar, wind, gas, nuclear, biofuels and carbon capture and storage (CCS). As an overview, Alex Laskey, president and founder of Opower, an energy efficiency SaaS company, explains how to address the growing demand for global energy through behavioural efficiency programmes.

According to Mark Kenber, chief executive officer of The Climate Group, an international NGO, solar power will bring a step change in global energy markets in the next decade. For Gregor MacDonald, an energy journalist, solar has become too cheap for governments to ignore.

Duncan van Bergen, general manager global gas & LNG market development at Shell, believes natural gas should become the backbone of Asia's energy system, not just a transition fuel. Keith Allott, head of climate change at WWF-UK, disagrees and thinks gas will fail to deliver on high hopes.

Ronan O'Regan, director of renewables and cleantech at PwC, argues that offshore wind will need to become cheaper and find new sources of financing if it is to live up to expectations. Steve Sawyer, secretary-general of the Global Wind Energy Council (GWEC), explains why wind power is a central part of the EU's strategy to reach 20% of final energy consumption from renewables by 2020.

Peter Kiernan, energy analyst at the EIU, explains why emerging economies will continue to drive nuclear power growth in spite of Fukushima. For Phil Burns, director at Frontier Economics, a think tank, nuclear energy policy should be informed by trade-offs between cost, safety and reliability.

Howard Herzog, senior research engineer at the MIT Energy Initiative, highlights how CCS needs reliable investment to unlock its true potential. For Sam Botterill, technical project manager for CCS and power utilities at the Energy Institute, CCS is a safe and reliable way to reduce carbon emissions.

James Wilde, director of innovation and policy at the Carbon Trust, argues that bioenergy has the potential to decarbonise electricity generation, heat and transport globally. Finally, Anandajit Goswami, coordinator at The Energy and Resources Institute, discusses the economic and environmental challenges posed by biofuels.

ABOUT THE REPORT

The Global Energy Conversation Part 3: Nurturing Energy Innovation is an Economist Intelligence Unit report, sponsored by Shell, which invites a group of energy experts to explain their views on technologies and policies to meet the world's energy challenges. It builds on two reports: 'Transitions from West to East', which examined the economic and political circumstances surrounding energy consumption, and 'Solutions to 2050', which explored solutions to meet rising energy demand and tackle climate change. The report was edited by Zoe Tabary.

To support the research, the Economist Intelligence Unit conducted a global survey in September 2012 of 731 senior executives from a range of industries to gauge their views on ways to stimulate energy innovation. Half of the respondents are from firms with US$500m or more in global annual revenue. The executives participating in the survey were drawn from Europe (22%), North America (20%), Asia-Pacific (19%), Latin America (19%) and Middle East & Africa (19%).

We would like to thank all those who participated in the research.

HUMAN BEHAVIOURS AND ENERGY EFFICIENCY

Alex Laskey, president and founder of Opower, explains how to address the growing global demand for energy through innovative behavioural efficiency programmes.

The global middle class is predicted to swell by 172% beween 2010 and 2030. Though increasing the quality of life for hundreds of millions, this population boom will also result in growing pressure on energy infrastructure and demand for reliable, affordable and cleaner energy supply.

While this could pose a threat, it equally presents a huge opportunity for those who can unravel the complexities of how we use energy and how usage patterns can be influenced to deliver real and lasting behaviour change. Truly embedding this change will also be reliant on support from policymakers who can develop innovative behaviour-based energy-efficiency programmes that reduce consumer energy use through cost-effective measures.

Thankfully, it seems the wheels are already in motion. In October 2012 the EU established the European Energy Efficiency Directive (EEED) to respond to this challenge. Through a common framework of measures, the directive aims to remove barriers in the energy market and promote efficiency in the use and supply of energy, to achieve a headline target of reducing energy use by 20% by 2020.

One of the measures that the directive will specifically promote is the empowerment of consumers to better manage their energy consumption. In the US, there are several examples of successful programmes that are already being implemented. Twenty-six states have set Energy Efficiency Resource Standards (EERS) to deliver efficiency savings of between 10% and 20% by 2020. Over 90% of US states with these standards are currently meeting or exceeding them.

Historically, utilities have favoured cost-effective programmes with low barriers to customer participation, such as subsidies for compact fluorescent lighting (CFLs). However, as the energy-efficient lighting standards are raised in the US, the effectiveness of CFLs on reducing overall consumption decreases. As a result, behavioural energy-efficiency programmes have become a compelling option. Taking advantage of the increased data collected through smart meters, utilities can detect patterns in use and opportunities for customers to save energy and money through simple changes to their behaviour.

Characteristics from the successful programmes include measurable and predictable savings for customers, cost-effectiveness, sustained impact and overall customer satisfaction. What the example from the US has shown is that as utilities engage their customers with more information about their energy use and potential savings in a timely manner, their participation and satisfaction increase, resulting in higher energy savings.

Taking these as key learnings, it would be advantageous for European counterparts to begin testing and exploring the potential of behavioural energy-efficiency programmes. While cleaner generation supply will be a key element in the world's ability to meet the growing demand, the lesson is that the most environmentally-friendly and cost-effective kilowatt is the one not used.

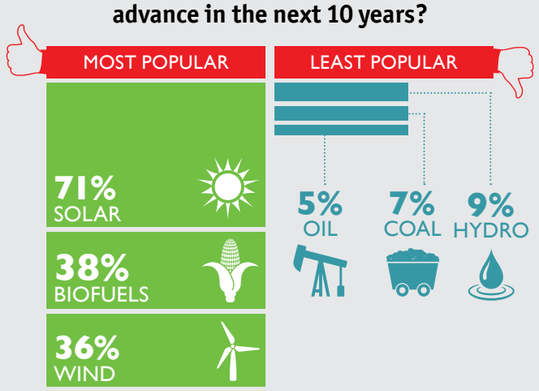
> ***Taking advantage of the increased data collected through smart meters, utilities can detect patterns in use and opportunities for customers to save energy and money through simple changes to their behaviour.***

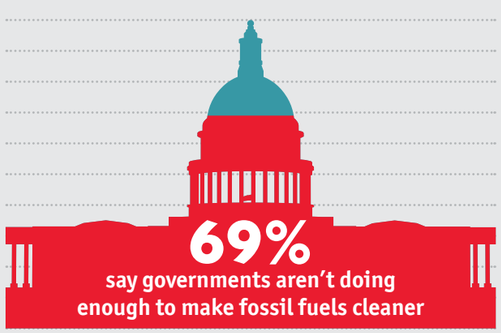
ALEX LASKEY is president and founder of Opower and responsible for engaging utility and government partners with Opower's purpose and products. He was invited to the White House to meet with President Barack Obama to discuss innovation and job creation in the green economy and to testify before the US Senate. He has been a Technology Pioneer at the World Economic Forum in Davos and serves as a Commissioner on the Alliance National Commission on Energy Efficiency Policy.

NURTURING ENERGY INNOVATION

TECHNOLOGIES AND RESOURCES

In which energy sources do you expect to see the most technological advance in the next 10 years?





69%
say governments aren't doing enough to make fossil fuels cleaner

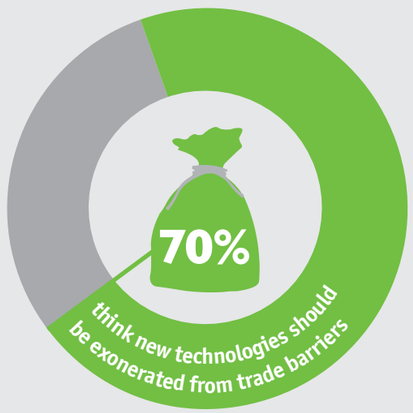
90%
OF PEOPLE THINK
RENEWABLES NEED TO BECOME CHEAPER
IF THEY ARE TO REPLACE FOSSIL FUELS
AS THE MAJOR SOURCE OF ENERGY

POLICIES

62%
of people think rewarding energy-efficient behaviour is the best way to increase energy innovation

44%
are supportive of subsidies for gas

20%
are supportive of subsidies for oil

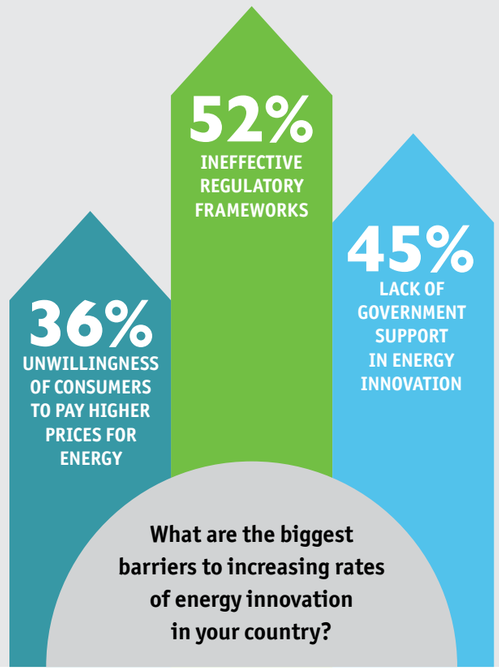


GROWTH

91%
of people think energy innovation is a driver of economic growth

BUT...

63%
think the world's current economic problems will limit the pace of energy innovation



Unless otherwise indicated, infographics depict the results of a survey of 731 people conducted in September 2012.

GAS CAN FUEL ASIA'S ENERGY FUTURE

Natural gas should be the backbone of Asia's energy system in the future, not just a transition fuel, argues Duncan van Bergen, general manager global gas & LNG market development at Shell.

According to the UN, by 2050 our planet will be home to 9bn people—2bn more people than we have today. It is also estimated that three in four people will live in urban centres, with Asia's fast-growing cities absorbing much of that growth. That's like building a new Singapore every month for the next 40 years.

The combination of population growth, urbanisation and vast expansion of the middle class will lead to significant growth in energy demand, which is forecast to double between 2000 and 2050. At the same time, the world will have to find ways to cut C02 emissions more drastically to avoid the impact of serious climate change. In Asia, the challenge will be even more acute – urban populations will grow from 1.9bn today to 3.3bn in 2050 and energy demand will continue to escalate.

Human ingenuity, innovation and technology, combined with the sustainable development of natural resources, hold the key to unlocking the energy needed today and in the future. Globally, this will include increased energy efficiency and the ramp-up of renewable sources, as well as the utilisation of hydrocarbons which will continue to provide a large part of the world's energy supplies, over 60% in 2050.

Natural gas is uniquely suited to be the cornerstone of a more sustainable energy future—one that can meet rising energy demand rapidly and securely, in a way that also reduces both air pollution in dense urban areas and global CO2 emissions. It should be the backbone of future energy systems as natural gas offers a reliable, competitive and cleaner energy source that can be realised fast, not just a back-up or transition fuel.

"Natural gas is set to play a unique role in fuelling developing countries' rapid economic growth."

Asia, for example, has seen a sweeping rise in natural gas production and consumption. Malaysia, Indonesia and Brunei all serve as long-term suppliers of liquefied natural gas (LNG). Thailand started importing LNG in 2011, peninsular Malaysia and Indonesia commenced this year. By the end of the decade, it is expected that six of the ten Association of South-East Asian Nations (ASEAN) countries will be importers of LNG.

According to the International Energy Agency's (IEA) Golden Rules set out in 2012, between 2010 and 2035 primary natural gas demand could increase by up to five-and-a-half times in China, and by over three times in India. Asia and the rest of the world are exploring multiple uses of natural gas including the more traditional use in power generation and as petrochemical feedstock, as well as the increasingly popular applications for highly-efficient and new uses in industrial heat, land and marine transportation.

Natural gas is set to play a unique role in fuelling developing countries' rapid economic growth. Renewables and energy efficiency will enhance that prosperity if the right investment decisions are made in time.

DUNCAN VAN BERGEN is general manager global gas & LNG market development at Shell. Mr Van Bergen's prior work at Shell includes a variety of commercial and business development roles in Europe, Asia, the US and Latin America. Prior to Shell, he led the Asian Gas & LNG practice at McKinsey & Co. Mr Van Bergen's expertise lies in energy markets, global energy and sustainability challenges and issues, energy market policy and reform.

WHY GAS ISN'T THE ANSWER TO CLIMATE CHANGE

Gas will fail to deliver on high expectations, says Keith Allott, head of climate change at WWF-UK.

Listening to the optimists in the gas industry, you would think that the world is on the cusp of a "shale-gas revolution" which will tackle climate change, keep energy bills down and enhance energy security. Large parts of the UK government—including, it seems, Chancellor George Osborne—are keen to promote a vision of the UK as a "gas hub" and reposition gas as a wonder fuel. Unfortunately, this new storyline pays little respect to the facts.

The UK, for example, is now dependent on imports for 65% of its gas supplies and this is set to increase despite any future shale-gas production. So any claim that more gas dependence is good for energy security looks highly dubious. Unlike renewable energy, where costs are declining rapidly, gas prices are expected to rise. Deutsche Bank has said that shale gas is unlikely to be a game-changer, concluding that "we do not expect the impact of shale-gas production on EU gas prices to be anywhere near as great as has been the case with US shale-gas production".

On the climate question, there are valid concerns about leaking, venting and flaring of gas at various stages of the extraction process. Setting these to one side, the carbon intensity of power generation from gas is around half that from coal. The UK's "dash for gas" in the 1990s and rapid shale gas expansion in the US have both helped to cut those countries' emissions by displacing some coal generation, although expansion of renewables and the economic downturn also contributed in the US case. Environmental NGOs aren't blind to these potential carbon savings but they are nowhere near enough to address the threat of climate change, let alone meet the internationally-agreed objective of limiting the average global temperature rise to less than 2°C.

To illustrate the point, the International Energy Agency's (IEA) Golden Age of Gas report compared two alternative energy scenarios, one of which sees a rapid expansion of unconventional gas production. In this scenario, global temperatures rise by at least 3.5°C, which would be devastating for people and nature. The difference in levels of warming between emissions in this scenario and one in which unconventional gas expansion is much slower and gas prices are higher is negligible.

So why does this gas scenario fail to deliver significant carbon savings? In the IEA's report, more unconventional gas leads to lower gas prices. This leads to less investment in energy efficiency and genuinely low-carbon forms of generation which offset the majority of the savings made by gas.

The gas industry used to describe gas as a "bridging" fuel—it now talks of it as a "destination", while renewable energy is frequently portrayed as an emerging niche that cannot deliver at scale. Yet, according to the UN Environment Programme, in 2011 investment in renewable power sources rose to $257bn and non-hydro renewables accounted for 44% of all new power capacity. Quite simply, we should see the gas industry's self-promotion for what it is: a turkey voting against Christmas.

Only with decisive policies by governments to dramatically improve energy efficiency and attract investment in low-carbon generation such as renewables can we have a hope of limiting temperature rises to 2°C. And as the IEA's most recent World Energy Outlook made clear, the vast majority of all fossil fuel reserves—coal, oil and gas—need to stay safely in the ground. Dashing to develop new reserves is steering the world towards a massive climate crash, and risks creating hugely expensive stranded assets.

Dr Fatih Birol, chief economist of the IEA, remarked earlier this year that "a golden age for gas is not necessarily a golden age for the climate". He is spot on.

"Only with decisive policies by governments to dramatically improve energy efficiency and attract investment in low-carbon generation such as renewables can we have a hope of limiting temperature rises to 2°C."

KEITH ALLOTT is head of climate change at WWF-UK, where he leads a team working on UK and EU climate change and energy policy, international climate negotiations, aviation policy and climate change adaptation. Before joining WWF-UK in 2006, Mr Allott spent much of his career working in various senior editorial roles for ENDS, the leading UK and EU publisher of environmental intelligence for business. He also worked for the UK's Royal Commission on Environmental Pollution, including contributing to its influential report in 2000 on energy and the environment.

CLEAN UP WITH SOLAR

Solar power will bring a step change in global energy supply in the next decade, claims Mark Kenber, chief executive officer of The Climate Group.

It is easy to be distracted by negative news headlines about solar energy these days: solar companies going bankrupt, photovoltaic (PV) supply much higher than demand and solar panels causing a new trade war. Still, much of the news agenda misses the wider point: the vast potential of solar power is already changing the energy outlook of many countries and promises to be the global energy success story of the next decade.

The solar PV sector is already a huge success. From a small industry primarily centred in Germany, it has managed to become a global $100bn industry with installed capacity exceeding 65 gigawatts (gw) in 2011, up from 5.4 gw in 2005—a 1,200% increase in six years. In Europe, despite heavy cuts in feed-in tariffs in a number of countries, deployment in 2011 increased by 54% compared with the previous year, to 28.7 gw. This is ten times the build level of 2007. At current growth rates, solar energy could be providing 10% of global power generation by the end of the decade.

There is no doubt that government subsidies have played a significant role in the expansion of PVs. But as subsidies dry up around the world it is the dramatic fall in PV prices and installation costs, and the medium-term cost certainty solar provides, that are driving growth.

A recent McKinsey & Co report found that by the end of the decade, PV costs could decline to $1 per watt peak (wp) for a fully-installed residential system by 2020. Even if costs fall to $2 per wp, the industry is still likely to install an additional 400-600 gw of PV capacity between now and 2020.

According to Bloomberg New Energy Finance (BNEF), the levelised cost of electricity (the cost distributed over a project's lifetime - LCOE) for conventional silicon PV declined from an average of $0.32/kwh in early 2009 to $0.17/kwh in early 2012, while thin-film PV dropped from $0.23/kwh to $0.16/kwh over the same period. As for the first quarter of 2012, BNEF pegs the levelised cost range at between $0.11/kwh and $0.25/kwh.

This means that PVs are now rapidly becoming competitive with fossil fuels. Countries with higher electricity prices, such as Germany, Denmark, Italy, Spain and parts of Australia, have already reached grid parity. Countries like Japan, France, Brazil or Turkey are expected to reach it by 2015. The Middle East and North Africa region is close to grid parity. In the US, solar PV technology is expected to reach grid parity for some projects in 2014, while China could achieve it in most of its regions by 2015-16.

The dramatic fall of PV prices and installation costs, and their increased competitiveness with fossil fuels will bring a step change in energy supply. In developed economies, PVs have the potential to disrupt the regulated utility industry. In developing economies, PVs could bring electricity to remote rural areas and improve the standard of living of millions. In an increasing number of countries, from Saudi Arabia to India and Japan, solar energy is now a vital part of future energy strategy and can drive a clean energy revolution forward.

The onus is now on decision-makers. Policy decisions should not be based on news headlines or influenced by incumbents' resistance to change, but on accurate, up-to-date information and data on solar energy's costs and competitiveness. More importantly, decision-makers should set a clear low-carbon energy strategy which has decarbonisation targets at its heart and is backed up by policy instruments. This will scale up the solar and other renewable industries, further lowering costs and making them even more competitive.

"Policy decisions should not be based on news headlines or influenced by incumbents' resistance to change but on accurate, up-to-date information and data on solar energy's costs and competitiveness."

MARK KENBER is chief executive officer of international NGO The Climate Group. He has worked on climate change for 15 years and is an expert on international climate policy. He advised former UK Prime Minister Tony Blair in the joint policy initiative, Breaking the Climate Deadlock, which produced a series of high-level reports outlining the economic and technological rationale for a global climate deal and its key components.

PRAGMATIC SOLAR

The time has come for governments to seriously consider solar energy, argues energy journalist Gregor MacDonald.

It is almost certainly the case that humanity has entered a third, historic energy transition. The first two, from wood to coal in the 18th century and then coal to oil in the 20th century, in retrospect seem obvious in their outcomes. But no such benefit of hindsight exists today as economies—western in particular—struggle with the end of cheap oil. Left to cast about for the next primary energy source, energy futurists have probed everything from algae to thorium as industrialism limps slowly away from fossil fuels. But one technology offers promise: solar.

Long considered too expensive to consider, solar may now be too cheap to ignore. Solar panels, employed to capture the diffuse rays of the sun, have crashed in price in recent years, causing havoc among solar manufacturers. Panels are now barely one-quarter of the price they were in 2008. The benefits have accrued instead to users, as efficiency of photovoltaic capture continues to advance, while prices continue to decline. The result? Nearly exponential growth in installed, global solar capacity.

But solar's emerging price competitiveness does not explain fully why world consumption has moved in just five years from 5 TWh (terawatt hours) to over 55 TWh. A myriad of government inducements and incentives, which have admittedly drawn criticism, have indeed provided a running start to the nascent solar industry over the past decade. But more recently, solar's ability to provide a much less complex energy alternative, say, compared with nuclear power, has drawn interest, especially in the developing world. In countries such as India, where hundreds of millions of citizens remain unserved by the power grid and constraints on coal-fired power capacity are formidable, solar is now gaining ground as a quicker, simpler way to add capacity.

The stagnation of nuclear power, meanwhile, provides a useful lens through which to compare the rise of solar. Global consumption of nuclear power was almost perfectly flat between 2001 and 2011 at just over 2,600 TWh. Governments should take notice because, priced in terms of future liability, nuclear power's enormous risk and expensive waste are ultimately borne by the public. If nuclear's long construction timelines and heady cost overruns are now a headache, perhaps government support of solar is no longer utopian but a practical choice.

Solar, like other technologies which capture diffuse energy, can never replace the energy density of fossil fuels. Oil, for example, with its 5.8m btu (british thermal units) per barrel, is a veritable miracle substance compared with biofuels, wind power and solar. But as the world economy continues its migration from liquid energy to the power grid, differentiation among energy sources will heighten. Against natural gas, solar offers power without environmental extraction costs. To coal, solar offers the 5bn people in the developing world, already suffering from terrible coal-fired pollution, a clean alternative. Importantly, solar offers the least complex on-ramp now to the power grid. In a world where simplicity itself will command a premium, solar offers surprising and tremendous value.

"Long considered too expensive to consider, solar may now be too cheap to ignore."

GREGOR MACDONALD has written for the Financial Times, The Oil Drum and The Harvard Business Review. He has appeared on MSNBC in the US, BNN in Toronto and the Keiser Report out of Paris. His writings and views have been cited in The Washington Post, The New York Times, the Los Angeles Times, WIRED and Foreign Policy, among others. In 2011 Mr MacDonald was named in the Top Twenty Tweeps for Keeps by Barrons as people to follow on the markets and the economy.

THE PROSPECTS FOR OFFSHORE WIND

Offshore wind will need to become cheaper and find new sources of financing if it is to live up to expectations, argues Ronan O'Regan, director of renewables and cleantech at PwC.

The deployment of offshore wind to date has been focused on north-west Europe, particularly the UK and Germany. Globally, countries such as China and the US have ambitions for significant deployment of offshore wind but have made limited progress.

The primary driver for investment in offshore wind continues to be governments setting energy policy with a commitment to reduce carbon emissions. This is reflected in the medium term, where in Germany, the UK and France alone, ambitions for 30 gigawatts (gw) of offshore by 2020 have been set, with further growth expected beyond 2020. With regard to the longer term, the EU recently set out its ambitions for renewable energy through to 2050 in its 2011 Energy Roadmap, which puts renewable energy at the heart of the shift to a decarbonised power supply.

This commitment to increase deployment of renewable energy has been most evident with EU governments in particular, where they have supported the sector through a variety of measures, the most important being revenue support commitments. While budget deficit issues have forced a rethink on support for renewables in some EU markets, the primary offshore wind regions have retained their commitment and indeed in Germany their commitment has increased following the announcement of a phased withdrawal from nuclear power.

However, the offshore wind sector is not without its challenges and these will need to be addressed if the sector is to fulfil its longer-term potential. Of these challenges, the need to reduce the cost of offshore wind and to access new sources of finance in the longer term will be central to ensuring that the technology achieves its growth ambitions.

The current cost of offshore is c €180/mwh, which is almost three times higher than the wholesale cost of power. These incremental costs for offshore wind are well above the incremental costs of onshore wind but below newer technologies such as wave and tidal. In any event these costs are currently recovered from end users through higher energy bills. In the current economic climate, there is even more scrutiny of the costs of energy and the offshore wind industry accepts that it will have to reduce its cost base over time. It is hoped that a combination of new technology (increasing turbine size, performance and reliability) and optimising the supply chain for cost-efficient delivery of projects, can bring the costs down to a level that minimises the required support.

As the size of offshore wind projects has increased, so too have the required levels of capital to deliver these projects. It is expected that new sources of capital will be required to supplement the current providers of capital (primarily large utilities). It can be expected that these sources of capital will be unlikely to take certain risks (for example, construction) until the industry has a better track record of on-time budget delivery.

Policymakers are currently considering how they can facilitate solutions to both cost reduction and financing challenges to ensure that the industry can realise

> *The need to reduce the cost of offshore wind and to access new sources of finance in the longer term will be central to ensuring that the technology achieves its growth ambitions.*

RONAN O'REGAN has been working in the European power sector for the past 20 years, both in industry and in PwC's energy team. He works with a wide range of clients, including project developers, lending banks, utilities, traders and pure play generators.

THE WIND ENERGY BOOM

Steve Sawyer, secretary-general of the Global Wind Energy Council, explains why wind power is a force to be reckoned with.

Wind power plays a central role in an increasing number of countries' immediate and longer-term energy plans. After 15 years of average cumulative growth rates of about 28%, global commercial wind power installations in about 80 countries at the end of last year averaged 240 gigawatts (gw). They are expected to reach 280 gw by the end of 2012, providing 2.5% of global electricity supply and saving approximately 400m tons of CO2 emissions. Mid-line projections have the industry supplying 8% of global electricity supply in 2020, saving over 1.1bn tons of CO2 annually, and depending on the pace of economic growth and new emissions reduction targets, it could well top 10 or even 12% of global electricity supply by the end of the decade.

China is now firmly established as the world's leading market, installing nearly 18 gw in 2011 to bring its total capacity to over 62 gw, and the government has ambitious targets for the future. The US is the world's second biggest market and is expected to have had a banner year in 2012, though with a precipitous drop-off in 2013 due to highly-politicised energy policy. India and Brazil are the two fastest-growing markets globally. In fact, in both 2010 and 2011, the majority of installations worldwide were outside the OECD, driven both by clear policies and growing electricity demand.

Wind industry is a central part of the EU's strategy to reach 20% of final energy consumption from renewable energy by 2020, and a central part of its emissions reduction strategy. Already providing over 6% of the EU's electricity, this number is set to more than double by the end of the decade. However, the recent upheaval within both the commercial banking sector and the euro zone have slowed its progress in southern Europe.

Due to both technology improvements and market forces, wind equipment costs have come down significantly in the past few years. This is making wind farms cost-competitive and allowing them to compete for market share against subsidised incumbents. Offshore wind is, in development terms, where onshore wind was 15 years ago—as it scales up, costs will come down.

The growth of wind power is taking place against the backdrop of a highly-publicised and often politicised debate about support for clean energy technologies in the absence of an effective price on carbon, air pollution, water pollution or fresh water consumption—these total about $600bn per year globally, about half of which goes to renewable electricity technologies. In comparison, politicians seem reticent to scale back on the $600bn subsidies (according to the International Energy Agency) that are expected to go to fossil fuels in 2012.

Wind power is a central player in our energy future. Whether it will supply 15%, 20%, or 30% or more of our electricity by 2050 will depend on a complex set of forces.

> *Wind industry is a central part of the EU's strategy to reach 20% of final energy consumption from renewable energy by 2020.*

STEVE SAWYER, secretary-general of the Global Wind Energy Council, has worked in the energy and environment field since 1978, with a particular focus on climate change and renewable energy since 1988. He spent many years working for Greenpeace International, representing the organisation at intergovernmental and industry levels primarily on energy and climate issues. At GWEC he is focused on working with intergovernmental organisations to ensure that wind power takes its rightful place in the energy options for the future, and with opening up new markets for the industry in Latin America, Africa and Asia.

DEVELOPING CARBON CAPTURE AND STORAGE

Carbon capture and storage (CCS) needs reliable investment to unlock its true potential, argues Howard Herzog, senior research engineer at the MIT Energy Initiative.

There are truths that cannot be denied. First, nature will determine how serious a problem climate change is, not our politicians. Second, it is always cheaper to vent CO2 into the atmosphere than to capture and store it. Therefore, it is unreasonable to expect CCS to be deployed on a large scale without strong climate policy to drive it.

The most important thing one can do to accelerate the development and adoption of CCS technology is to create commercial markets. While some markets exist for the utilisation of CO2, most notably CO2 for enhanced oil recovery (EOR), they have their limitations. Specifically, the cost for capturing CO2 from power plants is between two and four times the cost that EOR operators are willing to pay. Therefore, in the longer term, there is no substitute for climate policy that puts a high enough price on carbon to create robust markets for CCS. Since the implementation of climate policy is moving at a very slow pace, these climate markets may need a couple of decades to become reality. The key question then becomes what should we be doing now to develop CCS so it can be ready when called upon.

The two key overarching goals for a global CCS research and development strategy are (1) proving the viability of large-scale storage and (2) lowering the cost of capture. Without demonstrating the safety of long-term, large-scale storage, the public is unlikely to ever accept using subsurface formations to store large amounts of CO2. Without lower costs, CCS will not be able to unlock its true potential as a mitigation technology.

To adequately address these goals, the world will need to invest tens of billions of dollars over the next decade. However, traditional funding from government and industrial investment, revenues from selling carbon permits, are proving inadequate. New, reliable sources of funding are required. One possibility is a small surcharge (less than $0.001/kwh) on all fossil-generated electricity.

We also need to rethink our development strategy. We need to concentrate on fewer projects rather than spreading the funding out too thin (in many cases for political reasons). We will need to trade quantity for quality, ensuring that a limited number of demonstration projects produce maximum return.

In summary, CCS is critical for a secure, clean energy future. It is the only technology that can allow the continued use of our large fossil energy resources while drastically reducing their greenhouse gas emissions. However, progress to date has been much slower than desired, not because of the limitations of the technology, but because of lack of funding to develop and deploy them. Whether our expectations for CCS will be met in the future depends on our commitment to invest in it now.

> *The most important thing one can do to accelerate the development and adoption of CCS technology is to create commercial markets.*

HOWARD J. HERZOG is a senior research engineer in the MIT Energy Initiative. Since 1989 he has been on the MIT research staff, where he works on sponsored research involving energy and the environment, with an emphasis on greenhouse gas mitigation technologies. He was awarded the 2010 Greenman Award by the IEAGHG "in recognition of contributions made to the development of greenhouse gas control technologies".

THE NEW ENERGY LANDSCAPE

The UK government's Electricity Market Reform (EMR) bill is likely to drive carbon capture and storage (CCS), says Sam Botterill, technical project manager for CCS and power utilities at the Energy Institute.

The coming of the long-awaited EMR bill poses a most interesting prospect for the new year, as it began progress in the House of Commons in November 2012. The bill aims to provide certainty to investors and bring forward the investment in new infrastructure needed to move toward a diverse, low-carbon economy as affordably as possible. The intent is that this will also support the creation of over 250,000 energy-related jobs.

According to the Department of Energy and Climate Change (DECC), the amount of market support to be available for low-carbon electricity investment (under the Levy Control Framework) up to 2020 has been set at £7.6bn in 2020, which corresponds to £9.8bn nominal 2020 prices. This will help diversify our energy mix to avoid dependency on any one energy technology, increasing the amount of electricity coming from renewables from 11% today to around 30% by 2020, as well as supporting new nuclear power and CCS commercialisation.

The final announcement on the government's CCS competition adds another significant layer to the UK's energy story. The Energy Institute believes that this is one of the key areas where the UK can demonstrate its leadership on health and safety issues. Due to the knowledge-share approach involved in a government funding model of the type set out under the last competition, it will lead to a wide dissemination of knowledge demonstrating how CCS can be executed in a low-risk environment.

The realisation of a scaled demonstration project will require guidance that can be understood by both the current industry and the "next industry" to come. The concept of the next industry lies in the fact that in the course of time, companies that may not have previously had a history in the CO2 or offshore environment could potentially move into this space. These companies should be able to benefit from a mature process of developing good practice.

Globally, there are some major projects underway. Shell is pressing ahead with the Quest project in Alberta Canada, and in Saskatchewan the Boundary Dam project is also progressing well with its build programme, which on December 20th 2012 completed a deal for the off-take of piped CO2. The project, managed by SaskPower, will be the world's first commercial-scale plant. Australia continues apace with the Gorgon Project, while its Global CCS Institute (GCCSI) now has nearly 75 projects registered across the globe.

The idea to combine several technologies into CCS is barely 15 years old and while more progress is needed, it is worth noting how far it has come in such a short space of time. Practitioners in the area have accepted that the priority is to engage the public, demonstrating CCS is a safe and reliable method to remove CO2 from the world's developing power systems.

> *The idea to combine several technologies into CCS is barely 15 years old and while more progress is needed, it is worth noting how far it has come in such a short space of time.*

SAM BOTTERILL manages the Energy Institute's work in the area of carbon capture and storage through the CCS Technical Committee, which looks at hazards and technical issues relating to the introduction of this technology to both the on-and offshore environment. Mr Botterill has written for New Energy World Network and Think Africa Press on a range of political and financial issues.

BIOFUELS AND THE ROLE OF INNOVATION

We must continue to unlock the potential of bioenergy, argues James Wilde, director of innovation and policy at the Carbon Trust.

Unfortunately, there is no silver bullet that will solve the challenge of climate change. This means that low-carbon technologies will be required to significantly reduce carbon emissions. Many see this transformation as a cost to the economy, but responding to climate change represents a huge commercial business opportunity through the creation of new markets. Bioenergy has the potential to decarbonise electricity generation, heat and transport in the UK and globally.

Liquid biofuels used for transport are particularly controversial. They appear to have as many dissenters as advocates. Advocates see a dispatchable renewable energy source, which can use existing infrastructure, can be domestically sourced and could be used to generate low-carbon electricity when combined with carbon capture and storage (CCS). However, dissenters see an energy source that competes with food for agricultural land, creates emissions from land use change, generates air quality concerns and can impact negatively on biodiversity. The debate around bioenergy has moved on in recent years from "can this be done sustainably?" to "how much of this can we deploy sustainably and equitably?". Indeed the UK government's Bioenergy Strategy states that only sustainable deployment will be acceptable in the UK and calculates that around a tenth of UK energy could be provided by bioenergy by 2050. That is significant and we must continue to unlock its potential.

The key to this, and ensuring sustainable deployment goals are met, lies in innovation. Innovation offers the chance to increase deployment of more sustainable feedstocks and to develop and refine the technologies that can convert these, as well as waste, to useful energy outputs. Analysis by the Carbon Trust for the government found that innovation has the potential to reduce UK energy system costs by £42bn by 2050. International business development is calculated to provide further economic value to the UK to the tune of £19bn.

So where to innovate? When looking at priorities for innovation in biofuels in the UK, we found that the highest priority comes from woody and grassy crops with higher yields on marginal land, advanced biofuels demonstration, proof of integrated gasification systems at scale and high-efficiency biopower systems that are robust to a variety of feedstocks and ready for CCS.

Looking beyond the UK, one sector where we believe biofuels innovation is critical to unlock potential is aviation. This is a fast-growing sector where very few alternatives to fossil fuels exist and it represents an ideal market to focus on fast-tracking the commercialisation of biofuels. The sector is seeking a single "drop-in" solution and has a manageable number of major refuelling locations, while its large players are aligned around the nature of the challenge and willing to collaborate to find solutions. By focusing on this sector we believe biofuels will be able to truly show their worth.

> *The debate around bioenergy has moved on in recent years from "can this be done sustainably?" to "how much of this can we deploy sustainably and equitably?"*

JAMES WILDE is director of innovation and policy at the Carbon Trust. The Carbon Trust helps business and the public sector cut carbon emissions and supports the development of low-carbon technologies for the future. Mr Wilde has been at the Carbon Trust for nine years, leading policy and markets work which has informed the introduction of a number of new policies and spanned a wide range of topics in the UK and abroad—from the EU Emissions Trading Scheme, energy efficiency and low-carbon building design through to renewable and low-carbon technology innovation policy.

THE BIOFUELS EQUATION

Anandajit Goswami, co-ordinator at The Energy and Resources Institute, answers questions about biofuels and explains what environmental and economic challenges they pose.

What is the current situation in developing and developed countries concerning the production of biofuels?

In economic terms, first-generation biofuels such as bioethanol and biodiesel posit divergent stories across countries. In Brazil, bioethanol production costs have declined after sustained efforts by the government since the mid-1970s, through research and development, an integrated institutional approach and yield enhancement. The same can't be said of India's bioethanol programme, which began in 2003. Bioethanol programmes to accelerate the reduction of carbon emissions also have a long way to go in other developing countries of South Asia, including Sri Lanka and Bangladesh.

Within the EU and the US, biofuel production costs have failed to come down, partly due to a lack of standardised germplasm and feedstock variety to generate adequate biofuel supply.

What are the likely trends for the future?

Policies such as the EU's Renewable Energy Directive (RED) have directed demand for biofuels towards end-use sectors such as transportation, which has been criticised. A study published by four environmental groups called for the EU to modify its rules to use less damaging crop-based biofuels in transport. In October 2012 the European Commission published a proposal to limit the use of food-based biofuels to meet the 10% renewable energy target of the RED.

Therefore investors and technology producers have moved away from developed countries and tapped into biofuel resources in Asia and Africa to meet their domestic energy demands, supplemented by merchandise trade routes under various bilateral and unilateral agreements.

What, if any, are the environmental and economic risks associated with biofuels?

Investments in biofuels frequently disregard the social, economic and environmental implications of biofuel production. In countries such as India and China, for example, biofuels have been a significant element in the rise of food prices.

This argument is outlined in *Biofuel Delusion: The Fallacy of Large Scale Agro-Biofuels Production*, where authors Mario Giempietro and Kozo Mayumi denounce the overhyped promise of biofuels as a replacement for fossil fuels. They highlight the danger of biofuel production driven to a large extent by profit and of simultaneously ignoring sustainability implications. Second-generation fuels (cellulosic ethanol) and the possibility of cultivating marginal areas, unsuitable for food production, are cited as more effective ways of using biofuels.

What measures should countries adopt to fully realise the benefits of biofuels?

Biofuels offer a promising alternative to the twin challenges of meeting rising energy demand and addressing climate change. Conscious decisions and sharing of information as well as financial and technical assistance will be necessary to minimise the risks associated with biofuel production and to enhance its benefits.

> *Investors and technology producers have moved away from developed countries and tapped into biofuel resources in Asia and Africa to meet their domestic energy demands.*

ANANDAJIT GOSWAMI is a co-ordinator at the African division of The Energy and Resources Institute, specialising in first- and second-generation biofuels. He is also working on climate policy studies for the African Climate Policy Centre of the UN Economic Commission for Africa.

THE OUTLOOK FOR NUCLEAR POWER

Despite Fukushima, emerging economies will continue to drive nuclear power growth, says Peter Kiernan, energy analyst at the Economist Intelligence Unit.

The March 2011 earthquake and tsunami which disabled the Fukushima-Daichi nuclear power plant in Japan sent shockwaves around the world about the viability and safety of nuclear power.

However, the longer-term impact of Fukushima on the nuclear industry globally may be less than anticipated in the immediate aftermath of the disaster. Certainly lessons are being learned by the industry and regulators in several countries, not just in Japan, and necessary adjustments in safety measures and maintenance procedures will be made. The International Atomic Energy Agency forecasts that global expansion of nuclear power post-Fukushima will slow moderately.

All is not lost for nuclear power, with the impetus for capacity growth coming from Korea, Russia, India and China (KRICs). China and India are fast-growing economies that face rapidly-growing energy needs. They also depend heavily on coal. Following Fukushima, China suspended approval for new plants and conducted inspections on its operating and under-construction reactors. The pace of further approvals may slow, but nearly half of the nuclear reactors being built today are located in China. India, which faces a growing energy import bill, also needs to avoid a repeat of the power blackout that wreaked havoc in July 2012. In Russia and Korea, nuclear power is a long-established source of electricity supply and this will continue, with further construction of reactors.

In Europe and North America the story is different. Nuclear power already represents a large share of electricity supply—especially in France, Belgium, Switzerland, Sweden and Hungary—and nuclear power generation had reached something of a plateau. However, the fallout of Fukushima was felt the most in Europe, with Germany bringing forward its complete phase-out plan to 2022 and Switzerland deciding to shut down its reactors by 2034. In Europe, only a handful of reactors are under construction or planned, and countries that have excluded nuclear power so far are unlikely to change policy.

The US, which has the most number of reactors (104), only has one plant under construction. Future growth in capacity will likely be curtailed by the rapid growth in natural gas supplies—caused by the so-called shale gas boom—which has sharply lowered the cost of gas-fired power generation. This combined with poor euro zone economic performance which has depressed energy consumption and slashed access to credit, has also worked against prospects for nuclear power in Europe. The decline of US coal-fired power generation is causing surplus coal to find its way to Europe, making coal in Europe more price-competitive to gas.

The outlook for nuclear power in Europe and North America is sluggish, and the Fukushima disaster will compel regulators worldwide to monitor industry practices more aggressively. Growth in the sector will be slowed as a few countries phase-out nuclear power completely, while others slow the rate of further approvals or decide not to start up with nuclear power at all. The KRICs, however, will continue to drive the capacity growth in nuclear power.

> *High construction costs and, more recently, the global economic slump and the greater availability of cheaper alternatives—such as natural gas and coal—are likely to be more influential in restricting the growth of nuclear power among OECD economies.*

PETER KIERNAN is energy analyst at the Economist Intelligence Unit. He has a Master of Arts degree in International Political Economy and Development from Fordham University, New York, and since then he has worked in energy journalism and in consulting—in Washington DC and in London.

KEEPING THE NUCLEAR OPTION OPEN

Nuclear energy policy should be informed by trade-offs between cost, safety and reliability, argues Phil Burns, director at Frontier Economics.

At the end of 2011, the European Commission published the Energy Roadmap 2050, which explores the challenges posed by delivering the EU's decarbonisation objective while at the same time ensuring security of energy supply and competitiveness. It is clear that to achieve these levels of decarbonisation major investments will be needed to replace the current carbon-intensive generation park.

These investments will focus on low-carbon generation. This includes renewables, potentially carbon capture and storage (CCS) plants and, most controversially (post-Fukushima, at least), perhaps nuclear.

Before the Fukushima disaster there was much talk of a nuclear renaissance, and projects were mooted in several European countries. Sentiment switched following the disaster in Japan, with Germany accelerating its plant closure and Switzerland deciding on a cap of 50% of nuclear's share in production.

Energy policy is, inevitably, a political matter. This is particularly the case where nuclear power is concerned. But in setting energy policy, politicians can't ignore real-world constraints. Everyone would like to have an energy system which delivers safe, secure and cheap energy produced with minimal emissions. But, at least with today's technology, such systems don't exist.

European policy currently subsidises renewables heavily. Earlier this year Günther Oettinger, the European commissioner for energy, endorsed the idea of a new binding target for renewables after the existing 20% target for 2020. At what cost? Solar subsidies are costing German customers over €6bn per year. And neither solar nor wind power can provide security of supply alone.

Estimates of the costs of nuclear-generating capacity vary dramatically, both in desk studies and in real life. Take the Olkiluoto 3 plant in Finland which started out with a €3bn estimate and then ran into massive delays which have already cost a further €2.65bn. EDF's Flamanville plant in France started with a €3.3bn price tag—recent estimates stand at €8bn. However, it is important to bear in mind that Olkiluoto 3 is the first Generation III+ plant in the world and Flamanville is the first in France. Their costs have to be considered in this context.

So renewables are intermittent and expensive. Nuclear power involves big engineering projects with resulting cost uncertainty and will always bring with it safety concerns in the public's eye. But it looks likely to be cheaper than many renewable options. Traditional fuels such as gas, coal and oil will remain "dirty" until CCS technology is proven at industrial scale. Even then, they will be expensive until CCS technology matures and reduces in cost.

All of this means there is no single silver bullet. Energy policy needs to be informed by the trade-offs. In the wake of the Fukushima disaster, a reaction against nuclear power is understandable, but it is likely that this comes at a cost which politicians and voters need to understand. Future generations may not thank us for pressing on regardless, which is what a further binding renewables target post-2020 might just represent.

> *In the wake of the Fukushima disaster, a reaction against nuclear power is understandable, but it is likely that this comes at a cost, which politicians and voters need to understand.*

PHIL BURNS is a director at Frontier Economics, specialising in regulatory and competition analysis in the energy sector. He is an expert on utility regulation and liberalisation policy, and has shaped policy through his work with clients and his published work, which extends across sliding scale regulation, comparative efficiency measurement and incentive design to align commercial and policy objectives.

PART III: NURTURING ENERGY INNOVATION

NOTES

NOTES