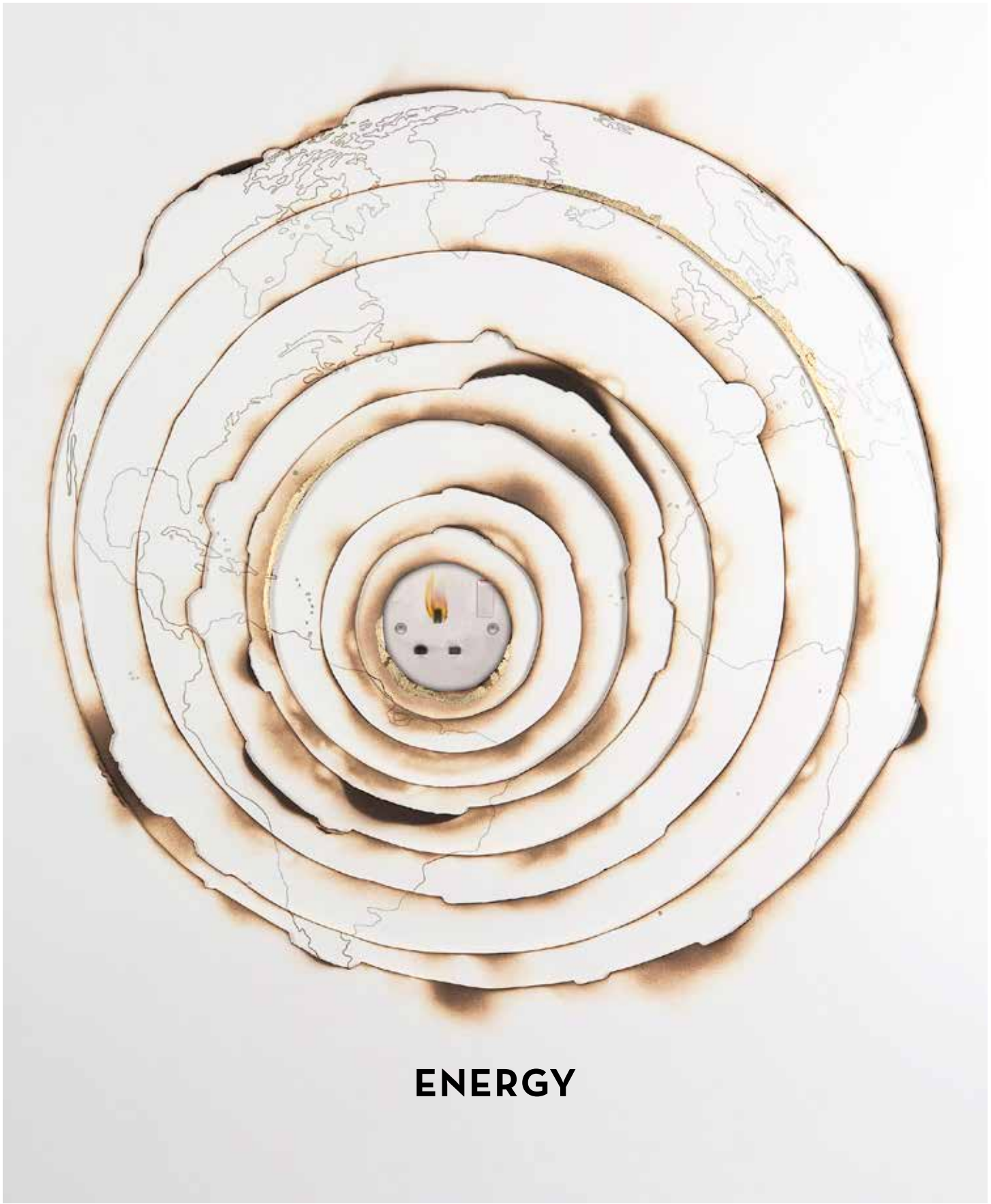
ENERGY

ENERGY

WELCOME

Welcome to the second issue of *Antenna* – where we focus on the major global trends that are shaping the world around us and that will have an impact on the markets.

In this issue we explore the world of energy, and the question of how we can ensure a future that is sustainable for our way of life as well as for our planet. The ability to harness different sources of energy has been central to the development of civilisation. It affects everything from our domestic routines to geopolitics; it involves the latest science and engineering; and it is increasingly influenced by regulation and market requirements.

Today, the energy industry is increasingly shaped by China's bold strategic ambition to dominate the market. The impact of this has often been huge investment, substantial growth and even precipitous price deflation. That has typically been a boon to consumers and advanced the spread of renewable energy sources abroad, but at the expense of shareholder returns.

This highlights how, from an investment perspective, the picture is more complicated than might be assumed. Indeed, while there is much debate about new technologies, it is striking how the traditional heavy hitters of big oil still have a role to play. Only by really understanding the choices in front of us, will we place ourselves in a position to benefit from the opportunities available.

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BREWIN DOLPHIN

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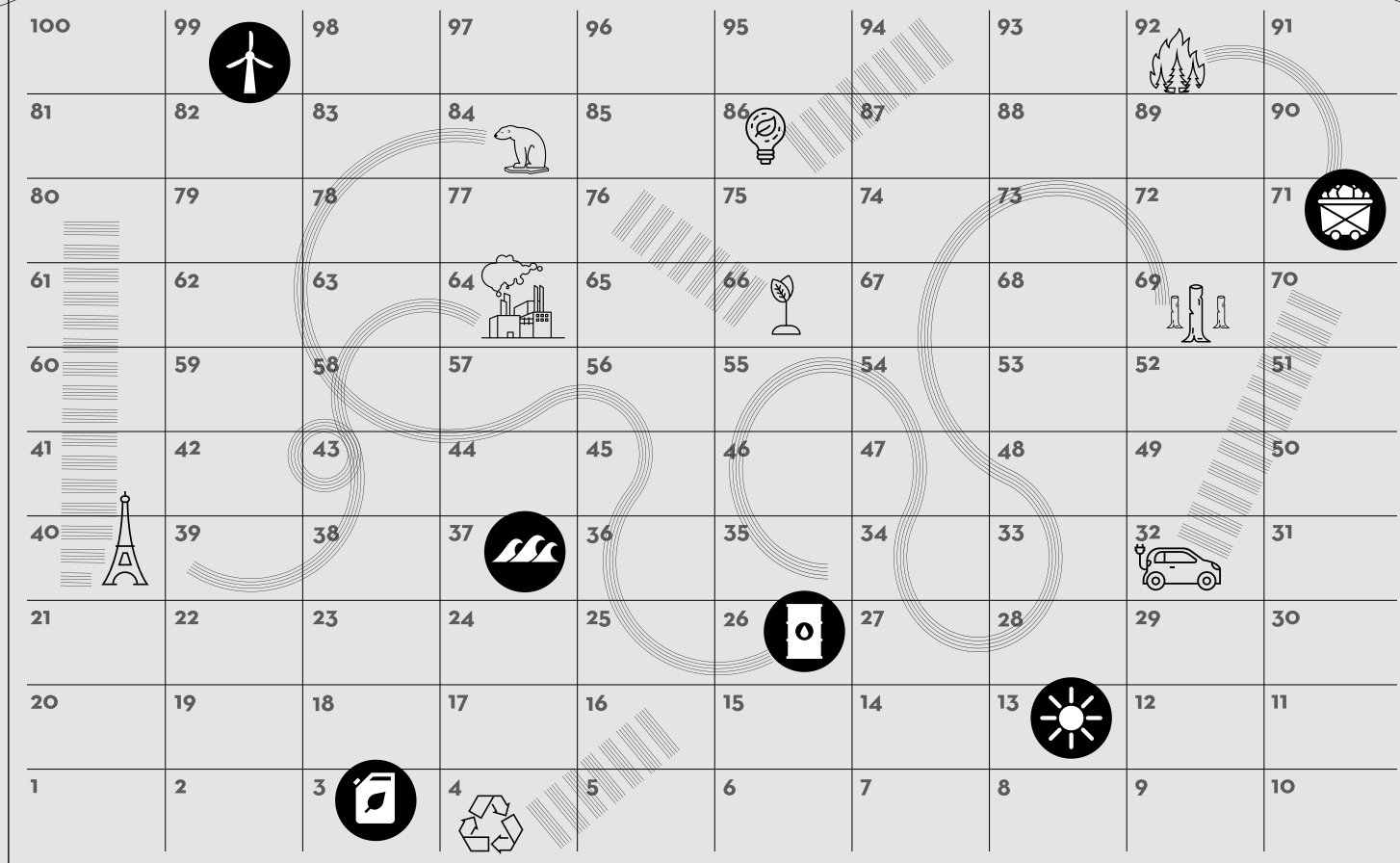


TIME FOR AN ENERGY GAME CHANGER?

Many are touting renewables as the future of our energy system, but we will still be reliant on fossil fuels for some time

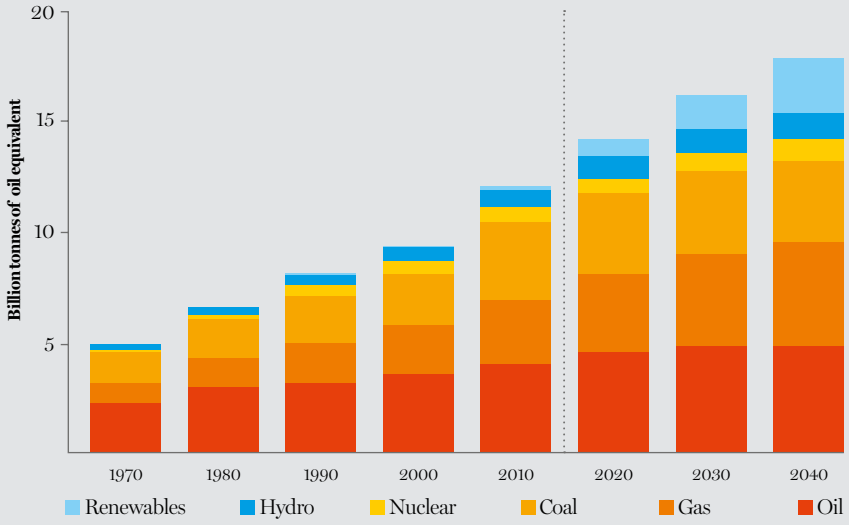
In terms of weather, 2018 was a year of extremes. An uncharacteristically prolonged bout of hot and sunny weather in the UK during summer might have raised some eyebrows, but was nothing compared to events elsewhere: snow in Florida for the first time in nearly 30 years at the start of 2018, a full 15 inches of snow in the Sahara Desert, and the 'Beast from the East' arctic winds that caused havoc across Europe. These were followed by record-breaking high temperatures across Europe during the summer and devastating forest fires in California in October and November. Such extreme events are causing considerable alarm, and are seen by many scientists as evidence of climate change.

In 2015, 195 countries signed the Paris Agreement, making a historic pledge to keep global temperature increases this century well below 2°C above pre-industrial levels, and ideally below 1.5°C. As the ink dried on the agreement, delegates commissioned a panel of scientists to investigate what will happen when temperatures reach the lower end of that spectrum and what could follow. The panel's conclusion, published in October 2018, was stark: we have 12 years to avoid environmental catastrophe.

While this is the biggest collective challenge in recent human history, the UN's report is clear that we have the means to meet it. The key lies in controlling carbon pollution, which must be cut to zero by 2050. The report outlines several paths to this end, but one theme runs through many of the recommendations: the transformation of our energy system.

Primary energy consumption by fuel

Based on current trends, with no significant policy changes. The continued scale of fossil-fuel consumption demonstrates the size of the challenge we are facing.



Source: 2018 BP Energy Outlook

To limit increases to 1.5°C, renewables would need to supply 70-85% of electricity by 2050, carbon capture and storage would need to increase significantly where fossil fuels are used and, in the gas-guzzling transport sector, low-emission alternatives would need to be rolled out rapidly.

But climate change is not the only factor influencing the shape of the energy sector. Try as we might to limit our fossil-fuel consumption, the global population is set to expand by nearly 50% by the end of the century. Added to this demographic pressure is the imperative of improving living standards in the developing world. Globally, more than one billion people lack access to electricity. As living standards improve, spurred on by industrialisation, demand for energy is following in step. And to serve this development need quickly, fossil fuels still represent a cheap, easy and reliable win.

HOW LONG WILL WE BE DEPENDENT ON FOSSIL FUELS?

Looking 20 years into the future, BP predicts we will still be heavily reliant on fossil fuels. By 2040, coal, oil and gas will each represent roughly a quarter of global energy consumption (75% overall), while non-fossil-fuel sources – renewables, hydro and nuclear – will together make up the final quarter. So although there will be a large increase in renewables capacity, this will be in addition to fossil fuels, rather than swiftly replacing them.

These figures reflect the extra demand created by those demographic and technological pressures. But they also show efforts to reduce carbon emissions. Carbon capture and storage – a means of removing CO_2 from the waste products of power generation, industrial processes, or even the air, and locking it away so that it cannot enter the atmosphere – should be an "urgent priority", according to John Browne, the former chief executive of BP.

As well as the significant inroads it is predicted renewables will make, natural gas should start to take a bigger share of total energy consumption. This will be valuable, as natural gas emits half as much CO_2 as coal and even fewer pollutants, but is more reliable than fluctuating renewable sources. Such benefits have already spurred China's policy of encouraging a transition from coal-fired power stations to gas, significantly increasing demand.

However, according to the recent UN report, gas use would need to be reduced by a minimum of 20% over 2010 levels by 2030 to not exceed the 1.5°C target. So, while natural gas is seen as a pathway to a low-carbon future, it is not a silver bullet. Only the massive deployment of renewable energy, or the sudden ramping up of nuclear power, would achieve the international community's aims. But given the societal and political constraints placed on nuclear power, the latter is unlikely.

WHAT COULD THE ENERGY TRANSFORMATION LOOK LIKE?

How the transition will pan out is very unpredictable. The power sector is leading the way. In 2017, the world added vastly more renewable power capacity than any other type of energy, according to the UN Environment Programme. That expansion was not just driven by environmental concerns, but by economics. The International Renewable Energy Agency forecasts that by 2020, all renewables will be cost-competitive with fossil fuels, and the best solar and wind projects significantly cheaper. China, the US and India are leading the charge, and will account for two-thirds of global renewables growth in the next three years.

Opinions vary widely about the speed at which our energy ecosystem will transition away from fossil fuels, often based on previous examples. But the change we are witnessing today is not like previous transitions. It is not a market evolving in the presence of a more efficient or cheaper technology. It is the proactive remodelling of a market in response to an environmental imperative. Government, the market and civil society are all involved in this process, and our success or failure in managing energy-related emissions will depend on all three working together.

Above all, it will involve more than just a remodelling of how we generate electricity, but also how we distribute and use energy. As with all fundamental economic transitions, this may not be a predictable process. It is in the complexity of the change that there will be opportunities for smart investors to profit. ■

A BRIEF HISTORY

(250 years of energy progress)

The development of humanity has gone hand in hand with innovations in energy, from the first use of fire, through to the harnessing of coal and oil and breakthroughs in nuclear and renewable sources

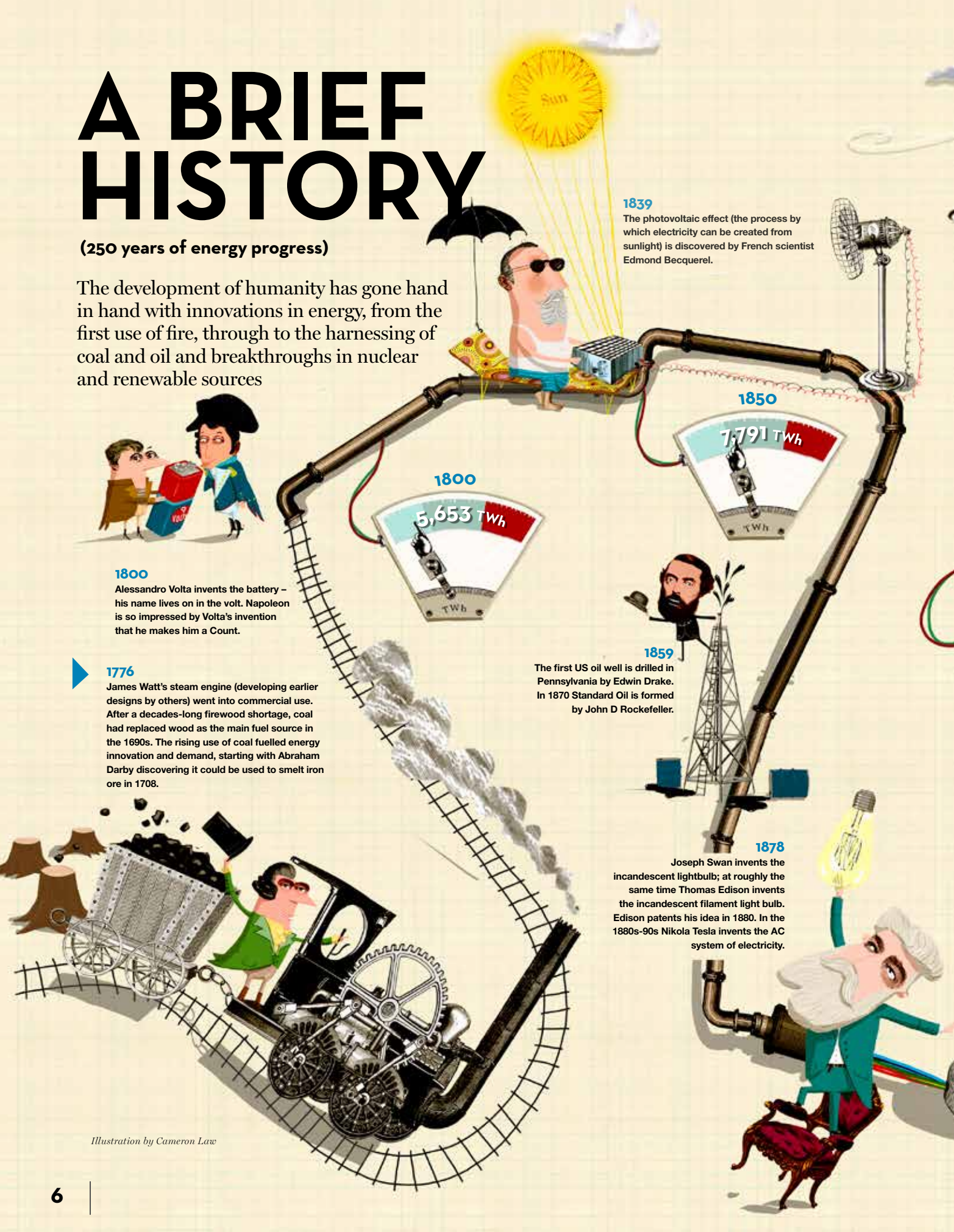


Illustration by Cameron Law

1980
The world's first wind farm is built in New Hampshire, US.

1997
The Kyoto Protocol is signed – an international treaty that extends the UNFCCC and commits state parties to reduce greenhouse gas emissions.

2015
The Paris Agreement is adopted by 195 members of the UNFCCC to reduce emissions. The signatories have pledged to cut their carbon output and keep global warming to well below 2°C above pre-industrial levels. In 2017 the US delivered its official notice to withdraw from the agreement.

THE FUTURE...
Flying cars, robot servants, fusion-powered rockets that could propel us to another galaxy...

1973
Worldwide energy shortages are caused by the oil embargo of key oil-producing countries.

1938
Nuclear fission is discovered by Otto Hahn and his assistant Fritz Strassmann. It had almost been discovered in 1934 by Enrico Fermi. He was awarded the Nobel Prize for his work in 1938; Hahn received the Nobel Prize in Chemistry in 1944. In 1942 Fermi built the world's first nuclear reactor.

KEY

Global primary energy consumption, measured in terawatt hours (TWh) per year.

GENERATION GAME

Generating electricity from emissions-free sources promises to solve the energy challenge. But is the world ready for renewable power?

Huge progress has been made in renewable energy over the past two decades. Much of this has been driven by an international consensus on limiting emissions, and the extent to which climate science has entered the public consciousness. However, political will and changing public opinion are not enough to sustain momentum on their own. There are a range of other factors that affect the success of adopting renewable energy: different countries have different natural resources; governments have varying policies and approaches to climate change; the wealth of individual nations affects their priorities and abilities; and there are also myriad energy security considerations.

In terms of affordability, the price of solar panels has fallen 73% since 2010, according to the International Renewable Energy Agency, and prices are expected to halve from today's rates by 2020. Onshore wind is around a quarter cheaper over the same period and is now the cheapest form of new generation capacity in many places, including the UK. Even offshore wind, once one of the most expensive forms of energy, has seen costs fall so rapidly that it is now competitive with coal, gas and nuclear. Costs are likely to fall further as fleets of floating wind turbines are installed further out to sea, enabling them to take advantage of higher and more consistent wind speeds.

Progress towards integrating renewables into the energy mix varies around the world, with countries such as Costa Rica, Norway and Uruguay well on the way to being 100% renewable, while the UK still obtains 74% of its energy from fossil fuels. Iceland is 100% renewable, for example, because it has ample hydropower and geothermal capacity and because its population is tiny. It is not so easy for the largest emitters such as China, the US and India, which are all huge economies with large populations. In India and China, as in many other emerging economies, lifting people out of poverty quickly through economic development has been a bigger priority than climate targets, which means coal power stations are still being built in both countries.

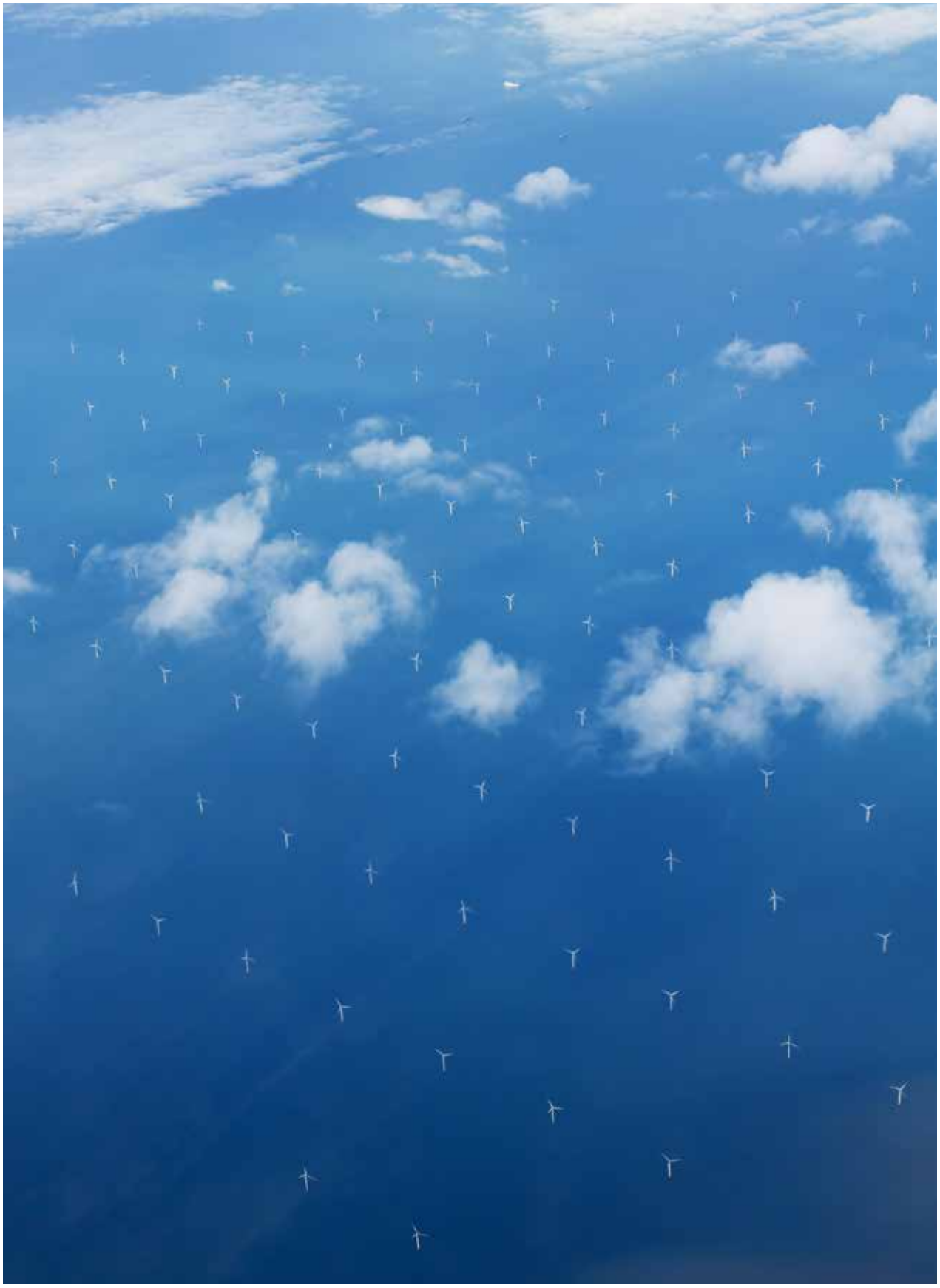
Political, economic and energy security considerations also come into play. Poland is the most heavily coal-dependent economy in the European Union and is reluctant to wean itself off the heavily polluting fuel because it does not want to depend on gas supplies from its historical rival, Russia.

In Germany, whose supportive policies kick-started the global solar market, renewable energy contributes a third of the country's power, more than double the proportion in the US. But it still sources 40% of its electricity from coal. This is partly because it decided to shut down its nuclear power plants early in the wake of the Fukushima nuclear disaster in Japan, and partly because of the influence of the coal lobby – the industry supports 20,000 jobs. That number is dwarfed by the 340,000 employed in the renewables sector in Germany, but the heavily unionised coal workforce is organised and politically well connected.

A SMOOTHER FUTURE

Yet, while the history of the renewable energy sector has been uneven, its future should be much smoother. It is important to remember that the industry is still relatively new – the first offshore wind farm was installed off the coast of Denmark only in 1991 – and governments around the world have been grappling with how best to support the sector.

The feed-in tariffs (FITs) introduced by many governments to encourage clean energy technologies have been victims of their own success. FITs pay out to green energy producers, including individual households. But with the cost of renewable technologies falling far faster than anticipated, governments have been caught out



by the popularity of the schemes. In countries where renewable energy markets are starting to mature, FITs are being phased out and some 67 countries, including the UK, have switched to auction schemes where the right to supply renewable energy is opened up to bids. These auctions have promoted competition and dramatically driven down prices.

The policy environment has improved, too. Over the past decade, governments have often appeared half-hearted in their support for renewables. It was widely held that embracing renewables would economically disadvantage countries relative to their peers, and integrating large amounts of renewables into grids was seen as impossible. However, since 195 nations signed the Paris Agreement in 2015, momentum has increased across the globe. In December 2018, negotiators from around the world attended the COP24 climate change conference in Katowice, where a deal was agreed to put the Paris Agreement into practice. Even where national governments have been lacklustre in shepherding change, local action has taken up the mantle. In the US, for example, where President Trump is notably hostile to action to tackle climate change, more than 230 cities and towns have committed to uphold the targets. And in Australia, state governments blocked national energy legislation they feared would jeopardise local renewables programmes.

The UK though is not doing as well as it could. Despite having introduced the world's first climate change law in 2008 and its target of cutting emissions by 80% from 1990 levels by 2050, the UK has a poor record on encouraging solar and onshore wind facilities. The Government has introduced a de facto ban on onshore wind projects, and it has also cut support schemes for solar, even though its own surveys consistently show that the public overwhelmingly supports the use of more renewable energy. Most recently, the Government has announced that, from April 2019, anyone who installs solar panels will not be paid for the excess power they export to the national grid. However, it is becoming increasingly difficult for a government focused on reducing energy bills to maintain these policies, as solar and wind are fast becoming the cheapest forms of new power capacity.

The strength of the economic drivers has made investors around the world increasingly confident about clean energy projects, not least because a growing number are being commissioned directly by companies that want to reduce their carbon footprint. Bloomberg New Energy Finance (BNEF) reports that corporations buying directly from generators committed to purchase a record 5.4GW of clean power in 2017. By August 2018, they had already exceeded that figure, having bought 7.2GW. Crucially, they are doing so not just for the environmental benefits, but because it is cheaper, reduces price volatility and gives them more control over their energy supplies.

Seb Henbest, Head of Europe, Middle East and Africa for BNEF, says that by 2050, almost half of power will be

Images from iStock

generated from renewable sources. Solar and wind are likely to remain the dominant renewable energy technologies for years to come, but there are other technologies waiting in the wings.

Wave power is one option that has received a lot of media attention. The technology is well understood but development has been held back by the challenge of making devices robust enough to withstand the marine environment. The hydrogen economy also has potential. When burnt, hydrogen releases only water and heat. However, it is not naturally occurring and so must be produced in the first instance. If this is done using surplus renewable energy, hydrogen could be used cleanly to power fuel cells in homes and cars or burnt to provide heating. But with virtually no infrastructure in place, the hydrogen economy seems a long way off at the moment. Similarly, other technologies such as biomass and biofuels have stalled in the face of the success of wind and solar.

A host of non-energy technologies, such as artificial intelligence and the internet of things, also have the potential to improve energy efficiency and the efficacy of the grid, which will make it easier for renewables to fill the gap left by fossil-fuel plants as they shut down.

The renewables boom is unlikely to be derailed by competition from oil and gas, even with the advent of new sources such as the US's shale gas resources, because of the need to cut greenhouse gas emissions and because clean energy costs will continue to fall. Fossil fuels are commodities, so their price will always be volatile, as recent years have shown, while renewable energy is technology-based so its costs are on a downward trajectory. Renewable technology will also improve, with breakthroughs such as solar windows raising the prospect of ever more diffuse generating capacity.

There is strong momentum behind renewables at the moment – the world reached one terawatt (one trillion watts) of wind and solar power capacity in June 2018, about half a century after the birth of renewable energy as an industry. The second terawatt is predicted to arrive by 2023, and to be 46% cheaper than the first. It seems that the momentum is all in renewables' favour – it just remains to be seen whether governments worldwide will adopt a renewables-focused approach. ■

THREE TAKEAWAYS

1. By 2020 the price of solar panels will have halved from today's rates. Onshore and offshore wind power costs will also continue to fall.
2. Although most countries are committed to climate change targets, in many the priority is still lifting people out of poverty. This often means a continuing reliance on fossil-fuel power generation.
3. Renewables' importance is unlikely to be derailed by a resurgence of oil and gas. As renewables are tech-based, their costs are on a downward trajectory.

OPPORTUNITIES:
GREEN SHOOTS

Investing in renewable assets is paying off for fossil-fuel energy giants

Rapid growth can often be associated with excellent investment returns, but it must always be allied to profitability. For unprofitable companies, the faster they grow, the quicker they consume shareholders' capital. Profitability is determined by companies that can do something that is difficult for peers to replicate.

In the solar industry, that is not the case. Solar is an incredibly fragmented industry, with almost 700 suppliers worldwide at the latest count. Part of this reflects the ease with which companies can enter the market, but it also reflects the support that the Chinese Government has shown for the solar power industry. Chinese companies are behind more than 80% of the expansion in photovoltaic component production, a market they already dominate.

This increase in capacity has been a factor driving down prices and also profits, with the MAC Global Solar Energy Stock Index (which tracks solar manufacturers) down more than 70% over the past decade.

Over the same period, in contrast, Royal Dutch Shell has given a total return of well over 100% and BP, despite halving in value due to the Macondo disaster, has still given a positive total return of 70%, highlighting the challenges that new entrants face.

Large oil and gas companies are not resting on their laurels and are instead reinvesting part of their cash flow in renewable assets. Shell, for example, has just established the first high-speed charging station in Europe for electric vehicles. They hope that this will allow them to become the energy companies of the future, as well as the present.

LIGHTS OUT

Are we sufficiently protecting our power grid from cyber attacks?

Over the past two years, the power grids of Ireland, Ukraine, Germany and the US have come under attack from cyber criminals based in Russia and China. To date, the largest power grid outage as a result of a cyber attack occurred in Ukraine in 2015, when 230,000 residents lost power for six hours. But what if hackers managed to cause a more sustained outage?

Julius Weitzdörfer, Research Associate at Cambridge University's Centre for the Study of Existential Risk, has assessed the UK as being "four meals from anarchy" were the national grid to come under a disabling attack. Taking down the power supply would have immediate consequences, and if an outage continued for an extended period of time, hospital systems would grind to a halt, fresh water supply would be affected and sewage treatment centres would stop working.

Cyber attackers trying to access major power companies or national grids do not go for their main targets directly, as such organisations have top-level security. However, there are always weaker links in the chain. Techniques such as 'spear phishing' and 'watering hole' attacks are common ways for cyber attackers to gain access to their larger, more secure targets via other parts of the supply chain.

So how can we make our networks more secure? AI and machine learning will be two major areas. The US Defense Advance Research Projects Agency has contracted BAE Systems to develop automated cyber defence tools. The company will combine machine learning and advanced cyber attack modelling to protect from large-scale attacks. Other methods include developing deceptive network technology (which confuses cyber attackers when they have breached a system) and increasing a company's amount of encryption. Blockchain (an ever-expanding list of records that are linked using cryptography and are resistant to their data being modified) may also enhance cyber security.

Investing in the human side is another key area. Educating and upskilling people – including both laypeople and tech experts – is vital in helping to prevent cyber attacks.

As our lives are increasingly digitised, the risks associated with successful cyber attacks will increase. Prevention is better than cure, so it is likely that cyber security and defence will continue to be in demand for the foreseeable future.

Images from iStock and Getty Images

POTENTIAL ENERGY

Using electricity generated from renewable sources rather than oil and gas could decarbonise our roads and homes. But how can we better control our energy flow and storage to ensure we have an even supply?

"STORAGE IS KEY TO THE SUCCESSFUL WIDESPREAD USE OF RENEWABLE ENERGY"

Under the fossil-fuel system, when the grid requires more power, the grid operator can call a gas-powered station to respond rapidly, firing up its turbines and using its gas stores. To enable the successful widespread use of renewable energy, we need to be able to do the same thing. Renewable energy storage is now becoming an option as domestic and utility-sized batteries become more viable.

As developed countries such as the UK move from a centralised, fossil-fuel-based system to one that incorporates distributed, low-carbon energy sources, they face numerous practical challenges. At the most fundamental level, grid operators have to manage demand while integrating a myriad of dispersed, weather-dependent wind and solar power plants. Which begs the question, how will the lights remain on when the wind is not blowing or the sun is not shining?

A growing number of renewable power projects are being built with a storage element included. Under 'energy arbitrage' arrangements, batteries charge during daylight hours or when the wind is blowing, then dispatch to the grid during darkness or on calm days, when electricity is more valuable. However, the most frequent application of utility-scale batteries is in the much more lucrative ancillary services market. Battery companies can bid for contracts that may, for instance, require them to respond within a matter of seconds to a demand for power from the grid operator.

Electric car company Tesla made a splash in 2017 when it connected a giant 100MW/129MWh battery system to the 309MW Hornsdale Wind Farm in South Australia to provide ancillary services to the state's creaking electricity grid. Within six months, the installation had reportedly taken more than 55% of this market from conventional steam turbine generators and reduced the cost of those services by 90%. However, opportunities in the ancillary market are finite, as it is getting increasingly competitive.

The long-term success of storage as a solution to generation peaks and troughs will depend, of course, on the cost competitiveness of battery technology. Lithium-ion is the predominant battery technology at the moment. These batteries are found everywhere, from smartphones and tablets to electric vehicles (EVs). Bloomberg New Energy Finance (BNEF) has identified 131GWh of lithium-ion battery manufacturing capacity worldwide. The bulk of this is in Asia, with almost 60% in China. By 2021, the research firm expects that GWh number to more than triple, with China controlling around 73%. Thanks to the burgeoning EV market and sharp increases in China's manufacturing capacity, lithium-ion battery prices are expected to carry on falling (despite fears last year that a spike in cobalt prices would reverse the long-term downward trend). Cheaper batteries should help to make renewable energy arbitrage economically viable during the next decade, which would help facilitate further penetration of wind and solar.

Other promising storage technologies include flow batteries. These are a cross between a conventional battery and a fuel cell. They last longer than lithium-ion batteries and can be quickly recharged. US aerospace firm Lockheed Martin is working on a utility-scale flow battery that it says will address some of the shortcomings associated with lithium-ion technology, such as its relatively short runtime and limited lifespan. The company says the battery will be made of inexpensive, non-toxic materials and be ready by mid-2019.

Yet, while batteries are part of the solution, they are not the whole answer. There are several problems with batteries. For one, they lose their charge when they are not charging, but more significantly, in countries such as the UK, energy demand peaks in the winter months, when there is less sunshine. Building enough batteries to store energy for use in the depths of winter that then sit largely redundant during the summer would be cost prohibitive.

The solution to renewable intermittency is therefore likely to be a mixture of different technologies. Hydrogen is another storage option attracting attention. Large volumes of the gas can be stored and converted to and from electricity using electrolysers and fuel cells, although costs will need to fall substantially for it to become feasible. Meanwhile, the potential of one of the oldest energy storage technologies, pumped hydro, is gaining fresh adherents, with Scotland's Loch Ness recently revealed as the site for a proposed 2.4GWh project.

International grid connections can also help by ensuring energy produced is not wasted if there is no demand from the national grid. Connection to markets (such as Norway) that have pumped hydropower storage capacity is seen as particularly valuable. Britain has 3GW of interconnector capacity, with an additional 4GW (including a link to Norway) due for completion by 2022.

MICROGRIDS

But to think of the intermittency challenge purely from a utility-scale perspective is to ignore fundamental changes that are on the horizon.

Improved battery performance and falling prices have increased the effectiveness of small-scale local power networks, known as microgrids, particularly in places where the conventional grid is unreliable. "We're seeing battery costs come down and microgrids connected to batteries are becoming the norm," says Alex Eller, Senior Research Analyst at Navigant Research. By 2026, the firm forecasts that almost 15GW of batteries will be connected to microgrids globally.

Ofgem, the UK electricity market regulator, warns that continued growth of microgrids could have major implications for the national grid. "Whilst the immediate consumers of such local schemes will benefit from reduced costs, the remaining consumers may increasingly have to pay a higher proportion of the costs [for the grid]," it said in an article published in 2017. It also pointed out that wealthy consumers are more likely to participate in microgrid schemes, with those who are less well-off left shouldering a greater share of the national grid cost burden.

But microgrids could change the nature of the national grid if they become widespread. Under such a scenario, utility grids could go from meeting almost all our electricity needs to merely topping up our supplies if and when needed, according to research published by consultancy EY. And as power generation and distribution becomes less centralised, so too could the responsibility for infrastructure.

It is not just consumers driving the trend towards decentralised grids. In Britain, UK Power Networks has announced plans to create a 'virtual power station' made up

Illustrations by Matt Dartford

"MICROGRIDS COULD CHANGE THE NATURE OF THE NATIONAL GRID IF THEY BECOME WIDESPREAD"

of solar panels on the roofs of people's homes, and battery technology, starting in London. The idea is that homes will be able to sell their stored power to the network operator, which will be able to remotely instruct batteries in homes to discharge at peak times. UK Power Networks says this will ultimately reduce costs across the grid because capacity can be built without adding more substations and cables.

Even those electric cars that we will increasingly see on our roads could become part of the national grid. Operating on the same principle as the virtual power station, a scheme by energy supplier OVO and carmaker Nissan will see owners of the new Leaf model able to sell their excess battery capacity from 2019. Drivers will be able to set the minimum amount of charge they need for travel the next day, while OVO tops up batteries during off-peak hours and sells electricity back to the grid when demand is high.

All of this consumer storage capacity, combined with utility-sized solutions, will help manage fluctuations in the supply of renewable energy, while redefining the grid and blurring the definition of consumer and supplier. But batteries will need to see price reductions before they can achieve anywhere near their true potential in tackling the intermittency challenge, and other solutions will also be needed to meet full demand. One thing is clear, though – the storage and distribution of energy will become increasingly diffuse. While this metamorphosis is taking place, we will need other sources to continue to provide us with a secure supply of energy. ■

THREE TAKEAWAYS

1. The development of renewable energy storage will be key to the successful widespread use of renewable energy.
2. However, this will depend on the development of cost-competitive battery technology. Flow batteries could be an efficient answer.
3. Decentralised grids look to be one option. These microgrids could cut costs for users, but, conversely, could mean that those still using the national grid could end up paying more.

OPPORTUNITIES:
POWER UP

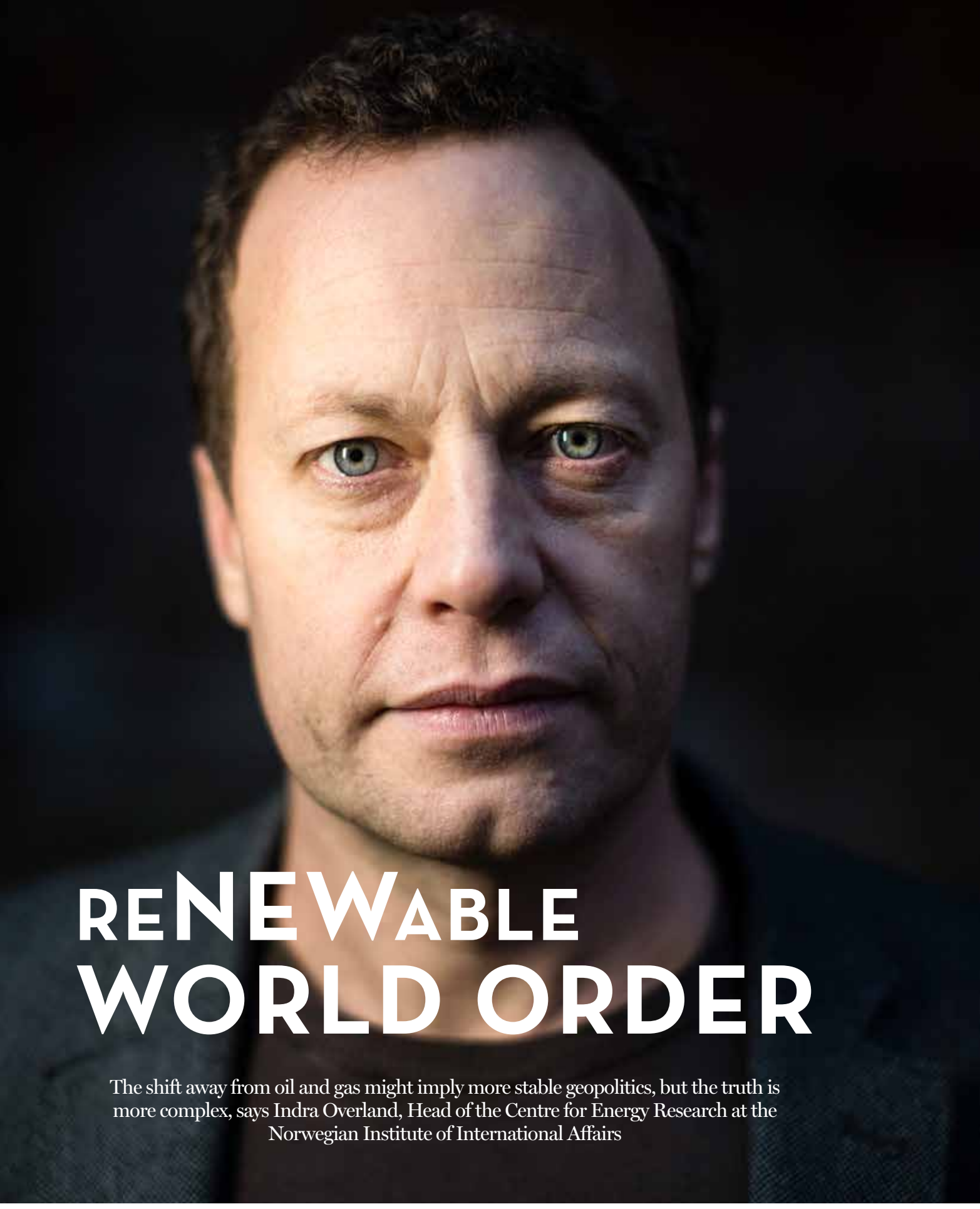
As the market becomes more competitive, diversification is the answer

In the world of storage, competition is beginning to heat up. Panasonic is the biggest producer of lithium-ion batteries in the world but it has started to face competition, particularly from Korean firms LG Chem and Samsung SDI. Most notable, however, has been the increase in competition from Chinese entrants.

The exciting growth market of batteries, therefore, is not without risks. Johnson Matthey is a company that is keen to avoid putting all its eggs in one basket. While it has growing businesses in battery materials and battery systems, it is also still improving catalytic converters and emission control systems to reduce emissions – this will continue to be an important business for the foreseeable future. Similarly, chemicals company Croda has a batteries division, while also helping to improve fuel efficiency for conventional vehicle users.

In diversifying to give themselves the best chance of success, they are following an approach that should not be lost on investors.

In terms of energy distribution, the market is diverse. For example, the North Sea Link is a joint venture between the UK's national grid and its state owned Norwegian counterpart, Statnett. The actual engineering, however, is the joint effort of a number of suppliers and contractors, with the cables coming from Nexans of Norway and Italian firm Prysmian. While there is a clear need for the skills these companies bring, they offer less exciting opportunities.



RENEWABLE WORLD ORDER

The shift away from oil and gas might imply more stable geopolitics, but the truth is more complex, says Indra Overland, Head of the Centre for Energy Research at the Norwegian Institute of International Affairs

"In the short term, an increasing share of renewables in the energy mix may be destabilising, because you could have [oil-dependent] regimes unravelling," says Indra Overland, Head of the Centre for Energy Research at the Norwegian Institute of International Affairs.

"But in the long term it will have a positive effect on stability in international affairs."

Over the past decade, the amount of hydrocarbons produced in the US has risen sharply, helped by a surge in shale output. The US oil renaissance has reinvigorated the country's energy industry and is helping to end the era of OPEC dominance of world energy markets. The International Energy Agency (IEA) now predicts the US will be the biggest global oil producer by 2023, with output of almost 17 million barrels per day (b/d). While this represents an important shift in the balance of power in world energy, it is probably just an interim step to a more profound change for oil producers as renewable energy erodes the dominance of fossil fuels.

Renewable energy is far more evenly spread around the world, and removing the need to fight over resources also removes one of the main underlying causes for conflict. All countries have some wind, sunshine or rivers that could be used to generate electricity. Some may still find it easier and cheaper to import energy from elsewhere, but there is the potential for most governments to harness their own resources if need be.

"Renewable energy resources are fundamentally more widely distributed than fossil fuels, especially oil and gas," says Overland. "So I think there will be less unevenness in the world energy economy, and that's probably a good thing for stability."

Even within the context of renewable energy resources, though, there are still potential problems that, at the very least, are likely to lead to competition between countries. In particular, renewable energy still depends on natural resources. Much attention tends to focus on so-called rare earth minerals, a group of 17 elements including dysprosium, neodymium and praseodymium (used in magnets in electric car motors and wind turbine generators), lanthanum (used in hybrid car batteries) and samarium (used in electric aircraft motors). Demand is also likely to increase for more readily available resources such as cobalt, lithium and graphite – all essential for battery technology – and copper, widely used in electricity grids.

Countries with large quantities of these materials can look forward to high demand and possibly high prices in the future, albeit with the volatility characteristic of commodities markets. It is hard to predict demand for specific minerals, though, as much depends on the evolution of renewable energy technologies. "There are definitely risks for some countries, but it is difficult to say which ones," says Overland. "We don't know which minerals [will be in demand] because it depends on technologies and they are changing."

How well a country endowed with important minerals will cope will vary. Overland points out that there is now greater understanding about how to avoid a 'resource curse' – when an influx of revenues from natural resources drives out other economic activity – but there are still dangers for less resilient economies.

Of the countries that have lithium, for example, Overland says: "Bolivia has a record of populism, although it has natural gas already so it has some experience. Chile [the world's largest lithium producer] is an extremely well-managed economy. Australia [the second-largest producer] is also a well-managed place and isn't going to be swallowed by some lithium resource curse."

On the other hand, the Democratic Republic of Congo, which produces more than half the world's cobalt, could be vulnerable. "Congo isn't ruined by cobalt prices, it's ruined by problems in Congo and the heritage of Belgian colonial rule," explains Overland.

Overall, China looks to be one of the best placed countries to benefit. It dominates the graphite market with 69% of world output and is a leading producer of cobalt and lithium. It also accounts for 84% of the world's rare earth mineral production, according to the World Mining Congress. All this will help to strengthen China's economic influence at a time when it is increasing its diplomatic and military reach around the world.

Other potential issues with the shift to renewables include the risk of cyber attacks on electricity grids and the vulnerability of cross-border electricity networks. However, in many ways these are simply new aspects of existing issues. After all, the oil trade has long been vulnerable to disruption, particularly at key choke points such as the Strait of Hormuz.

The renewables industry is gradually coming to terms with such challenges. In January 2018, the International Renewable Energy Agency (IRENA) launched a Global Commission on the Geopolitics of Energy Transformation. Chaired by Ólafur Ragnar Grimsson, former president of Iceland, it has been tasked with examining the international supply chain for rare earth minerals, cross-border electricity trading, changing investment patterns and new aspects of national energy security, among other issues. The commission will report its findings in early 2019.

Whatever further conclusions are reached, it is inevitable that there will be winners and losers from the switch to renewable energy. The history of past energy

transitions – from wood to coal and then from coal to oil and gas, for example – shows how they can drive improvements in lifestyles and industrial innovation. However, such changes can also leave local or national economies that relied on the previously dominant fuel struggling to adjust to the new reality, with painful socioeconomic consequences.

Countries that currently rely heavily on oil and gas revenues and have little else to fall back on look particularly vulnerable to the rise of renewable energy. It will not simply be the loss of income that will create difficulties for them, though. As revenues fall, so too will confidence in their wider economies and, with less money available, governments will have limited ability to deal with the fallout. Countries such as Venezuela and Nigeria could be vulnerable on this count, along with the Gulf countries.

"The dramatic story is in the unravelling. It's the transition process, the potential collapse of states and the relatively rapid changes," says Overland. "Who will care about the Gulf if there isn't oil there? They would be left to their own devices. There are people in Saudi Arabia who are more religiously extreme than the current rulers."

On the other hand, the winners of the new world order are likely to be countries that either have the intellectual property (IP) rights for renewable technologies or the natural resources needed to underpin them. According to Overland, among those that look best placed are the US, China and Russia.

"Russia is so big and it has all types of natural resources," says Overland. "So it will trade its natural resources with whoever has the IP rights, which will be the US or China. Europe has very little – it doesn't have many resources and it doesn't have much IP either."

One thing that no one can be certain about, though, is just how quickly all this might happen. "I'm not sure what will happen and whether it will happen in five years or 50 years, but when things happen I think they will be abrupt and dramatic," says Overland. "I don't think it's going to be a gradual process. I think it's likely to reach some tipping point and then it will be contagious."

Photography by Christopher Olsson

ONE QUESTION

WHAT NEEDS TO CHANGE FOR THE WORLD TO DITCH ITS FOSSIL-FUEL HABIT?

CLAUDIA KEMFERT, Professor of Energy Economics and Sustainability at the Hertie School of Governance and Head of Energy, Transportation and Environment at the German Institute of Economic Research

"For a world without fossil fuels to become a reality, we need alternatives such as renewable energies, electric mobility, fossil-free drives or energy storage. On the other hand, societies must be prepared to bear the costs of a greener future – the polluters must pay for their own damage and compensate the victims. Furthermore, society must be able to fully adjust to sustainability with more savings, the avoidance of waste and the consistent recycling of all raw materials. All this must be made possible by smart policy frameworks, such as pricing CO_2, promoting sustainable technologies and ensuring that society is strengthened by that transition."

PETER KIERNAN, Lead Analyst, Energy, The Economist Intelligence Unit

"Two things are essential: finance and technology. Currently, hundreds of billions of dollars are invested every year in renewables, other low-carbon sources and energy efficiency, but this will still need to rapidly increase over the next two decades. The most recent IPCC report highlights that US$2.4 trillion (about 2.5% of global GDP) will be needed annually in climate-related investment between now and 2035 to limit the global temperature increase to 1.5 degrees. This is a significant upscale on what is currently spent. It is also important to understand that decarbonisation of the economy involves not just the electricity sector but other sectors as well, such as transport, industry and buildings. In the power sector there are ready-made alternatives to fossil fuels, but decarbonising other sectors will be a greater challenge where alternatives have not yet been developed or are too expensive. The spread of electric vehicles could be a starting point in deploying a low-carbon pathway in sectors other than electricity."

ANGUS MCCRONE, Chief editor, Bloomberg New Energy Finance

"Clean technologies are winning the cost battle in both electricity – via wind, solar and battery storage – and in transport, via electric vehicles (EVs). New wind and solar projects are already undercutting the cost per megawatt-hour of new coal- and gas-fired plants in many countries, and EVs will be cheaper than competing gasoline cars on both a lifetime and upfront cost basis by the late 2020s. However, world CO_2 emissions are already far too high for climate stability and are unlikely to peak for ten years or so because of the commitments already made to fossil-fuel generation. So there is a need for fresh government policies to accelerate the decommissioning of coal plants, assisting the transition in affected areas, and to clear obstacles that are in the way of the take-up of EVs. Regulations to improve the quality of air in urban centres are likely to be an important part of this."

Illustrations by Paddy Mills

THE BIG SWITCH

It is easy to think that cleaning up our energy habit is about shifting to renewable sources. But this alone will not bring carbon emissions under control, unless our relationship with energy consumption fundamentally changes at an individual level

Demand for energy can be split into three core areas: electricity (where the biggest source globally remains coal); transport (predominantly oil); and heating (mainly gas). Non-fossil-fuel power generation can make our increasing electricity consumption less environmentally harmful, but for the bigger picture to truly improve we need to tackle our consumption habits as individuals.

The UK population is forecast to rise by 3.6 million over the next 10 years, meaning an increase in energy demand. In addition, the 'energy rebound effect', where the gains from greater energy efficiency are undermined through human behaviour, needs to be seriously examined and addressed. For instance, a more energy-efficient home heating system may result in less energy being used, but it may also mean that the financial gains from a smaller energy bill go on carbon-intensive activities instead, such as long-haul flights. It could also, conversely, actually result in more energy being used, as people feel they do not need to be as careful with their consumption.

We also face the hurdle of decarbonising the infrastructure on our roads and in our homes. Transport and residential heating account for 45% of all energy used across 19 of the world's most developed countries, according to International Energy Agency (IEA) statistics.

On our roads, most agree there will be a shift away from diesel and petrol cars; the challenge lies in what will take their place and how fast the transition can be achieved. In two of Europe's biggest economies, France and the UK, governments have pledged to end the sale of new petrol and diesel cars by 2040. The UK has set an interim target for 2030 of half of all new cars sold to be ultra-low emission. This would include electric, hybrid and vehicles running on new fuel sources such as hydrogen and biofuel.

Harald Heubaum, Lecturer in Global Energy and Climate Policy at SOAS University of London, says biofuels are not going to be the solution to our transport problems because they are not actually sustainable. "If anything, we should be moving funds out of first-generation biofuels and putting them towards genuinely low-carbon options," he says. "One of those is electrification, but hydrogen fuel cells also deserve another look. In the short term, we'll also need greater fuel efficiency and hybrid models."

Speed of uptake for new vehicle technologies will be determined by the market as well as policy. Kingsmill Bond, New Energy Strategist at think tank Carbon Tracker, argues that changes in the market are likely to follow the development path of energy technologies such as wind and solar, where traditional analysts have consistently underestimated the pace of growth due to falling costs. Bond points out that small drops in market share can have a profoundly disruptive impact and argues that major tipping points occur when a disruptive technology takes only 2–3% of the market. In China, electric vehicles (EVs) took 2.4% of market share in 2017, with over three million on the roads, while globally two million EVs were sold. Nearly 40% of new car sales in Norway in 2017 were electric models. Iceland and Sweden also saw a significant proportion of new car sales going electric, representing 11% and 5% of their countries' 2017 market share respectively.

As Simon Harrison, Group Strategic Development Manager at consultancy Mott MacDonald, points out: "There is huge car industry momentum towards electrification. This will drive scale economies and performance improvement. Fortunately, the car industry sees itself in a survival battle with the technology industry for personal mobility, so the driver for change has become something outside of the climate debate." That makes the proposition for change much stronger, throwing focus on the infrastructural implications of widespread EV use, from charging points to sufficient electricity generation.

Various infrastructure solutions are being explored around the world. In the UK, for example, startup

Urban Electric is trialling pop-up EV chargers that retract underground, addressing the problem of those 43% of UK households that only have on-street parking. One big challenge is how to manage long journeys without extended stops at charging points. At the moment, hybrids tend to be the car of choice for conscientious consumers who go on extended journeys. But in Sweden, one solution currently being tested is electrified roads. A mile-long stretch of public road outside Stockholm has been fitted with electric rail, which transfers energy to cars and trucks through moveable arms trailing underneath the vehicles.

The national grid in the UK has also highlighted the possibility of rolling out more rapid chargers that take just five to 12 minutes. In the US, San Francisco-based hire company Scoot and Chinese startup carmaker CHJ are planning a new joint venture exploring the potential to run a fleet of EVs without charging infrastructure, simply by making it possible to change batteries at battery swap stations in the space of a moment or two. This is building on huge success in China, where electric scooter and bike rental fleets are being run this way.

Whatever the process of providing power to the vehicle, however, the implementation of large-scale electrified transport will require a correspondent increase in electricity generation and management. One big question is how long that will take.

Filippo Gaddo, Director of Energy, Economics and Regulation at engineering firm Arup, says the evidence suggests we should expect a 10–20 year transition to EVs for passenger vehicles (and hydrogen for heavy goods vehicles) in the UK. "Such transition may be slow to start but it will accelerate once the required infrastructure is in place, mainly because the UK will require almost the same amount of infrastructure to accommodate an EV fleet of 10 million as that of 20 million," he says. "The investment in EV charging networks will need to be in place by 2030 [to meet the Government's target of ending petrol and diesel cars sales by 2040]."

HOT HOUSE

There is far more change on the horizon, though. According to Gaddo: "Finding a solution to the decarbonisation of heating is the most important challenge over the next 20 years. It is as important as the transition from internal combustion engines to EVs in the transport sector."

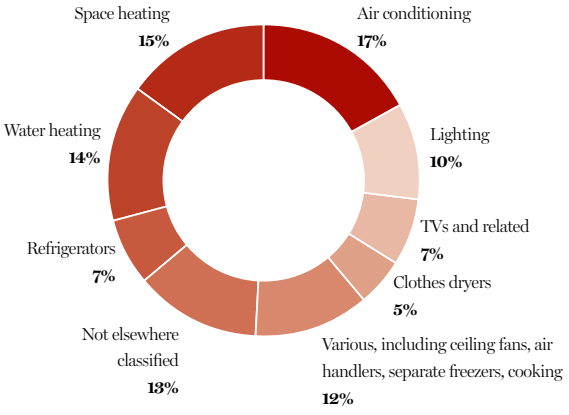
Gas is getting a relatively good press at the moment while the bad boys of fossil fuels, coal and oil, are still on the scene, but to limit global temperature rises to even 2°C, natural gas use will need to drop 26% by 2060 from 2014 figures. At a national level, the UK has pledged to reduce greenhouse gas emissions by 80% by 2050, which is likely to mean that heat-related carbon dioxide emissions will need to be near zero by that year, according to researchers at Cardiff University's Energy Systems Research Institute.

The UK gas and electricity regulator, Ofgem, has called the decarbonisation of heat arguably the biggest challenge facing UK energy policy over the next few decades and the Government has been looking into the cost of the process. In a world where heating is often provided by gas, the process will be difficult and expensive, as infrastructure in homes and industry will need to be refashioned.

Some of the practical solutions include at least partial electrification of heating, improvements in energy efficiency in buildings and consumption, the use of lower-carbon gas, hydrogen networks and further development of heat

Illustrations by Peter Crowther

Residential electricity consumption by end use, 2015



Source: US Energy Information Administration

networks. The latter, otherwise known as district heating, is a system whereby hot water is produced centrally as part of another process – such as waste-to-energy or industrial process heat – and piped into homes.

The challenge of decarbonising the heating system is compounded by: the pressure added to the grid at peak times by electrification; a slow turnover of building stock; an increasing preponderance of renting reducing investment; and a fragmented supply chain lacking the scale and ability to act in anything more than small pockets of influence.

Mott MacDonald's Harrison believes a diversity of approaches to be likely, depending on the regional context. These may range from hydrogen delivered through gas networks to district heating (using centralised hot water production) to electric heat pumps (which use energy to move heat from cold to warmer locations). The latest thinking points towards hybrids; for example, electric heat pumps topped up by hydrogen or low-carbon gas at peak times.

The details of redeveloping our heat and transport infrastructure appear overwhelming, but they will need to be worked out if we are to stand any chance of meeting climate change targets. Transition from old systems to new also provides opportunities for investors. The speed of that change will depend on government policy, market innovation and consumer action, but also on reliable electricity distribution, and infrastructure with the capacity to meet growing demand. ■

THREE TAKEAWAYS

1. Transport and residential heating account for some 45% of total energy usage across the world's 19 most developed countries.
2. Ofgem has said that decarbonising heat is one of the most significant challenges that the UK will have to tackle over the next few decades.
3. No matter what changes are made at an infrastructural level, it is only in conjunction with a change in individual consumption habits that these will have a game-changing effect.

OPPORTUNITIES:
ENERGY SHIFT

The move to electric vehicles will drive growth in related industries

Few would doubt that the most significant change to the way in which we consume energy will come from the assumed shift from internal combustion engines to electric vehicles (EVs). The growth of that market is highly dependent upon developments in batteries.

For now, the market leader appears to be Tesla (in combination with Panasonic). However, Tesla is a controversial company, with serious doubts over whether it can achieve its production targets. Furthermore, China has identified EVs as another of the markets it wishes to lead in, raising the risk that it will oversupply the battery market in the same way it oversupplied the solar industry.

This leaves leading companies in the automotive battery market, Tesla/Panasonic and China's Contemporary Amperex Technology, as rather risky plays on both the growth of the industry and each company's respective market share within it. There are, however, a huge range of sub-component manufacturers that provide much of the real innovation behind this market.

GKN, recently acquired by Melrose, is the industry leader in producing the powertrain components of EVs. Renishaw's additive manufacturing process is invaluable in prototyping components for EVs and can be used in their eventual production. Beyond cars, Airbus and Rolls-Royce are working on commercialising electric flights.

The more specialised a function is, the more likely it is that the sub-component producer can charge a reasonable margin for it. The role of the final manufacturer, by contrast, becomes more of an assembler and retailer in a market that we can expect to be very competitive.

LIGHT-BULB MOMENT

If we can crack fusion power, the world as we know it could change completely

Scientists have been trying to crack nuclear fusion (which would provide carbon-free energy) for decades now, but thus far the old joke about fusion always being 30 years away has held true. But with ITER (the International Thermonuclear Experimental Reactor) in southern France, the largest project to date, almost up and running, and with more private companies on the scene, we could finally be on the verge of a breakthrough.

In a nuclear fission reactor (the reactors used in our current nuclear plants), a large atomic nucleus is split into smaller nuclei. These collide with other nuclei in a chain reaction, thereby releasing a huge amount of energy. In nuclear fusion the opposite happens. Two atomic nuclei fuse together, releasing energy. This is the process by which the sun generates its energy. However, as the sun's mass and therefore gravitational force is so much more immense than Earth's, for us to create the same process, the atoms must be heated to a temperature hotter than the surface of the sun.

If nuclear fusion were successfully developed, it would change the way the world is powered. Having an unlimited, environmentally friendly energy resource at our fingertips would completely change our way of viewing the future and possibilities for the world. It would provide clean energy on a scale not previously seen. The two materials needed for the fusion process are deuterium and tritium. Tritium is radioactive and can be produced from lithium, but deuterium can be extracted from seawater – meaning any country with sea access would have a key input readily available.

Nuclear fusion's impact on world energy geopolitics would be paradigm-altering. With the world no longer reliant on oil, and therefore on the Middle East, the region would cease to be such a flashpoint. With no single country having the monopoly over nuclear fusion, it is no exaggeration to say the world order would be completely changed. Similarly, Russia's stronghold over the post-Soviet space and Europe would be dramatically reduced. Poland, for example, which continues to rely on coal power as a way to avoid being under Russia's thumb, would be able to switch to a cleaner energy without fear of its larger neighbour. Fusion's offer of freedom could make it the energy of a truly equitable future.

There is enough deuterium available in seawater to power nuclear fusion for an almost unimaginable period of time – about 30,000 years, it is estimated. As more fusion reactors are built around the world, more fossil-fuel resources can be retired, decreasing the amount of CO_2 in the atmosphere and helping to mitigate the effects of climate change and reduce pollution levels. In addition, although electricity created via fusion will initially be slightly more expensive, according to ITER it will fall in price owing to economies of scale. With carbon-free cheap electricity available worldwide, standards of living in less developed parts of the world will increase in bounds.

Once fusion power is harnessed, what then? Could it transform air travel, providing supersonic, affordable access and bringing far-flung parts of the globe ever closer? Some designers, such as Spain's Oscar Viñals, certainly think so. But there is talk of the technology pushing humanity even further, with fusion-powered rockets, using the power of the stars to take us to the stars. These would create more energy and in a more efficient way than the rockets currently in use. Due to the levels of radiation produced, the rockets would have to be designed to protect their human occupants; but, once achieved, we would be able to go further than ever thought possible. Fusion power would truly be a giant leap for mankind.

Lev Artsimovich, known as 'the father of the tokamak' (a type of fusion reactor), said that fusion would be invented when we needed it. With the world experiencing huge climate change, and seemingly on the verge of environmental disaster, might that time now have come? ■

Images from iStock and Getty Images

ENERGY

FURTHER READING

LESTER R BROWN
THE GREAT TRANSITION: SHIFTING FROM FOSSIL FUELS TO SOLAR AND WIND ENERGY

Brown and his co-authors focus primarily on solar and wind power, as they see these as the two key renewable energy sources of the future. Not only will a shift to renewables hopefully prevent climate disaster, but the move will also democratise energy supply – all countries have access to the wind and sun. The book is clearly in favour of a green, non-fossil-fuel future, but backs its statements up with a wealth of data and sources.

DANIEL YERGIN
THE PRIZE: THE EPIC QUEST FOR OIL, MONEY AND POWER

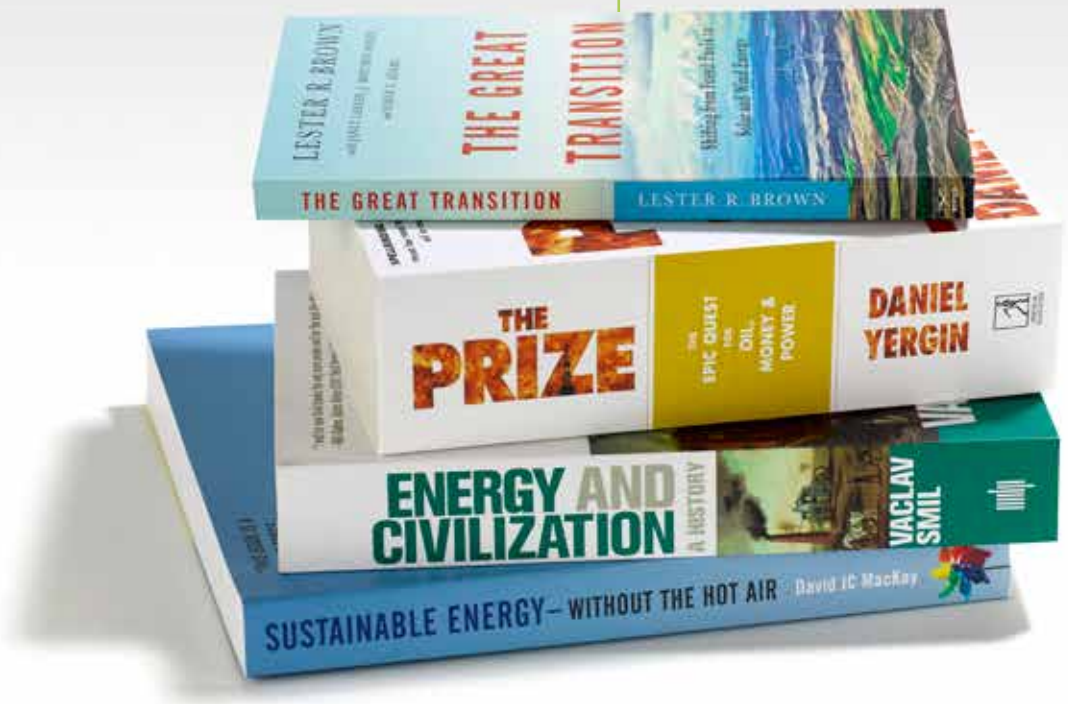
Winner of the 1992 Pulitzer Prize for general non-fiction, this book is lauded for the engaging way it presents a history of the oil industry. Yergin's accessible style means that he deals with a complex topic in a way appealing to those who may not previously have known about the intricacies of this vital industry.

VACLAV SMIL
ENERGY AND CIVILIZATION: A HISTORY

In this technical, yet accessible, volume, Czech-Canadian scientist Smil looks at the way humans have used energy through the ages, from pre-agricultural societies to the modern day. Our ability to harness ever greater sources of energy has shaped the way we live. Smil says we have thus far experienced three major energy transitions, and we are currently facing our fourth: the move away from fossil-fuel sources.

DAVID JC MACKAY
SUSTAINABLE ENERGY – WITHOUT THE HOT AIR

Initially a self-published endeavour, this book swiftly received widespread attention and became regarded as a key text on the topic. MacKay, who sadly passed away in 2016, said that he started to write the book because he was "distressed by the poor quality of the debate surrounding energy". Bill Gates recommends this text as one of the most important in the energy arena.



Photography by Pixeleyes

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