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Balance of power tilts from fossil fuel to renewables

Old certainties no longer hold sway as new plans for energy supply surprise, argues *Ed Crooks*

These are strange days in the energy business. Startling headlines are emerging from the sector that would have seemed impossible just a few years ago.

The Dubai Electricity and Water Authority said in May it had received bids to develop solar power projects that would deliver electricity costing less than three cents per kilowatt hour. This established a new worldwide low for the contracted cost of delivering solar power to the grid — and is priced well below the benchmark of what the emirate and other countries typically pay for electricity from coal-fired stations.

In the UK, renowned for its miserable overcast weather, solar panels contributed more power to the grid than coal plants for the month of May.

In energy-hungry Los Angeles, the electricity company AES is installing the world's largest battery, with capacity to power hundreds of thousands of homes at times of high demand, replacing gas-fired plants which are often used at short notice to increase supply to the grid.

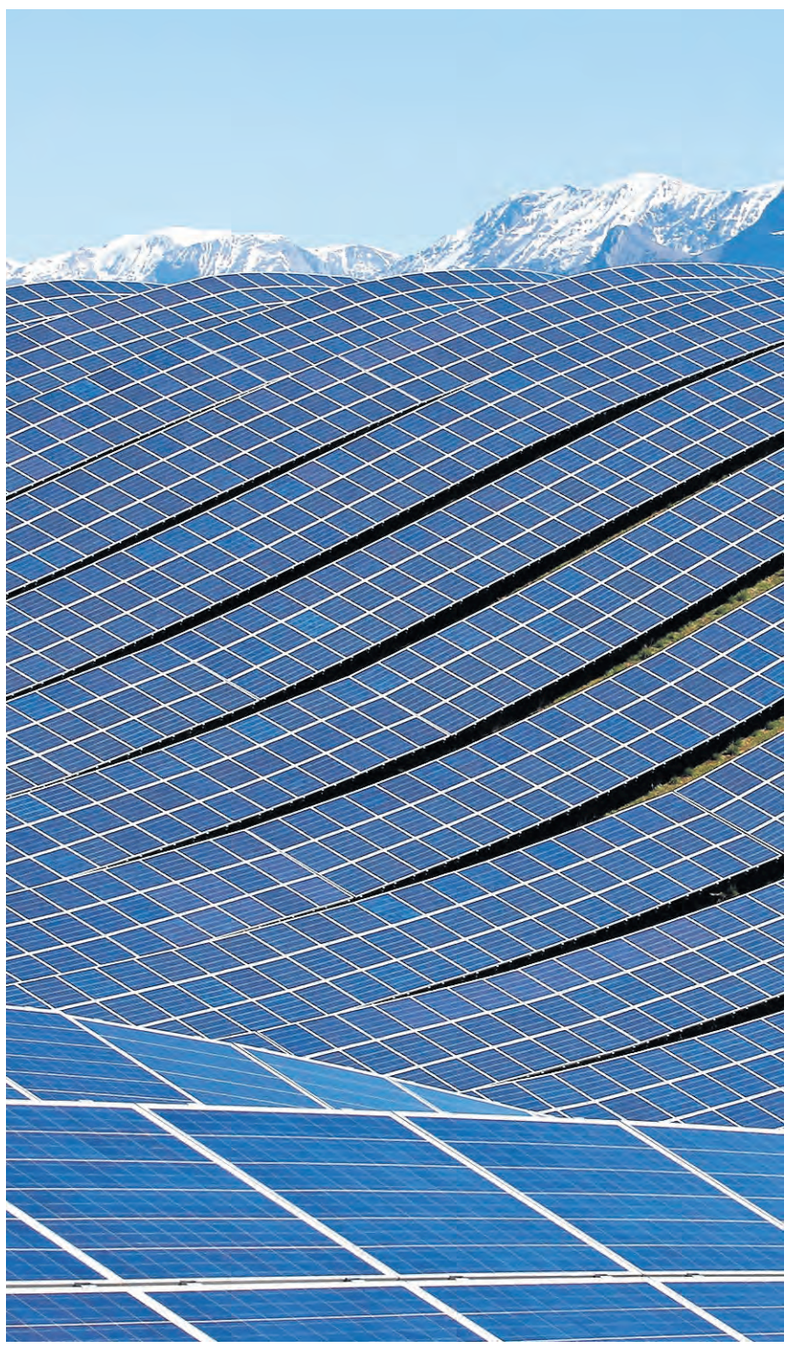
Trina Solar, the Chinese company that is the world's largest solar panel manufacturer, said it had started selling in 20 new markets last year, from Poland to Mauritius and Nepal to Uruguay.

It is not only renewable energy that is throwing out such remarkable news. Production costs in the US shale oilfields have been cut by up to 40 per cent in the past two years, according to Wood Mackenzie, the research company. Cargoes of liquefied natural gas have been heading from the US to the Gulf, making the surplus in North America available to the markets of Dubai and Kuwait even though they sit within the world's largest oil and gas producing region.

The implication of those stories is to suggest there are momentous changes under way in the global energy system, undermining received wisdom in the sector. It is clear that the world is shifting toward renewables and — as a proportion of total consumption — away from oil, gas and coal.

Within the markets for fossil fuels, some sources such as gas are becoming favoured over others such as coal. The question for policymakers and industry experts is how far and how fast these changes can go.

Down the decades, an attitude of cynicism in the face of the latest trends has generally been the smart position to take on energy. Assets such as oilfields and power plants are big investments that have operational lives lasting for many decades, and so the fuel mix and fleet of power-generating assets turns over slowly.



Shock of the new: a solar park in Provence, France — Reuters/Jean-Paul Pelissier

Within the markets for fossil fuels, some sources such as gas are becoming favoured over others

Spencer Dale, chief economist at BP, published a fascinating chart in June showing the rate of adoption of existing energy sources and technologies, which makes clear that it is often a lengthy process. For example, in 1899 gas provided just 1 per cent of the world's primary energy needs. Five decades later, that figure had grown to 8 per cent.

While renewable energy has been growing fast, it is coming from a very low base. "Modern renewables" — mostly biofuels, wind and solar, but not

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Inside

Dismal delivery puts big oil projects at risk

Project planning

The majors can no longer afford delays or cost overruns on 'megaprojects', writes *Ed Crooks*

Oil companies have tens of thousands of employees, tens of billions of dollars in reserves, and decades of experience in running large investment projects.

Yet time and again big oil companies prove themselves incapable of completing their projects on time and on budget.

In 2009 Chevron's Gorgon, a liquefied natural gas project in north-west Australia, was expected to cost $37bn and start production in 2014. It has ended up costing about $54bn and came on stream this year. Soon after it started, it suffered a gas leak that meant production had to be shut down.

Kashagan, a $50bn oil development in the Caspian Sea in Kazakhstan, took nine years to move into production after it was given the go-ahead in 2004.

Within weeks of celebrating first oil, the international consortium running the project was forced to shut it down after corrosive gas was discovered to be leaking from pipelines. Production is expected to restart next year.

Those are far from isolated occurrences. A study of 365 oil and gas "megaprojects" by Ernst & Young, the professional services firm, found 64 per cent faced cost overruns and 73 per cent were behind schedule.

Of the 20 largest, only seven were being delivered in line with the budget approved when the final investment decision was taken. Three were running 75-100 per cent over their initial budget, and the average cost overrun was 23 per cent.

Analysis published in June by McKinsey, the management consultancy, showed eight recent large oil and gas projects had ended up costing more than twice as much as originally estimated.

"The industry has got a real problem," says Chris Pateman-Jones of Ernst & Young. "Projects are becoming larger and more complex and more challenging . . . Even if they were to hit their targets, they could still be uneconomic."

Such analysis illustrates the quandary facing the oil majors such as BP and Chevron, challenged by the boom in shale oil and gas production from their smaller, nimbler rivals in North America and by state-controlled rivals in resource-rich countries. Their fortunes are also threatened by policies to cut carbon dioxide emissions that are curbing demand for fossil fuels.

> If projects cannot be made more efficient, they may never get off the ground.

Yet with oil prices low and capital spending plans slashed, the prices of oil services and equipment are falling. So, this could be a good time to start spending on projects that will come into production as oil prices recover.

But such a strategy will only pay off if those projects are completed efficiently. "To reap the benefits of investing in these large projects at the bottom of the cycle, it's critical that the operators deliver them on time and on budget," says Angus Rodger of Wood Mackenzie, the research company. "The industry's recent record at delivering major projects has been dismal, so that needs to improve."

Even before the oil price crash of 2014, large developments were falling out of favour because of rising costs and declining profits across the sector. In 2007-13 there were about 40 large projects approved by the oil and gas industry worldwide each year, Mr Rodger says. Last year there were just eight, and this year there are likely to be about ten.

Chevron has signalled a shift away from large projects towards smaller investments, including in shale in North America.

But even those that do have shale reserves find it hard to compete with their smaller, more agile rivals such Devon Energy and EOG Resources, which have made all the running in the industry. In shale, bigger is not better.

For big oil companies, projects such as deepwater oilfields or liquefied natural gas plants will continue to be critical to their future.

There are steps that they can take to improve the economics of those investments, some of them learned from other industries.

One is to use new technologies to cut costs. 3D printing, for example, can reduce the need for large inventories of parts to be kept or delivered to projects that are often in remote locations. Another is better contract design that gives suppliers an incentive to hold down costs.

"The history of the industry is that there has been an adversarial relationship between operators and contractors not because they are bad people, but because the business incentives set it up that way," Mr Pateman-Jones says. "I think we will move to much more effective ways of delivering projects."

If projects cannot be made more efficient, he adds, then they may never get off the ground. "If I were investing in some of these really big projects, I would be questioning whether they really made sense over a long period of time."

Balance of power tilts from fossils to renewables

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hydro or traditional biomass — provided just 2.5 per cent of the world's primary energy last year, according to BP.

That said, there are examples from history of when energy systems have changed rapidly after reaching tipping points. Oil consumption had been growing steadily through the late 19th and early 20th centuries, but really took off during and after the first world war, as warships switched from coal to fuel oil and armies became mechanised with petrol- and diesel-engine vehicles.

Nuclear power had a similar surge between the Arab oil embargo against the US and other countries in 1973 and the Chernobyl accident of 1986.

Government policies to address the threat of climate change are today's equivalent.

The commitments to take action to combat climate change made by 195 countries at the Paris talks at the end of last year are a sign that, however contentious the issue may be politically in the US, on a global scale the pressure is unlikely to dissipate any time soon.

This special report includes examples of innovative technologies that could bring further change to parts of the energy industry. Small modular nuclear reactors, for example, intended to avoid the staggering cost of their larger rivals, are being proposed for use in the US or the UK by 2025.

At the same time, fossil fuel companies are making strides in their efforts to remain competitive. This is not easy. Not only have oil and gas prices plunged over the past two years, but in the long term weaker demand and more abundant supply are expected. Valuations of companies in this sector have been badly dented.

Some new energy technologies, meanwhile, are not making much progress, such as the development of power plants that capture and store the carbon dioxide they produce. It is commonly assumed among policymakers that carbon capture has become essential if humankind is to enjoy the benefits of fossil fuels while avoiding their polluting effects.

500,000
The number of US homes to be powered by a single battery

2.5%
'Modern renewables' share of world primary energy output

It is clear, too, that the growth of renewables and other low-carbon energy sources will not follow a straight line. Investment in "clean" energy has been faltering this year after hitting a record in 2015, according to Bloomberg New Energy Finance. For the first half of 2016, it is down 23 per cent from the equivalent period last year.

Even so, the elements are being put in place for what could be a quite sudden and far-reaching energy transition, which could be triggered by an unexpected and sustained surge in oil prices. If China or India were to make large-scale policy commitments to electric vehicles, they would have a dramatic impact on the outlook for oil demand.

In Ernest Hemingway's *The Sun Also Rises*, a character says he went bankrupt "two ways. Gradually, then suddenly." There is a chance that a profound shift in our energy system could sneak up on us in the same way.

Kenyans use solar power to help water their dry land

Irrigation Renewable power reduces agricultural labour costs and diesel demand, says *Anjli Raval*

Tilling the land: farmers working irrigated fields

Subsistence farmers in rain-scarce Kenya are looking to solar-powered irrigation systems to aid their thirsty crops.

Until now, in the country where 80 per cent of the land faces low and unpredictable rainfall, many farmers have chosen to eliminate rain-fed agriculture from their crop rotations.

Others irrigate their land by flooding it from a nearby river or lake, which can erode the soil and deplete its nutrients. Or they use an expensive and inefficient diesel-fuelled pump for drip irrigation.

But solar irrigation technology from SunCulture, a US company, now seeks to transform the fortunes of subsistence farmers in arid areas.

The company's apparatus uses solar power to pull water by electric pump from the source into a raised tank. Gravity then pushes it through irrigation pipes to water crops with emitters regulating the flow to targeted areas.

Alice Migwi, a farmer from Limuru in central Kenya, has been a SunCulture customer since 2013. She says her solar irrigation system has increased yields, saved water and cut fuel and labour costs. "I needed a more efficient system to manage the watering of crops," says Ms Migwi, who began by planting staples such as spinach and carrots but is now growing mulberries and capsicum, which generate greater returns. "It would take over an hour for the watering process, and now it is 15 minutes."

By using the solar technology Ms Migwi says her annual revenues have grown 10 per cent over the past three years to 18m Kenyan shillings ($180,000). "My workers can now focus on the quality, by weeding, taking care of the produce, harvesting, rather than focusing on menial tasks such as watering," she adds.

With a payback period of just one three-month-long growing season, the drip-irrigation system can boost crop yields by 300 per cent and will save up to 80 per cent of water use, according to the irrigation company.

Samir Ibrahim, chief executive and co-founder of SunCulture, says his company is the first to commercialise solar powered irrigation in Africa. His company designs, makes and sells its solar powered irrigation systems to 630 customers, as well as providing maintenance support.

SunCulture began after Mr Ibrahim was approached by Charles Nichols, his friend and co-founder, with the idea to provide renewable energy for east Africa's farmers.

Most of Kenya's farmland is unsuited to agriculture that depends on regular rainfall, with just 5.4m hectares capable of growing crops, says Mr Ibrahim. More than 80 per cent of this land needs irrigation to be productive, but only 4 per cent of Kenyan farmers irrigate. This limits the country's ability to guarantee food supplies and also the earning power of many farmers.

SunCulture began after the pair entered a social venture competition at New York University and came second. Seeing the potential for the business, they raised around $200,000 in seed capital from friends and family and launched a pilot project in Kenya. Since arriving in Nairobi in October 2012, they have raised $4m from grant organisations and bodies such as US Aid. They are in the process securing more funds.

"We've had to create the support infrastructure from scratch. The ecosystem does not exist for us to piggyback off other industries," says Mr Ibrahim, who adds it is important to consider farmers as customers, not recipients of aid. Technicians and agronomists certified by SunCulture provide farmers with on-site training, soil analysis and other support by mobile phone. Rapid delivery and installation across Kenya are included in the price of the system.

> 'The biggest barrier is the upfront cost – not every farmer has the capital required to buy our goods'

But SunCulture's kits are not cheap. At almost $3,000 to cover a single acre, the cost is prohibitive for many farmers. "I had savings and that has helped me to buy the technology," says Ms Migwi. "I worked in the corporate sector for 15 years. But for the average farmer it is still too expensive."

Mr Ibrahim says he hopes that the cost can be brought down. He concedes: "The biggest barrier for farmers is the upfront cost — not every farmer has the capital required to buy our goods. This keeps us up at night."

SunCulture is working on technologies, such as its "mist" irrigation apparatus that are more affordable. It is also branching out into financing. In the next two months it plans to launch pay-as-you-go solar irrigation packages that cost as little as $2 per day. It also hopes it can branch out across the continent.

Crop yields achieved by Africa's farmers trail world averages by as much as 50 per cent. But with fuller access to capital, technology and know-how to boost output, the World Bank estimates by 2030 farmers on the continent could create a $1tn agribusiness market.

Patience is a virtue for bruised cleantech investors

OPINION

Benjamin Gaddy and Varun Sivaram

In 2006, Silicon Valley began to bet big on clean-energy technology. Seduced by visions of making a fortune while saving the planet, venture capitalists invested a then-record $123m in the first round of fundraising for 16 such companies that year. In 2008, they would sink nearly $1bn in over 100 new clean-energy companies.

But when these investments began to flop, the cleantech bubble abruptly popped. Since 2009, VCs have barely funded 25 new cleantech companies a year, slowing investment to a trickle.

What went wrong? And where should cleantech go from here? To answer these questions, we compared the performance of every medical technology, software technology, and cleantech company that received its first round of VC funding between 2006 and 2011. We found that betting on cleantech start-ups just did not make sense for VCs, because cleantech could not deliver the outsized returns found in other sectors. This conclusion is alarming because new technologies are desperately needed to confront climate change. Still, guided by the lessons learnt from the cleantech VC boom and bust, new private and public funding sources may be able to better support revolutionary technologies.

VCs make investments in risky start-ups assuming that nine out of 10 will fail, but are betting one will succeed wildly enough to make up for the rest. And because most VCs have a fixed timescale for investment, they often need to reap these returns within five years to pay back investors. This model works well for software companies like Instagram, which in two years returned backers 29 times their invested capital when Facebook bought it. Facebook itself achieved a market value of $104bn when it listed on the stock market — another way that companies can "exit," or return capital to their investors.

Sadly, in our study, we found that cleantech companies lagged behind counterparts in software or medical technology. In particular, companies developing new solar panels, batteries, biofuels, other energy materials and manufacturing processes collectively destroyed over 80 per cent of the initial capital investment by VCs. Many required large amounts of funding to build factories and their technologies took longer than five years to develop. The few that succeeded still did not deliver enough capital return for VCs to justify staying in the sector.

Difficulties in moving from lab to full-scale production help explain why cleantech companies lagged behind software start-ups. But many of the successes in the medical technology sector must also make the expensive leap from success in the lab to production at scale. So some other factor is needed to explain the gap in financial success between medical technology and cleantech start-ups.

Looking at the nature of exits from the two sectors offers a clue. Medical technology start-ups were 50 per cent more likely than cleantech start-ups to return profits to investors through an early lucrative acquisition. But there is a dearth of large investors willing to buy cleantech start-ups, which therefore often end up as stranded companies — ones that have run up against the capital and time constraints of VCs in spite of their promising technologies.

> A new wave of public and private support will be required to reboot investment in cleantech

Without a likely pathway to a profitable takeover and facing a long grind to win support for an IPO, the cleantech sector has outlived the patience of VCs unwilling to lock up capital for a decade or tolerate massive expenditures to scale up production.

So it is unrealistic to expect VCs to return to cleantech in a big way — over the last decade, they have invested nearly $40bn in the sector and may lose up to half of it. Commercialising cleantech will require a more diverse set of actors and funding models.

Many leading oil companies have sold their clean energy portfolios over the past decade and slashed their research budgets, adding to the sector's problems. Fortunately, some progress on funding is under way. On the sidelines of last year's Paris climate change summit, Bill Gates, along with 27 other billionaires, committed to providing more "patient capital" for risky cleantech ventures pursuing fundamental science breakthroughs — that is, they will invest early, provide substantial capital, and tolerate long delays before potential returns. The US, China, and India are among 20 countries to have signed the Mission Innovation pledge to double public research and development funding in cleantech to a collective $20bn by 2020.

Still, demonstrating first-of-a-kind products and building factories to churn out units at scale will require further infusions of capital.

Supportive public policies could attract such capital from institutional investors such as pension funds and family offices, which are set up to wait for decades to reap returns but can be inexperienced technology investors.

Government procurement could also be used to create market beachheads for advanced technologies. But a new wave of public and private support will be required to reboot investment in cleantech after the VC boom and bust.

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Public funding

Subsidy support for 'dirty' fuels across the world still exceeds that for renewables

The extent to which fossil fuels and renewable energy sources enjoy public support through subsidy has become a highly charged subject in continuing discussions about how to curb climate change.

Statistical analysis by the International Energy Agency shows there are large transfers from the public purse that encourage the consumption of polluting fuels.

The IEA calculates that the global subsidy bill for fossil fuels stood at about $490bn in 2014, although reductions in the market price of oil, gas and coal since then will have lessened that total. Recent falls in fossil fuel prices could help governments attempting to reform or scrap this level of taxpayer support, the IEA argues.

Subsidies to aid the deployment of renewable energy technologies were $112bn in 2014, with another $23bn spent on supporting biofuels. So, while many developed countries are increasing financial backing for the expansion of green energy supplies, total subsidy support for "dirty" fuels across the world still exceeds that for renewables by a considerable margin.

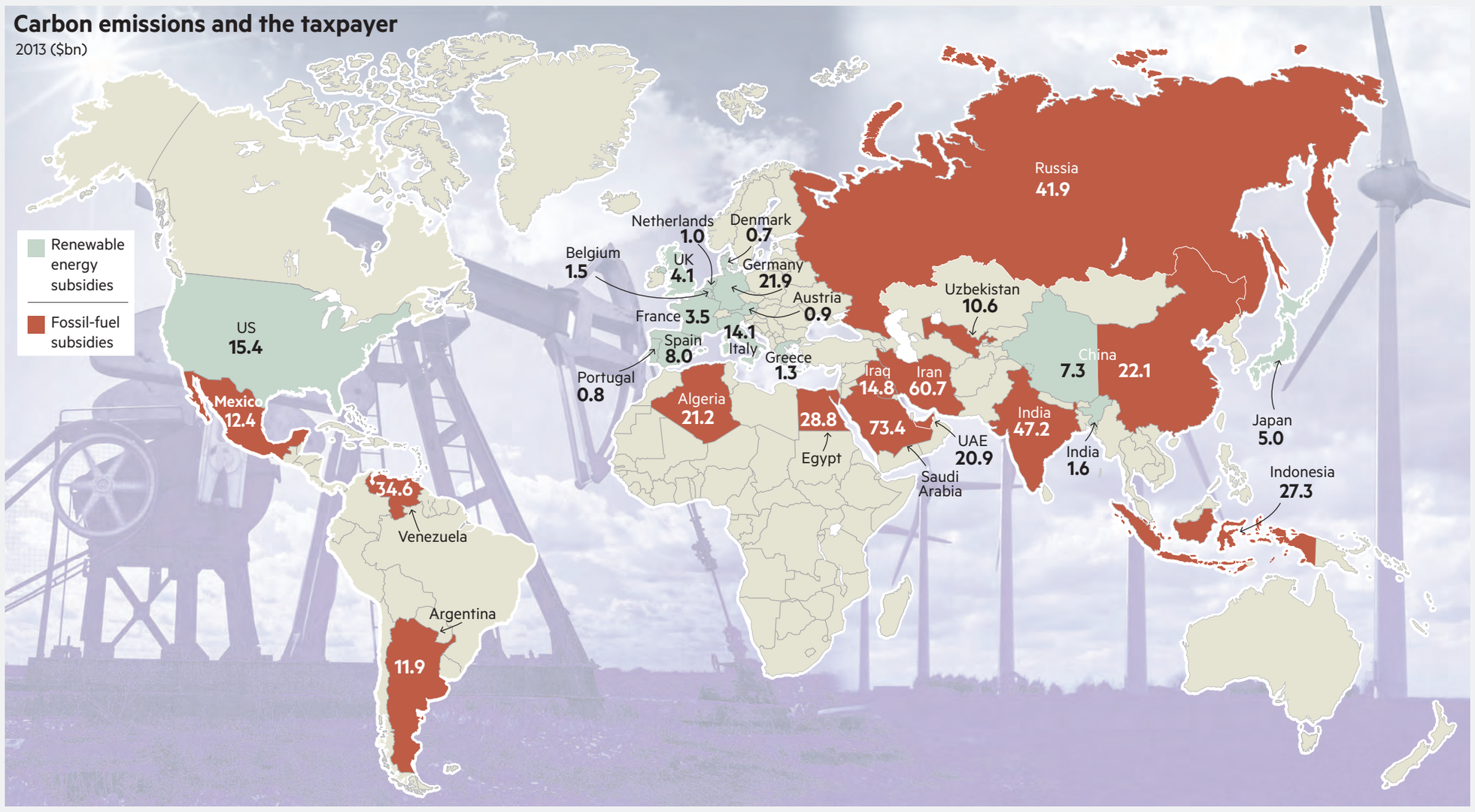
China stands out among leading countries by spending billions of dollars a year in subsidising the production and consumption of both fossil fuels and renewables.

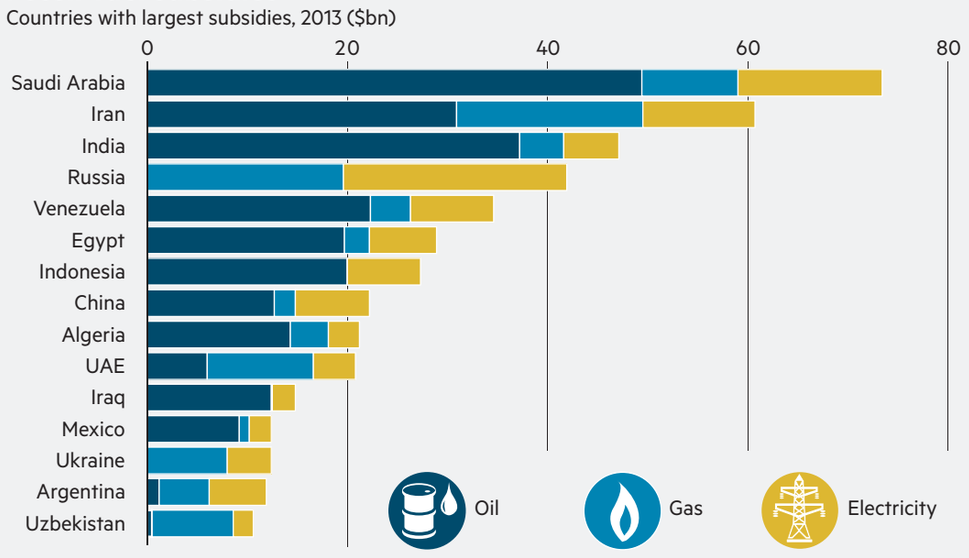
Yet most countries can be divided into those that put taxpayers' money into subsidies for carbon-intensive forms of energy and those favouring greener alternatives.

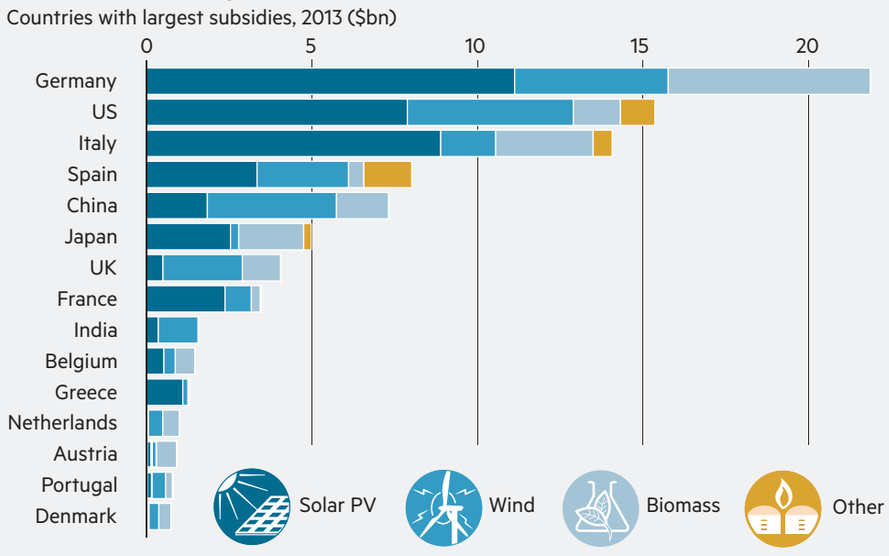
Although richer OECD countries are big producers of CO_2 emissions, they also dominate the list of leading backers of green energy. It is non-OECD countries that lead the list of carbon subsidisers.

Data show that in some oil-producing states, large-scale subsidies of public consumption of fossil fuels represent between 15 per cent and 20 per cent of GDP. Iran, Libya, Venezuela and Turkmenistan fall into this band.

Michael Kavanagh







FT graphic Source: IEA

Small is beautiful for some nuclear designs

Atomic power

Scaled-down plants offer price gains over conventional sites, reports *Kiran Stacey*

As delays mount at large new nuclear power projects around the world, more attention is turning to smaller alternatives, which industry experts hope may help provide the next generation of electricity.

So-called "small modular reactors" — miniature nuclear power plants with a capacity of less than 300 megawatts — could provide an alternative to mega-plants like the two 1.6 gigawatt reactors planned at Hinkley Point in Somerset.

The UK project is one of a number of delayed or abandoned nuclear power schemes, which have left policymakers around the world looking for cheaper, less risky options to meet electricity demand.

SMRs are designed as shrunken versions of larger plants; they can be made in factories and moved by train, truck or barge to the site. Developers say that if enough are built in the same factory, costs per unit of energy output can be driven down well below those of larger plants.

Small reactors are already used on nuclear submarines and in some developing countries such as India and Pakistan. But only recently have the industry and politicians begun to take seriously the idea that they could be made economically on a large scale.

Anurag Gupta, nuclear director at KPMG UK, says: "SMRs promise all the benefits of nuclear — low cost and green power — but without the significant cost and schedule overrun issues that have beset conventional large nuclear projects."

Since the invention of nuclear power, bigger has generally been seen to be better. Once a company had gone through the time and expense of securing a site along with planning approval and grid connections, most wanted to build as much capacity on that site as possible.

But many of those stations have been plagued with problems, which some blame on their size. Plans by EDF, the French energy company, to build new reactors in France and Finland, for example, have gone billions of euros over budget — something many experts blame on the difficulty of making such large structures safe.

Tapani Virolainen, a Finnish nuclear regulator, recently told the Financial Times: "It took more time to build [these plants] because there are more huge structures [to protect] against aircraft crash and so many safety systems."

> 'We think we can get costs down — as long as enough [SMRs] are commissioned'

Large projects such as these have also had trouble getting financed — one of the principal causes of delay at Hinkley Point has been the difficulty EDF is having raising the money needed for the £18bn project.

For now, small-scale nuclear industry proponents are focused on proving the technology can work at costs low enough to make it competitive. The countries that are furthest along are, unsurprisingly, those with the most developed nuclear energy industries.

Russia is in the process of converting two small reactors which used to power icebreakers. They will eventually be placed on barges which can then be moved to where they are needed.

The US and the UK are both trying to catch up. The UK recently took a leaf out of the US book when it announced it would run a competition to find the best SMR design, with £250m on offer to help with research and development.

"The US and the UK are in a race at the moment, and that is driving both forward," says Jared DeMeritt, programme director of MPower, an SMR developer. "We think 2025 is a realistic start date for the first small modular reactor in the west, which will be in one of these two countries."

MPower's design shows some of the ways that smaller plants can avoid the pitfalls of larger ones. In its case, MPower plans to bury all safety-critical equipment — including the reactor and the fuel vessels — underground, thereby minimising the need for expensive physical defences.

Despite the optimism among some in the industry, there remain significant hurdles to widespread use of SMRs. Firstly, even those building them privately admit the first ones will cost roughly the same per unit of electricity produced by a large reactor until costs can be driven down. One executive says: "Over time, we think we can get the costs down — as long as enough of them are commissioned."

But advocates of SMRs say that even if they prove more expensive for the electricity produced, costs are less likely to escalate and more likely to be fully funded.

David Hess of the World Nuclear Association says: "Financing is a huge policy risk, and SMRs reduce that. And if the project goes wrong, at least less money has been wasted."

This wheel's on fire: a nuclear reactor design by General Atomics of the US

Electric cars must charge harder to get into fifth gear

Motoring Despite the hype, electric vehicles enjoy niche rather than mass-market appeal, says *Peter Campbell*

Earlier this year snakes of people camped outside Tesla stores to place orders for the Model 3 electric car, handing over $1,000 deposits even though they had not seen the vehicle's full design or specification.

The company, the biggest carmaker never to use an internal combustion engine, has achieved a market value of $33bn when producing just 50,000 cars a year — compared with a valuation of $47bn for General Motors, which last year made more than 6m cars.

Yet despite Tesla's sales success, take-up of electric vehicles among consumers remains tiny. Fully electric cars (those without a combustion engine) account for less than 1 per cent of new car sales in the UK — which only rises fractionally when hybrids are included.

Road transport accounts for more than 17 per cent of global CO2 emissions, according to figures from Transport & Environment, an environmental lobby group. Migrating car use to electric vehicles could make a big contribution to curbing man-made carbon emissions. Greg Archer, a director at the group, says: "Combined with the rapidly falling costs for batteries and renewable electricity, it is clear electro-mobility is becoming increasingly affordable and offers an unrivalled opportunity to decarbonise vehicles."

Large carmakers such as Volkswagen and Fiat are developing either electric or hybrid technology, but this is partly based on attempts to meet stringent environmental emissions standards across their product ranges rather than necessarily satisfying public appetite.

"You have to bear in mind that today for the majority of people, electric vehicles aren't the right solution for them yet," says Erik Fairbairn, chief executive at charging infrastructure group Pod Point. "We need to see a development of the tech before we see it becoming mainstream."

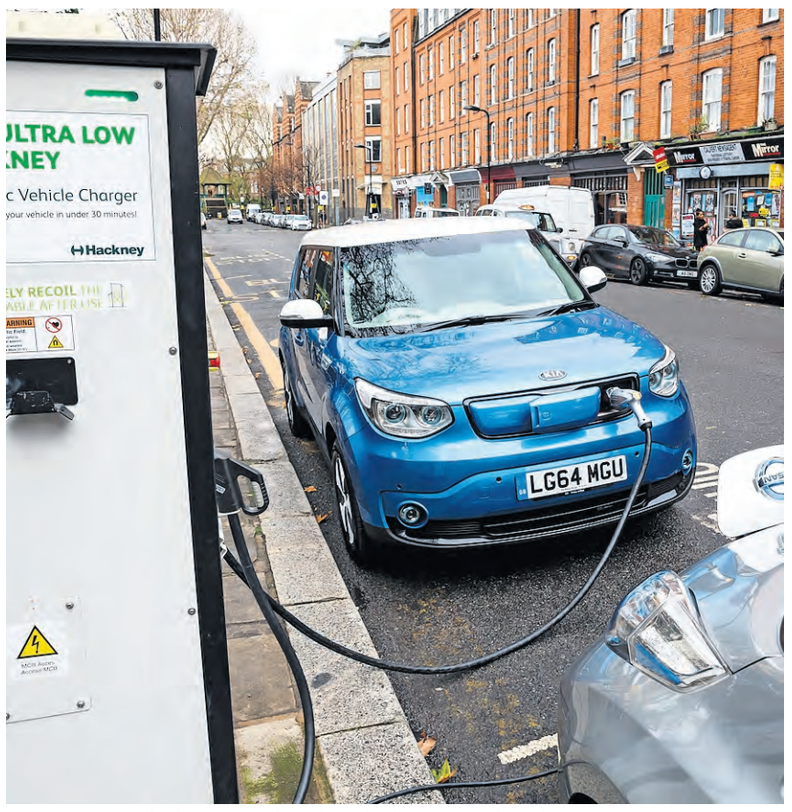
Three barriers stand in the way of mass adoption of electric powered vehicles: price, range and ease of charging.

The greatest contributor to the price is the battery, which can account for a significant portion of the cost of an electric car. The dominant force in battery powered cars is costly lithium ion technology, the same used in laptops and mobile phones.

A welter of other options are being pursued, from magnesium-based batteries to those that use silicon rather than carbon anodes. Solid state batteries, which promise much greater power and more flexible sizes, are also being investigated.

Other alternatives to combustion engines include hydrogen fuel cells, which use the planet's most abundant element to drive their motors.

Toyota, which led hybrid adoption with its Prius cars, has already launched a fully hydrogen-powered model. Once purchased, the cars are supposed to be virtually free to run, with the cost of an electric recharge being minimal.



Tuppence a mile: low-cost electric vehicles at a recharging point in London

The second, and most significant, public concern about electric vehicles is the range. Recent models such as the Nissan Leaf and the BMW i3 are limited to go under 100 miles — though BMW offers a range extender in the form of a petrol-driven engine to recharge the battery as it drives.

Tesla's Model S and X cars, which claim to travel in excess of 250 miles on a charge, remain prohibitively expensive for many, costing between $70,000 and $120,000. Carmakers are pushing to hit a sweet spot on technology and price — a $35,000 car that can travel more than 200 miles.

> Ease and speed of charging – at home and en route – are the final challenge

Tesla's Model 3, still at least two years from the road, is one example of a vehicle capable of both, but rival models are well under way. The Chevy Bolt, an all-electric car from General Motors, will have roughly the same range and price, while mass-market manufacturer VW has pledged that a quarter of its sales will be electric cars by 2025.

Once the technology and price reach the right point, adoption could rise to 7-10 per cent, predicts Pod Point's Mr Fairbairn, "at which point Joe Public will see them everywhere".

The ease and speed of charging both at home and en route are the final hurdle. In the UK, there are about 25,000 installed charging points, of which around 3,000 are publicly available in car parks or on high streets. So-called "destination chargers" — at workplaces, hotels and leisure sites — are also increasingly common. But more are needed to make electric motoring a reliable option for many.

"Everywhere you park you need charging points," says Mr Fairbairn. Unlike petrol stations, where motorists can fill up in a few minutes, electric charging takes much longer.

Current technology allows batteries to deliver around 30 miles of range for every hour of charging. It would take the power output of 1,000 kettles to charge a car fully in two minutes, says Mr Fairbairn — and rapid charging is damaging to most batteries. "The nature of electricity doesn't support the power transfers you need for two minute-charging, even a long way in the future," he says.

High ambitions for carbon capture falter

CO2 recovery

Governments have been scaling back their support for emission reduction schemes, writes *Kiran Stacey*

Last November, the UK government suddenly cancelled plans to spend £1bn helping to develop carbon capture and storage (CCS), seen for years as vital for reducing emissions.

The move shocked many in the industry, not least because of what senior ministers had said about the technology in the past. In 2007 David Cameron, then prime minister, warned that without CCS the UK might not meet its targets for reducing carbon emissions.

The UK is not the only country looking again at the support it has promised to CCS, which many oil, gas and coal producers argue could help mitigate consumption of their fuels. Last year, the US federal government suspended funding for a project in Illinois called FutureGen, which had aimed to be the first "clean-coal power plant" by 2012.

"CCS is struggling around the world," says Stuart Haszeldine, professor of carbon capture and storage at the University of Edinburgh. "But that is because of governments around the world being unable to bite the bullet on how to deliver it. No government has sorted out how to make it into a profitable and repeatable business."

Advocates of CCS argue that carbon dioxide produced from power stations or other industrial uses could be siphoned off at large scale and reasonable cost and injected into deep underground rocks. This would prevent the CO2 from leaking into the atmosphere and contributing to the warming of the atmosphere.

The technology already exists: in the 1970s the oil industry started to inject the CO2 it produces back into rocks to generate more pressure and force more oil from below the ground. But the emphasis of CCS is now firmly on its environmental potential.

Shell, for example, has been running the Quest project in Alberta, Canada, since last November. The scheme has stored nearly 1m tonnes of CO2 so far, the company says — equivalent to the emissions of 250,000 cars in a year.

"We carried out the scheme there very much because the Canadian and Albertan government helped support it," says Tim Bertels, who manages CCS projects at Shell. The company received C$890m from the Albertan and the national governments, part of which was given to cover the high upfront costs and part of which is made in payments for the carbon stored.

There is no reason this model cannot be widely deployed to cut the emissions of coal or gas power plants, but the costs are high.

Last year, the Boundary Dam coal-fired power plant — also in Canada — became the first electricity generator to fit CCS technology. But that scheme, which cost C$1.4bn, would not have been viable without a 10-year deal to sell the captured carbon dioxide to the Canadian oil group Cenovus Energy for use in enhanced oil recovery.

Having taken the decision to scrap the UK's CCS development competition, Mr Cameron explained in January that the high costs were part of the reason. "At the moment, it seems to me that with carbon capture and storage, while I completely believe in the idea, the technology is not working," he said.


'While I completely believe in the idea, the technology is not working' David Cameron

The International Energy Association estimates that up to $4tn of CCS projects would be needed to keep the world's climate goal of limiting global temperature rises to 2°C.

But the Carbon Capture and Storage Association argues that without this spending the cost of meeting the target will rise 138 per cent. "After Paris, the need for CCS is greater than ever," says Prof Haszeldine. "Can we meet our climate targets without it? No."