The new power superpowers

Energy transitions change the world, writes Henry Tricks. So who will be the winners and losers from clean power?

TO ENTER TAFT, two hours north of Los Angeles, you drive along the "Petroleum Highway", past miles of billboards advertising Jesus. God's country is also oil country. Spread over the sagebrush hills surrounding the town are thousands of steel pumpjacks (pictured), contraptions that suck oil out of the ground. They look like a herd of dinosaurs. Some Californians would describe the oil industry in the same way.

The oil produced at Taft is not produced by hydraulic fracturing, or fracking, as much of it is in Texas and North Dakota. It is so heavy it needs to be steamed out of the ground, in a process known locally as "huff and puff". Yet Kern County, with Taft on its western edge, produces 144m barrels of oil a year, the second highest output of any county in America. Fred Holmes, a third-generation oilman and patron of the West Kern Oil Museum, says he is proud of the heritage, however much it irks local drivers of electric Tesla cars that the Golden State has such a carbon-heavy underbelly. "Oil is renewable energy. It just takes longer to renew," he quips. He has built a giant wooden derrick at the museum to celebrate it.

In its heyday, oil was prized in southern California. The Lakeview Gusher, which blew on the edge of Taft in 1910, became as emblematic of a boom era as the gold rush farther north. Taft also played a starring role early on in the geopolitics of energy. In 1910 the American navy, worried about its dependence on insecure coal supplies, commissioned its first oil-fired destroyer. Two years later President William Taft created the first naval petroleum reserve in Taft's Elk Hills to guarantee supplies of oil in the event of an international crisis. It came into its own in the second world war, when production soared. The president gave the town, formerly called Moron, a better name.

Since then the geopolitics of energy—usually defined as the impact of energy flows on the power and influence of nations—has been mostly about the world's thirst for oil. The efforts to secure it, safeguard its shipment, stop enemies from getting or keeping hold of it, and monopolise it ▸▸

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ACKNOWLEDGMENTS

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if possible, loomed large in 20th-century history (see chart).

Since oil and gas are exhaustible and not available everywhere, they have often been rationed, to the benefit of an oligopolistic group of producers. Consuming nations have long felt that the scarcity of oil makes them more vulnerable. That is why, since the Arab oil embargo of 1973, every American president has seen the country's dependence on imported oil as a weakness. Policies like the "Carter Doctrine" proclaimed by the then president in 1980, which asserted the United States' right to use military force to protect its strategic interests in the Middle East, were aimed at ensuring a stable supply of oil.

This notion of scarcity is coming to an end, thanks to three big developments. The first is America's shale revolution, which has turned the country into the world's biggest combined producer of oil and gas (see chart, next page). After decades of declining output since the 1970s, America is now producing as much oil as it has ever done: 10m barrels a day in November last year. It is making the country less reliant on imported oil, which has helped it shed a long-standing paranoia about such dependence. This could reduce the country's need to expend blood and treasure to protect supply routes from the Middle East. And it has added an abundance of oil and gas to world markets that has benefited energy consumers everywhere.

The second major change is taking place in China as it attempts to move from an energy-intensive economy to a more service-led one. Without choking off economic growth, in the past few years it has made staggering progress in moderating its demand for coal and oil, slowing the rise in electricity consumption, deploying gas and renewable energies and arresting the growth of carbon-dioxide emissions. It remains the world's biggest importer of fossil fuels, but its experience with filthy air and its concerns about over-dependence on imported oil have made it keener to harvest more of its own wind and sunlight. It also has by far the world's most ambitious plans for electric vehicles. Subsidies and a streak of energy authoritarianism have played a big role. But in its own way, China's energy transition has been as remarkable as America's.

These two developments play into the third, longer-term trend: the need to create a low-carbon energy system to fight climate change. The Paris agreement of 2015, though a milestone, still leaves a huge distance to travel before global warming can be stopped. To achieve that, trillions of dollars will have to be invested in wind and solar energy, batteries, electricity grids and a range of more experimental clean-energy sources.

This so-called energy transition has set off a global race for the best technologies and raised concerns about access to the rare earths and critical minerals needed to make the necessary hardware. As Francis O'Sullivan of MIT Energy Initiative, part of the Massachusetts Institute of Technology, puts it: "We are moving from a world where the value of the energy is embedded in the resource to where technology is the resource."

The democratisation of energy

This special report will look at the energy transition from the perspective of America, the EU and China as well as petrostates such as Russia and Saudi Arabia. It will pinpoint winners and losers. It will argue that America is at risk of squandering an early lead, obtained by using natural gas and renewables to slash emissions, promoting clean technology and helping pioneer the Paris agreement. China is catching up fast. Saudi Arabia and Russia are in most obvious peril.

The past few years of growing American self-reliance and Chinese self-restraint have offered a glimpse of the foreign-policy implications of a new energy order. For America, some see it as a windfall, the title of a recent book by Meghan O'Sullivan of Harvard University. She says the shale revolution has helped temper predictions of American decline, made it easier to impose sanctions on adversaries, helped create a global gas market to ease Russia's stranglehold over Ukraine, and reduced tensions over China's pursuit of energy resources. She describes it as "a boon to American power—and a bane to Russian brawn".

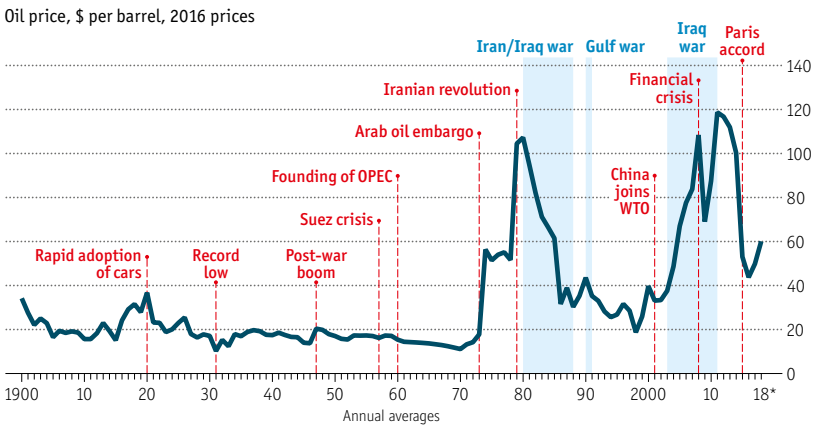
The beauty of the energy transition, enthusiasts believe, will be to give communities "super powers" over their energy, not turn countries into energy superpowers

That may be over-optimistic. Russia and the OPEC oil cartel have been surprisingly successful at cutting production to counter the shale glut. They have also turned towards China, which is pouring money into their energy infrastructure. Most important, American shale risks entrenching reliance on oil even more deeply in the global economy, with potentially perilous consequences for the climate. If America focuses too much on producing fossil fuels, it may lose sight of the need to develop cleaner energy for the future.

The geopolitical implications of the broader energy transition will be even more complex. When in January a global commission to study the geopolitics of clean energy was launched under the auspices of the Abu Dhabi-based International Renewable Energy Agency, the underlying hope was that such a development would make the world "more peaceful, stable—and boring". Champions of clean energy believe that boring is good. Unlike hydrocarbons, renewable energy is potentially available almost anywhere. Collaborative efforts to halt global warming could lead to open-source development and the sharing of technology. As power generation becomes more dispersed (examples include Germany, China and California), regions may become more self-sufficient in energy, a process labelled "en-

There she blows

Oil price, $ per barrel, 2016 prices



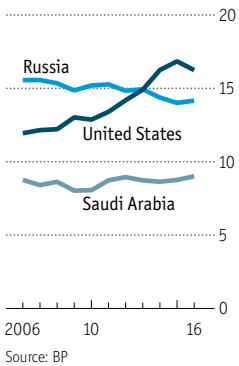
Sources: BP; Thomson Reuters; *The Economist*

*To February 20th

ergy democratisation". In Africa and elsewhere, enhanced access to energy, via mini-grids and rooftop solar panels, could reduce energy poverty even as the global population is soaring.

David Criekemans of the University of Antwerp points out that from the Industrial Revolution onwards, energy transitions such as that to coal and then to oil have changed the world. This latest one could have equally far-reaching effects. "The [nation] state and central power supply go hand in hand. They need one another," he writes. He expects decentralisation of the energy supply to boost the power of regions in relation to central authorities. The beauty of the energy transition, enthusiasts believe, will be to give communities "super powers" over their energy, rather than turn countries into energy superpowers.

Pumped
Oil and gas production
As % of world total



Source: BP

Yet the transition has plenty of potential to cause geopolitical friction, too. The most obvious example is the challenge it will pose to economies that depend on petroleum. A new book, "The Geopolitics of Renewables", edited by Daniel Scholten of Delft University of Technology in the Netherlands, argues that the clearest losers will be those blessed with ample fossil-fuel reserves and those who bet on oil for too long without reforming their economies. The book also notes that,whereas in the traditional energy system the main constraint is scarcity, with abundant renewables it is variability. This could be mitigated by cross-border energy trade, but that, too, could cause arguments.

As economies become more electrified, with "supergrids" to handle the additional power demand from urbanisation, electric vehicles and unimaginable quantities of data, the risks could multiply. Grid politics could replace pipeline politics. Ukrainian saboteurs, for instance, reacted to Russia's annexation of Crimea by cutting off electricity supplies to the peninsula in 2015. Chinese investment in grids in Europe and Australia is also under scrutiny, on national-security grounds. And ever more electrified economies are at ever higher risk from cyber-attacks.

The new power tool

It seems inevitable that the geopolitics of energy will develop into a contest to see which country can produce the most energy of its own, and which has the best technology. Miguel Arias Cañete, the EU's commissioner for climate and energy, explains that, "We are on an irreversible pathway to renewable energy…those who don't embrace the clean-energy transition will be losers in the future."

The EU has set itself a clear goal to decarbonise all energy by 2050, and has appropriate market structures in place. That puts it in a strong position. China, too, is firmly committed to clean energy and boasts some impressive clean-tech entrepreneurs. America, for its part, has invented much of the world's clean-energy technology; and the shale revolution has opened up vast potential supplies of natural gas that can generate electricity far more cleanly than coal, serving as a bridge to a lower-carbon future. But the country risks losing its focus. It is divided between fossil-fuel fundamentalists, mostly Republicans, and clean-energy enthusiasts, mostly Democrats, who cannot agree on the best way forward for the economy and for the climate. ■

America

All hail the shale

The shale revolution has had an impact abroad, but not always to America's benefit

WHEN RYAN ZINKE, America's secretary of the interior, turned up for his first day in office a year ago, the ex-Navy Seal arrived on a horse called Tonto, wearing a cowboy hat. Since then, the man leading the Trump administration's charge to unlock vast tracts of federal land for oil and gas drilling has brandished American oil like a gunslinger. Using a slogan favoured by President Donald Trump, he talks of "energy dominance". Explaining the concept to the Heritage Foundation, a conservative think-tank, last year, he said: "Our goal is an America that is the strongest energy superpower that the world has ever known…America's strength relies on American energy. And I don't want to see us ever held hostage to a foreign country to heat our homes or to power our nation." He made it clear that by energy he meant chiefly oil, natural gas and coal.

As with many of the Trump administration's favourite terms, the meaning of energy dominance is hazy and depends on the audience. At the World Economic Forum in Davos in January the president struck a more conciliatory note than Mr Zinke, promising to use American oil and gas to provide energy security to its allies. "No country should be held hostage to a single provider of energy," he said. But the point of energy dominance is that Mr Trump wants America to produce and export more oil, gas and coal and will try to undo years of environmental safeguards and regulations to achieve it.

He has picked a good moment. Not only has America's oil and gas production soared; the shale revolution has greatly reduced the country's dependence on imported crude oil and petroleum products, from 57% a decade ago to about 20%. The effect on the trade balance, the focus of Mr Trump's "America First" policy, was already dramatic even before he took office. The energy-trade deficit has come down from $416bn at its peak in 2008, when it accounted for half the total trade deficit, to $53bn in the first ten months of 2017, less than a tenth of the total.

The decline in import dependence has already had geopolitical effects. In her book, "Windfall", Meghan O'Sullivan shows that between 2011 and 2014 American oil replaced supplies disrupted by political developments in Sudan, Syria, Iran and Libya, "nearly one barrel for one barrel". That helped keep oil markets stable. Plentiful oil at home has also made it easier for America to impose sanctions on oil producers it views as dangerous. It helped persuade other countries to pressure Iran to sign a deal putting its nuclear ambitions on hold in 2015, because they did not fear a resulting spike in global oil prices. As Amos Hochstein, the State Department's energy envoy at the time, muses, "It was lucky timing that America became an energy superpower."

Foot on the gas

Natural gas may have strengthened America's hand abroad even more than oil. In 2017 the country became a net gas exporter for the first time in 60 years. This has helped establish a global market in natural gas, giving the world easier access to a fuel that produces only a quarter as much carbon dioxide as coal and half as much as oil.

For now, America's biggest gas export market is via pipelines to Mexico, creating what is fast becoming an integrated

Ryan Zinke, America's secretary of the interior, has brandished American oil like a gunslinger

North American energy powerhouse (as long as Mr Trump does not kill off the North American Free-Trade Agreement). But globally the change is being driven by exports of liquefied natural gas (LNG). The dome-like LNG tankers heading out from Louisiana and Texas are creating a market that can flexibly and cheaply deliver gas where it is needed. LNG exports took off only in 2016. By 2022 America is expected to vie with Australia and Qatar as one of the world's biggest LNG exporters.

More LNG helps the transition towards cleaner energy, potentially slowing (though not stopping) the pace of global warming. A global LNG market also eases one of the thorniest problems in energy geopolitics: Russia's use of gas pipelines to bully neighbours such as Ukraine. American LNG is still more expensive than Russian gas, so not much of it is sold to Europe. But its mere presence helps reassure the Europeans about their energy security. Partly in response, Gazprom, a Russian gas giant, has turned eastward, offering piped gas and LNG to China, where demand is also rising.

Mr Trump is pursuing China, too, offering LNG as a way to narrow the bilateral trade imbalance. Daniel Yergin, vice-chairman of IHS Markit, a consultancy, points to this as an example of how trade in energy might actually soothe global tensions. He says that China now sees America as part of the solution to its energy needs, rather than a competitor for scarce resources. Mr Trump has also discussed LNG exports with leaders from India and South Korea, Mr Yergin notes. "He has become the world's number one LNG salesman."

Unintended consequences

This windfall is likely to continue. America's oil and gas output is still rising. According to the International Energy Agency, by 2025 the shale revolution will have unlocked more oil and gas in America more quickly than in any other country, including Saudi Arabia in its heyday from 1966 to 1981.

The Trump administration wants to build on this success by making life easier for fossil-fuel producers. In his first year Mr Zinke has sought to smash what he calls a "fortress of red tape", open up offshore reserves to drilling (except in Florida, where it risked jeopardising the political ambitions of Rick Scott, the Republican governor), and ease restrictions on coal mining and natural-gas production imposed under President Barack Obama.

Whether all this deregulation will make much difference to domestic energy production is questionable. Jason Bordoff of Columbia University writes that markets play a much bigger role. Cheap natural gas, for example, hurts coal far more than the clean-power regulations that the Trump administration is now promising to remove. And Congress, state governments and the courts can block policies to stimulate fossil-fuel production and roll back environmental regulation, whatever the wishes of the federal government.

The geopolitical effects of the shale boom have been complex and have been compounded by other policy shifts such as sanctions and protectionist trade policies. Some experts feel that the idea of "energy dominance" sounds imperialistic. The mere idea of "weaponising" oil undermines years of American efforts to persuade countries like Russia not to use energy for political ends.

Some of America's trade policies may also be counterproductive. The country's withdrawal from the Trans-Pacific Partnership, a trade agreement which includes some of America's biggest potential LNG customers, such as Japan, was self-defeating, because it makes it harder for America's allies to import its LNG.

Stephen Cheney and Andrew Holland of the American Security Project, a think-tank, argue that America's greatest contribution to global energy security since the oil shocks of the 1970s has been to keep global energy markets fluid. Some analysts worry that this fluidity would be jeopardised if the Trump administration were to use oil and gas as a bargaining chip in bilateral relations, as China has done.

Although the shale revolution has been good for global consumers, it has not been a clearcut benefit to American influence abroad. The collapse of oil prices in 2014 nudged OPEC, Russia and other producers into an "OPEC-plus" alliance, raising Russia's profile in the Middle East at a time when an inward-looking America was less engaged. Moreover, the use of sanctions against Iran, Russia and Venezuela has created a perception among some countries, including China, that America is playing a "dirty economic game". This has brought its opponents closer together, says Sarah Ladislaw of the Centre for Strategic and International Studies in Washington. China has offered financial support to all three of those countries. Rosneft, Russia's biggest oil company, is tapping Venezuelan oil in exchange for cash.

Matthew Bey of Stratfor, a risk consultancy, talks of a "mosaic of forces" threatening American energy diplomacy as China overtakes America as the world's biggest energy consumer. He notes the alarm caused in Washington, DC, by the recent news that China might take a preferential stake in the planned initial public offering of Saudi Aramco, the world's biggest oil company. "It's not just Russia against the West," he says. "It's Russia, China, Iran and others looking at pragmatic opportunities to chip away at Western hegemony."

Above all, Mr Trump's tub-thumping for coal, oil and gas appears to run counter to a worldwide push to lessen dependence on fossil fuels, improve energy efficiency and combat global warming. So although, for now, Americans may feel relief at the shale boom, it could prove a double-edged sword. If their country continues to promote fossil fuels at the expense of cleaner energy sources, its dominance is unlikely to last. ■

Europe

Power struggle

Germany has led Europe's energy transition, but at a high cost to its neighbours

AT THE UN climate summit in Bonn last November some Americans came up with their own riposte to President Donald Trump's decision to withdraw from the Paris agreement. Outside the main conference building they put up a tent housing a rowdy coalition of people from 20 states and 110 cities under the banner "We are still in". Some non-American delegates at the conference found this fringe event more reassuring than the climate talks themselves. It showed that, even without Mr Trump and the federal government, local activists in America are committed to the spirit of the agreement.

The EU and China, each in its own way, are taking up America's mantle of climate leadership. The task remains daunting (see box). At present the EU has the boldest plans. It wants to lead the clean-energy transition, aiming to reduce its greenhouse-gas emissions in 2050 by 80-95% from 1990 levels, which means almost entirely decarbonising its energy system. Germany reckons that its experience of launching an *Energiewende* (energy transition) in 2000 qualifies it to help lead the world away from fossil fuels. But not all its neighbours like the model it offers.

Start with gas. For the next few decades Germany is likely to rely on imported natural gas as it phases out its nuclear and coal-fired power plants and brings in more electricity generated by wind and solar. Gas reserves elsewhere in Europe, such as the Netherlands, are declining. So Gazprom, the Russian energy giant, backed by five energy multinationals, has launched a project to lay a new pipeline to Germany, Nord Stream 2, under the Baltic Sea. This would double the capacity for Russian gas piped to Europe by 2019. It would also replace most of the gas flowing to Europe along the Brotherhood pipeline via Ukraine and Slovakia, reducing their transit revenues (see map on next page).

Nord Stream 2 is highly divisive. The European Parliament says it increases Europe's dependence on a single route for gas imports, which is bad for energy security. American diplomats say it exposes Europe to manipulation of supply by Russia, as happened with Ukraine. (It also undermines America's export strategy for shipping more LNG to Europe, though they keep quiet about this.) Foreign-policy hawks believe it strengthens Russia's economic influence over Europe and weakens Ukraine.

Russia and Germany retort that it is purely a commercial venture. Its supporters do not see it as a potential Russian choke-

Word of warming

Clean energy may not yet have reached a tipping-point

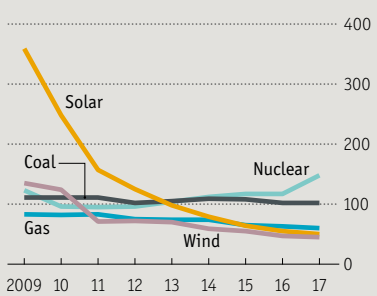
HE CALLS IT "the geopolitics of the gap". Carlos Pascual of IHS Markit, a consultancy, says that one of the biggest challenges for the world's policymakers in coming years will be to strengthen pledges made in the Paris agreement. They still amount to barely one-third of what is necessary to keep global temperatures from rising more than 2°C above pre-industrial levels.

Renewable-energy advocates talk of a "tipping-point" at which renewables become cheap enough to drive fossil fuels out of the electricity mix. To hear them talk about falling costs, you would think the world was almost there (see chart). Yet excluding hydropower, renewables still produce only 8% of the world's electricity, and far less of the energy needed for heating, cooling and transport, which are harder to decarbonise.

A few statistics in a new book, "Taming the Sun", by Varun Sivaram, of the Council on Foreign Relations in Washington, DC, highlight the obstacles to be overcome before solar photovoltaics become a mainstream energy source. However fast the price of a kilowatt-hour of electricity generated by solar panels has fallen, he writes, the price of a gigabyte of data storage in a microchip has fallen a million times faster. The recent drop in solar prices has been due to economies of scale, not improvements in performance.

Clean equals cheap

North America, average cost of energy
$ per MWh



Source: Lazard, levelised cost of energy analysis

Moreover, Mr Sivaram argues that although solar panels are cost-competitive as a niche energy source, their economics become less attractive the more they are deployed. That is because they cannot be turned on and off, so they flood the electricity market when the sun is high, driving down wholesale prices. The more solar power is added to the grid, the lower its value.

Batteries could help solve that problem by storing the power for times of strong demand. But no one has yet invented a lithium-ion battery capable of storing solar energy for long periods of time to even out seasonal variations in sunlight. Electric vehicles (EVs) could speed up the energy transition, by cleaning up the transport component of energy and offering a way to store electricity, too. But mass electrification brings its own problems.

In order to incorporate large quantities of renewables, interconnected power systems will be needed so that those with an abundance of clean energy can share it with those who lack it. The risk is that these will recreate the vulnerabilities of cross-border pipelines. Karen Smith Stegen of Jacobs University in Germany argues in "The Geopolitics of Renewables" that interconnected grids are relatively safe because all the countries involved want to keep the electricity flowing smoothly. But high-voltage, direct-current transmission lines, such as those now being proposed between north Africa and Europe, may be more at risk of meddling.

None of these problems is insurmountable. New, more efficient solar technologies are being developed. Financial innovation is creating new ways of investing in renewable energy. Elon Musk, of Tesla and SpaceX fame, may yet produce lithium-ion batteries cheap enough to revolutionise transport. In the West he gets most of the attention, but China is also doing much pioneering work, from EVs to supergrids.

hold but as a way to bind Russia more closely to Europe, because trade makes each more dependent on the other. Yet the plan has created a rift between Germany and its eastern neighbours.

That is also true of the *Energiewende*, underlining how divisive even clean energy can be when its effects spill across borders. Germany initially saw its dash for solar and wind as a purely domestic issue. The decision to phase out nuclear power after Japan's Fukushima disaster in 2011 was a response to a deep-rooted domestic environmental lobby. Germany did not consult its neighbours on ramping up renewables, even though its grid is linked to many other countries' energy systems.

The foreign-policy ramifications have become wider since. Notwithstanding Nord Stream 2, renewables are part of a strategy to reduce the country's dependence on fossil-fuel imports (most of its coal and oil also come from Russia). Moreover, Germany hopes the *Energiewende* will give it a global edge in clean-energy technology. Siemens, for instance, has become a global leader in wind-turbine manufacturing.

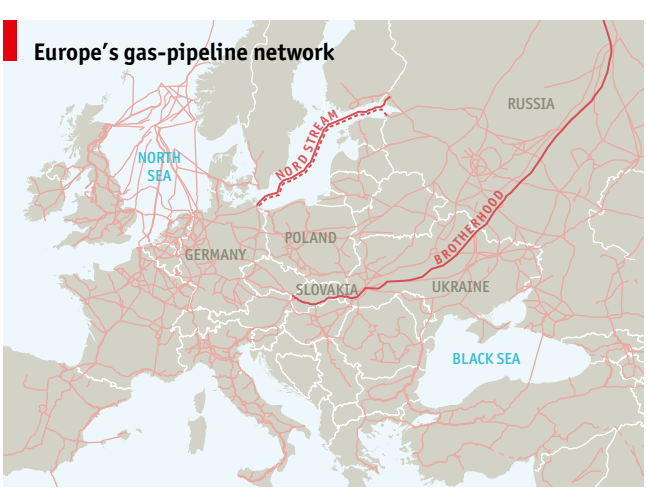
But the rapid spread of wind power in northern Germany, and the lack of transmission lines to the industrial centres farther south, has caused headaches. Thomas Sattich of the University of Stavanger in Norway writes that when the wind blows hard, surplus renewable energy is pushed to neighbours such as Poland, the Czech Republic and the Netherlands, clogging up their electricity systems. Excess renewable energy also brings down wholesale power prices, which is bad for investment. .

On the grid

The best way of dealing with such problems is more cross-border co-ordination, as well as more high-voltage power lines. The European Commission is finalising packages to redesign the block's electricity markets. In January European lawmakers proposed increasing the EU's goals for the share of renewables in the energy mix to 35% by 2030.

Norway, with its abundance of round-the-clock hydroelectricity, wants to play a role as Europe's "green battery". It is also among ten countries by the North Sea that subscribe to the North Sea Countries' Offshore Grid Initiative, which aims to create a regional supergrid. Miguel Arias Cañete of the European Commission says that such interconnections are essential if the goal of 35% renewables is to be achieved. But he also notes resistance from local communities to large, unsightly power lines, and from national-grid operators to surrendering autonomy. Sometimes the commission must wish for the sort of control over energy policy that China's mandarins enjoy. ■

Europe's gas-pipeline network



China

The East is green

China's strength in clean-energy technology is growing rapidly

WHEN IT COMES to energy, no country generates such bittersweet superlatives as China. It is the world's largest consumer of coal and the second-largest of oil, after America. It has the largest power-generation capacity, by a wide margin. It also produces more carbon dioxide than any other country.

China is hoping to deal with this over-dependence on fossil fuels partly by rebalancing the economy away from energy-intensive industries. But it also leads the world in clean energy. In recent years, through a combination of subsidies, policy targets and manufacturing incentives, it has spent more on cleaning up its energy system than America and the EU combined. Last year alone it shelled out $132bn, according to Bloomberg New Energy Finance (BNEF), a consultancy.

The International Energy Agency (IEA) says China has one-third of the world's wind power, a quarter of its solar capacity, six of the top ten solar-panel manufacturers and four of the top ten wind-turbine makers. It sells more electric vehicles than the rest of the world combined. It also leads the world in construction of nuclear power plants. In December it gave the go-ahead for what is expected to be the world's largest carbon-trading scheme.

Given China's thirst for energy, the combined impact of these advances in renewables is still relatively small. Non-fossil-fuel energy, chiefly hydro and nuclear, accounts for only 12% of its total energy mix. And China is far from self-sufficient. That is why, for the next decade at least, China's main energy-related geopolitical concern will be the need to secure fossil fuels.

This is already evident in the plethora of deals that its state-owned companies are doing with oil and gas producers in the Middle East and Russia, both to finance new projects and to help develop them. But China is also reaching out to America.

Zou Ji of the Energy Foundation, a think-tank, says the immediate priority for China's energy policymakers is to curb the dirtiest uses of coal, especially heating urban homes with it. For this, America's shale revolution may be a blessing, he says. By adding large quantities of liquefied natural gas (LNG) to global markets, it has made it cheaper and easier for China's coastal areas to switch from coal to gas. Last year the country's LNG imports grew by 50%.

Increasingly China is looking to America to help it diversify its sources of supply. In February China National Petroleum Corporation, a state behemoth, signed the first ever long-term contract to buy LNG from an American supplier, Texas-based Che-

niere Energy. Mr Zou says that more energy interdependence between China and America, particularly in the LNG market, could be good for relations between the two superpowers, especially if it helps reduce America's trade deficit with China.

Eventually, China's increasing production and use of renewables, batteries and electric vehicles (EVs) are also likely to have geopolitical consequences, even if that is not the government's primary aim. China could benefit in three ways.

All power to the yellow emperor

First, by being able to produce more of its own energy, it will reduce its reliance on fuel imports that may be vulnerable to global instability. Second, its "soft power" will be strengthened. This is already evident in its leadership role in the Paris climate agreement. Third, and perhaps most important, the development of clean-energy technologies—especially batteries and EVs—could put it firmly in the vanguard of the energy transition, ahead of America and Europe, and provide a new impetus for economic growth.

Currently the race is wide open. No country has an unassailable lead. Whether clean-energy technology becomes a source of healthy competition or geopolitical friction will depend largely on global trade. If it becomes bogged down in protectionism, trade wars and cyber-crime, everyone will lose. But that need not happen.

So far, many in the West have been sceptical about China's role in renewable-energy technology. The country's solar industry is thought to have piggybacked on Germany's generous renewable-energy subsidies and has benefited from massive government support. In 2012 the European Commission launched anti-dumping and anti-subsidy investigations of Chinese solar-panel imports. The following year the two sides reached a settlement, followed by the imposition of minimum prices. In 2014 America slapped import duties on Chinese solar-panel imports. In January the Trump administration imposed more tariffs on imported solar panels, most of which come from China.

The Chinese have bungled some of their own renewable-energy policies, building large-scale projects in remote locations without the transmission lines to support them. Some Western experts argue that China lacks adequate regulatory structures for a smooth transition to clean energy. And in 2010 the Chinese authorities halted most exports of rare earths, raising fears about their stranglehold on the supply of minerals critical to green-energy technology (see box).

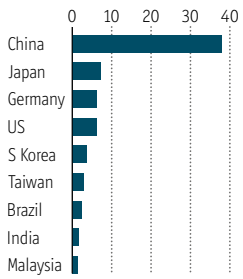
However, such criticisms risk underplaying the sheer entrepreneurial zeal that the Chinese put into clean energy, and their growing ambition to decentralise as well as decarbonise the energy supply. Both may give China a dominant position in developing the energy technologies of the future.

For instance, the world's biggest solar-panel manufacturer, Shanghai-based Jinko Solar, is a relative newcomer that started only 11 years ago. Since 2013 it has quintupled global production to a mighty 10 gigawatts (GW) a year and doubled its global market share to 10%. Gener Miao, its head of sales, explains that the firm has succeeded by internationalising its marketing efforts and relentlessly investing in technology. Support from the Chinese government now mostly goes on early-stage research projects, he claims.

Another case in point is one of China's biggest wind-turbine developers, Envision, also from Shanghai. It has invented turbines that operate at low wind speeds so they can be placed close to urban centres, rather than in the country's remote northwest. But the company views the turbines merely as a cash cow for a bigger ambition: to create a global "energy internet", or operating system, that helps companies manage locally produced, or "distributed", energy assets such as turbines and solar

Red star performer

Total clean-energy manufacturing value added, 2014, $bn



Source: National Renewable Energy Laboratory

Clean could get dirty

A scramble for minerals used in renewable energy is under way

TO GLIMPSE A potentially troubling side of the clean-energy business, look at the giant Anglo-Swiss oil-trading firms. They are betting on a scramble for battery materials to power electric vehicles.

Glencore, one of the world's biggest commodities companies, plans to double its production of cobalt by 2020, which it reckons will give it 40% of the market. Cobalt is an important raw material for lithium-ion batteries, found mostly in the Democratic Republic of Congo (DRC). But Saad Rahim, chief economist of Trafigura, a rival, says battery producers will use more nickel and less cobalt in nickel-manganese-cobalt cathodes to avoid dealing with the DRC, which has a tainted reputation. Last year Trafigura agreed to spend $200m funding a nickel mine in pristine Finland.

America produces few of the minerals it needs for renewables. In December President Donald Trump issued an executive order to speed the search for new sources of minerals at home. America relies on imports for 70% of its lithium, and on imports and releases from the National Defence Stockpile for 75-80% of its cobalt.

In an accompanying report, the United States Geological Survey (USGS) said that America's dependence on imported minerals had soared since the 1970s and that China produces 85% of the world's rare earths, used extensively in renewable-energy applications such as wind turbines. The USGS also identified China as the main producer of minerals such as germanium and indium, used for solar power, and graphite, used in fuel cells and batteries; and as the world's largest refiner of cobalt, using material mostly from the DRC.

There is no risk that these resources will run out. Deposits of lithium, for example, are thought to be 3,000 times current annual output. But their supply could be manipulated for political ends. In 2010 China drastically cut its export quotas for rare earths, leaving the world scrambling for alternatives. The curbs were lifted in 2015.

These minerals are scarce only because deposits in other parts of the world have so far been uneconomic to extract, but that may change as demand for transparently sourced minerals increases. In Australia investment in battery minerals such as lithium and cobalt is already booming.

In America domestic supplies will depend largely on investors' appetite for putting their money into materials with extraordinarily volatile prices. The country's only functioning rare-earths mine, Mountain Pass in California, went bankrupt in 2015 as prices plunged. It has since been bought out by a consortium led by, of all things, a Chinese rare-earth producer.

panels, electric vehicles, battery storage and commercial electrical appliances. Launched in 2016, Envision says the system already manages more than 100GW of renewable assets globally (more than America's entire wind capacity).

China is also upgrading its regulatory structure. Sophie Lu of BNEF says that distributed solar energy accounted for almost one-third of the 53GW of new solar capacity installed in China last year. This surprised everyone because until recently all renewable energy had been installed in remote areas on a utility scale. The aim is to spur reform of China's gargantuan power company, State Grid. "The government is using technology, innovation and power-market reform to break the monopoly of the grid," says Ms Lu.

In future the main bone of contention may be the new technologies developed to make renewable energy and storage ever more cost-competitive. Some American experts fret that by giving a low priority to renewable energy, the Trump administration may put America's industry at a disadvantage in relation to China's. Since President Trump decided to pull out of the Paris agreement, he appears to have jettisoned America's pledge to double the $6.4bn the government is due to spend on energy innovation by 2020. China pledged $7.6bn, so it may soon take the lead. Equally telling, research by Devashree Saha and Mark Muro of the Brookings Institution, a think-tank, shows that patents and venture-capital investment in clean-energy technologies in America recently peaked. Patenting, they said, was increasingly done by foreign firms, especially Chinese ones.

If China's growth in clean-energy technology leads to more protectionism, along the lines of the Trump administration's move in January against imports of solar panels, clean tech could become a trade battleground. The same could happen if China denies Western energy technology a meaningful place in its markets (as it has done with American internet firms) or restricts access to its rare earths. But technology also provides scope for collaboration. If America, the EU and China can build that into the transition to renewables, energy geopolitics will start to look a lot more promising. ■

Running on empty quarter

Petrostates

When the sun sets on oil

The Middle East and Russia are ill-prepared for a low-carbon future

THE HIGHLIGHT OF a trip to the vast Shaybah oil field in Saudi Arabia's "empty quarter" is a stroll at dusk to the top of a range of silky sand dunes. There you can watch the sun set over the pride of the Saudi petroleum industry as a muezzin in the mosque below strikes up a call to prayer. Unfortunately, executives from Saudi Aramco, the state oil company, challenged your correspondent to a running race. By the time he reached the top, he was coughing so badly that he missed the sunset; and the banter drowned out the muezzin. "If only we could turn this sand into silicon for solar panels," one joked. "We'd be rich."

Like many petrostates, Saudi Arabia, the world's biggest oil exporter, is aware that demand for petroleum may one day fall victim to solar panels, electric vehicles, more frugal consumption and so on. But how seriously do the big oil producers take the threat? The answer comes in two parts. The first concerns their response to the recent onslaught of American shale production. The second is about their reaction to the prospect of "peak oil" (the beginning of the end of the world's addiction to oil) over the next few decades. For now, the former appears to carry far more weight than the latter, even though peak oil may eventually cause what some call "the mother of all oil crises".

Start with the impact of shale. The galloping rise in American oil production up to 2014 caught many traditional oil producers off guard and contributed to a rapid increase in global oil stocks to unsustainably high levels. The subsequent oil-price crash clobbered oil-producing countries that had been spending lavishly on social programmes. They acted swiftly.

A reeling Saudi Arabia unveiled a plan to sell off 5% of the world's biggest oil company, Saudi Aramco, to raise $2trn for the country's public-investment fund. This is part of the kingdom's so-called Vision 2030 strategy, designed by Mohammad bin Salman, the crown prince, to reduce the country's dependence on oil and diversify the economy to provide new sorts of jobs for a young population. But in the absence of high oil prices it is unlikely to raise anything like the sums he wants.

In late 2016 OPEC and non-OPEC producers, led by Saudi Arabia and Russia, agreed to curtail production by a combined 1.8m barrels a day (or about 2% of global output) to push up prices. So far the plan has not only worked, it has set the stage for an "axis of love" between Russia's president, Vladimir Putin, and Prince Mohammad. Despite their support for opposite sides in the Syrian civil war, and despite Russia's long-standing friendship with Iran, they now talk of developing long-term joint projects, especially involving Russian natural gas.

Whether they are seriously preparing for the longer-term threat—of falling oil demand as the world switches to electric vehicles—is harder to answer. Publicly, leaders of Saudi Arabia and Russia dismiss the risk that demand will collapse. They predict that cars, trucks and planes will still consume growing amounts of fuel into the middle of this century, and that plastics and petrochemicals will still use a lot of oil. But some observers think that concern about peak oil is leading them to hedge their bets and may be one reason the Saudis are selling off part of Aramco.

Drill, habibi, drill

What should petrostates do about output if oil demand ebbs? In theory they should pump as hard as possible now so they can bank the money while they can. But that would set off a battle for market share among producers which would drive down oil prices further. Those with the lowest costs, such as Saudi Arabia, which can produce oil for as little as $6 a barrel, might feel that this is a fight they are bound to win.

However, a paper published in January by Spencer Dale of BP and Bassam Fattouh of the Oxford Institute for Energy Studies casts doubt on this idea. It argues that Middle Eastern oil produc-

ers should focus not on the cost of extraction but on the "social cost" of oil: their spending on social commitments such as health care, education and public-sector employment. The authors use the oil price needed to achieve balanced budgets as a rough proxy. This is close to $60 a barrel. Mssrs Dale and Fattouh argue that until such countries can shift their economies away from oil, they will need to cover these social costs. So instead of fighting each other for market share, they will seek to maintain long-term alliances, such as the current OPEC-plus arrangement. Yet in the past such pacts have always unravelled because of cheating on quotas. And investors in Aramco might balk at sacrificing short-term revenues for long-term strategic objectives. So perhaps the Aramco IPO will be the high-water mark of Saudi Arabia's co-operation efforts.

If the producers are not able to control the market, reform will become more urgent. But it will be tough. Saudi Arabia's Vision 2030 depends almost exclusively on the will of the young crown prince, who has ripped up a long-established model of rule by consensus, with unpredictable consequences. His sense of urgency is not matched by experience, and progress is patchy. Saudi Aramco is taking longer to list than planned.

Other Middle Eastern producers, such as the United Arab Emirates, are also hedging their bets, talking up clean energy but also reaffirming their commitment to using fossil fuels for half their energy needs until at least 2050. Like Saudi Arabia, they are blessed not just with oil but with sun and space, which offer ideal conditions both for large solar-photovoltaic parks, which harvest the sun during daylight hours, and concentrated solar plants, which store the heat generated by the sun in molten salt and release it as electricity at any hour of day or night. But at present Middle Eastern oil producers see renewable energy mainly as a way to use less oil and gas at home so they have more of it available for export. They do not consider clean energy to be an existential threat.

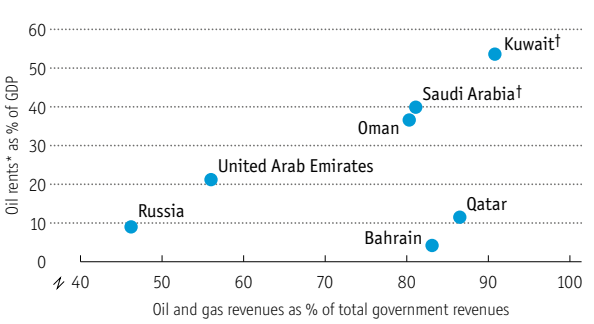
As for Russia, it appears to be even blinder to the prospect of the energy transition. It has given short shrift to renewables. Beyond oil and gas, most of its attention is on nuclear energy. And it is still betting heavily on oil. Partly thanks to global warming, last year it started drilling in the Laptev Sea, in the Arctic Circle, despite low prices and semi-frozen terrain that would put off most Western oil companies.

The wild card for petro-producers is what happens to demand for oil and gas in the developing world, particularly in China. Last year China overtook America to become the world's largest oil importer, and those imports are forecast to continue growing rapidly for at least a decade. At least for now, China's energy relationship with the Middle East and Russia is likely to become closer. State companies from all three regions are investing in each other's assets. Chinese funding has helped Russia finance drilling projects, despite Western sanctions. The same may happen with Iranian gas. Saudi Aramco has invested in a refinery in China's Fujian province. Russia has offered to sell Arctic gas to Saudi Arabia.

The end of oil will not be linear. If oil prices slump, electric vehicles may look less attractive. Concerns about over-investment in oil may produce unexpected price spikes. But if the producers do not embrace economic reform, they could find themselves in deep trouble very quickly. They need only look at Venezuela to see how rapidly falling oil revenues can force an autocratic state to break its bargain with the people, leading to economic turmoil, social instability and regional tension. ■

Hooked on the black stuff

2012-16 averages



Sources: Haver Analytics; World Bank *Sale price minus production cost †Oil revenues only

Prospects

A good, clean fight

How to take the geopolitics out of energy

ON THE EVE of the first world war a young Winston Churchill switched the Royal Navy from coal to oil. As Daniel Yergin put it in his book "The Prize", the reliance on doubtful supplies of oil from Persia rather than Welsh coal turned energy security into a question of national strategy. Churchill responded that "safety and certainty in oil lie in variety, and variety alone."

The same is true of energy today, but the variety of available sources now extends far beyond oil. Military planners are taking note. Since 2003, when America's current defence secretary, James Mattis, drew attention to the vulnerabilities in warfare caused by the "tether of fuel", America's armed forces have invested in a variety of clean-energy technologies: wind turbines, solar panels and mini-grids are common on military bases. So are experiments. A year-long naval exercise in 2016 involved a strike group powered by a mixture of conventional fuels, nuclear power and biofuels made from beef fat.

Access to abundant energy helps a country fight wars. It also supports peaceful projections of power. This special report has argued that those with the most readily available and reliable sources of energy, and the ability to produce and export new technologies, will be winners as the world reduces its dependence on oil. The losers will be those whose vested interests and lack of alternatives keep them wedded to fossil fuels. But the

transition need not be a geopolitical battleground. Two factors could help: better collaboration and greater localisation.

In the energy field, collaboration has deep roots. According to Stephen Cheney, a retired Marine brigadier-general who heads the American Security Project, a think-tank, it emerged after the oil shocks of the 1970s as consuming countries sought a way of jointly ensuring energy security in the face of soaring prices. One result was the creation of the Paris-based International Energy Agency (IEA) in 1974, with a broad mandate to work for energy security and co-operation on energy policy among its members, chiefly large energy consumers. In 2001, 28 of the IEA's members each agreed to establish strategic petroleum reserves, equal to 90 days' worth of net imports, as a buffer against supply shortages.

Another result was the global oil market, generating price signals that alert consumers to oil shortages and gluts. America and its allies have supported it since the 1970s by helping underwrite the secure flow of oil, keeping sea lanes open and supporting stable regimes (however odious) in the Middle East. This market has now been extended from oil to gas. Trade in liquefied natural gas is growing, and pricing has become more flexible.

The transition to clean energy is partly driven by the need for ever bigger efforts to tackle global warming. Among other things, that means clean energy needs to expand from electricity, which gets most of the attention now, to heating, transport and industrial processes. It involves building a spider's web of cross-border grids to help offset the variability of sun and wind power. As the transition gathers pace, it may even require support for petro-economies made vulnerable by the switch.

Countries and regions that lack the right climate may need high-voltage transmission lines to feed them clean energy from thousands of miles away. New IEA-type organisations may be required to ensure that such supplies are not "weaponised". And if the worst happened and climate change proved catastrophic, the world would need to come together to deal with the consequences, such as mass migration and water wars.

Technology is another area of potential collaboration. The best guarantee of this would be free markets. Trade wars and other forms of protectionism stymie innovation. Putting quotas on critical minerals, as China did in 2010, would resemble the worst cartel-like tactics of the oil markets.

International agreements on technology also help. On the sidelines of the Paris accord in 2015, 22 countries and the EU as a block pledged to double their research-and-development funding for clean energy. (Some very rich people, led by Bill Gates, also pledged to spend billions on breakthrough technologies.)

The need for more of this is compelling. In solar energy, for example, 60 years of silicon-cell technology has probably gone as far as it can. Perovskite solar cells, a more recent discovery, already come close to silicon's performance and may be more efficient. They can be made cheaply and, unlike rigid silicon cells, can be applied to flexible films of plastic. They are close to commercial launch, though durability is still a problem.

Decentralised power

Localisation is a second way of depoliticising energy. The fossil fuels that powered the 20th century were produced by oligopolies, fed into centralised networks and sold on the premise of scarcity. Supplies were seen as finite. Renewable energy such as solar and wind is abundant but intermittent. Supergrids are one way of overcoming this. Minigrids involving locally produced wind and solar power, electric-vehicle batteries, small-scale hydropower and small modular nuclear reactors may be another. Some of the companies mentioned in this report are working towards such localised solutions, including Envision, a Chinese firm that hopes to create an "operating system" for small-scale producers and users of energy, to help keep supplies stable. It has also invested in Germany's Sonnen, which sells batteries that become virtual power plants when connected to other households.

If they succeed, local communities, districts and regions may get more say in the energy system, weakening the influence of national utilities, as has happened in Germany's *Energiewende*, albeit at wasteful expense. Some of the more energy-secure regions may compete with countries to influence global policies. Leaders from California, New York and other renewable-friendly states in America are trying to help shape global climate talks even as the Trump administration turns away.

Such "energy democratisation" could provide better access to electricity for the 2bn people likely to be added to the global population in the next few decades. It could help decentralise economies and counter the perception that the market works just for the rich and powerful. It could also open up a whole new realm of innovation, just as oil did with motor cars, suburbanisation, air travel, plastics and mass food production in the 20th century. The great game of green energy need not be winner takes all. ■

On the eve of the first world war a young Winston Churchill switched the Royal Navy from coal to oil