Chapter 8: The Geopolitics of Renewable Energy

> Big things have small beginnings.
>
> —*T. E. Lawrence*

Evolution, Maybe Revolution

Energy revolutions do not happen every day. The last major energy revolution happened more than 100 years ago, when coal was superseded by crude oil as the main source of energy globally. Coal-powered steam engines had been the lifeblood of industry, trains, and ships for more than a century, but in 1895, two German engineers, Gottlieb Daimler and Carl Benz, had the idea of putting a petroleum-powered internal combustion engine into a horse carriage, thereby giving birth to the first practical car.

Because internal combustion engines were more compact, they were easier than bigger steam engines to fit into the small space available in carriages and were thus given preference. But this choice was made initially for practicality reasons, not because the internal combustion engine was more efficient or cheaper. Indeed, in the early years of the car, different drivetrain options competed with each other. Steam-engine cars existed alongside electric cars and internal combustion engine cars. In the end, the gasoline-powered car won the commercial race. Meanwhile, in shipping, the switch from coal-powered steamers to petroleum power was triggered by Winston Churchill's decision after World War I to switch from coal to petroleum as the power source for all British warships, a decision later mirrored by British civilian shipbuilders.

Geoeconomically, the switch from coal to oil as the main source of energy in transportation heralded a multidecade-long decline in coal mining. High-cost producers in England, Wales, German's Ruhr area, and the border areas between France and Germany became uneconomical and finally closed operations in the middle of the 20th century. Coal survived as a power source only for electricity generation and remained the dominant source of such energy until the early years of the 21st century.

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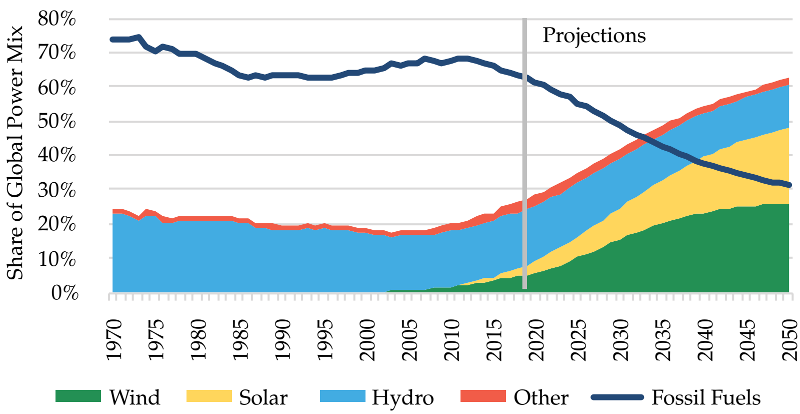
With the transition from coal to oil came a transition in geopolitics. The Ruhr area and the border between France and Germany, which had been contested in many wars, became largely irrelevant from a geopolitical perspective (although the Ruhr is still a wealthy industrial region). Instead, the focus shifted to the oil-producing regions of the Middle East—geopolitical backwaters until the 1930s. Today, we face a similar transition, this time from oil as an energy source to nuclear power and renewable energy sources, such as wind and solar power. Just like a century ago, many different technologies are competing for investment, from solar photovoltaic (PV) energy, to wind (onshore and offshore), to geothermal energy and biomass. The list goes on, but today, wind and solar PV seem likely to emerge as the most dominant renewable energy sources of the future, so we focus primarily on these two in this chapter.

Although we call these transitions "energy revolutions," they are more evolutionary than revolutionary in their development. Oil took several decades to supersede coal as the main source of energy in houses, transportation, and industry, and renewables will take several decades to replace oil, gas, and other fossil fuels. Today, wind and solar energy account for approximately 8% of global electricity generation, hydroelectric power stations account for 16%, and other renewables account for approximately 3%. As **Exhibit 1** shows, almost two-thirds of the electricity produced today is still generated using fossil fuels.

Over the next three decades, until 2050, wind and solar are projected to rise to 48% and renewables to increase in total to 62.5% of total power

Exhibit 1. Share of Renewables in Global Power Generation Mix



Note: Numbers do not add to 100% because nonrenewables other than fossil fuels, such as nuclear power, are excluded.
Source: Bloomberg New Energy Finance (2019).

generation, according to Bloomberg New Energy Finance (BNEF 2019). Oil will continue to play a role in the economy of 2050, but a much diminished one compared with today. With this diminished role could come diminished importance of the Middle East and other oil-producing regions from a geopolitical perspective—but one should not be so sure about that, as we will learn later in this chapter.

To assess the transition to renewables, we should note that, in some respects, they are very different from fossil fuels. First, renewable energy sources are available everywhere and are not localized the way oil, gas, and coal are. Thus, the need for the kind of transportation infrastructure typically used to transport fossil fuels from their source to the region of end use is reduced in the case of renewables. Crucial transportation chokepoints of today, such as the Strait of Hormuz or pipeline routes, are not something we will necessarily have to worry about in the future.

Some people argue that because renewables can be deployed in a decentralized fashion (every household could theoretically install solar panels on the roof or a windmill in the backyard), the rise of renewables leads, in a sense, to a democratization of energy production and reduces the need for central infrastructure and large-scale utility companies. In reality, economies of scale mean that this democratization process has its limits, but in Germany in 2016, 31.2% of renewable power generation was owned by private investors and was "behind the meter" (International Renewable Energy Agency [IRENA] 2019). In countries with lots of sunshine and high retail electricity prices (looking at you, Australia), solar PV installed on rooftops could become a major source of electricity by 2050.

Another crucial difference between fossil fuels and renewables is important for geopolitical analysis. Fossil fuels are stocks and can be stored easily for a long time. Renewables are flows, which means they never get exhausted and are more difficult to disrupt but also are more difficult to store. Thus, with the rise of renewables comes a need for efficient energy storage systems such as utility-scale batteries. And these technologies, as we will see, might create new geopolitical chokepoints.

Lower Prices Drive Growth of Renewables. Before we dive deeper into the geopolitics of renewables, a word of caution. Projections by major energy and renewable energy organizations such as BNEF, the International Energy Agency (IEA), BP, and IRENA all are subject to significant uncertainty. The rise of renewables depends heavily on GDP growth, the political will to fight climate change, and cost efficiencies resulting from technological progress, all of which are notoriously difficult to predict.

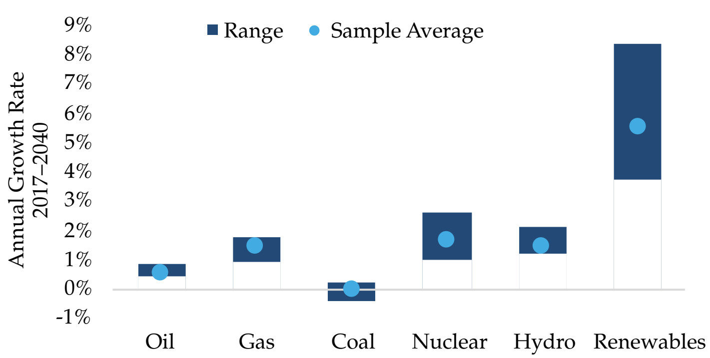
Exhibit 2 shows the estimated annual growth rates of different energy sources until 2040, as projected by BP in 2019. The company ran several different scenarios and made certain assumptions to assess the estimation uncertainty in each sector. It found that the uncertainty around the growth forecasts for oil, coal, and gas was much smaller for each than for renewables. It also found, however, that oil and gas will experience annual growth rates in the range of 1% to 2%, whereas coal demand likely will stagnate. In contrast, annual growth rates for renewables range from 3.7% to 8.4%, with a sample average of 5.5%. Thus, even the most pessimistic scenario for renewables shows annual growth rates that are more than twice as large as the most optimistic case for natural gas and more than three times as large as the most optimistic case for oil.

Renewables are slowly but steadily catching up with fossil fuels as the main source of power generation and eventually will overtake them, but the process is evolutionary, not spontaneous. This is a point on which all forecasters agree, whether they are energy companies or independent think tanks. Forecasts for renewable energy growth, however, have been wrong in the past and will be wrong again in the future.

Whereas forecasts for asset returns or earnings growth tend to be too optimistic for so many other areas of finance, renewables have a long history of surprising to the upside. Analyzing more than a decade of annual forecasts by the IEA for the growth of renewables shows that every year, the IEA had to revise its growth forecasts upward because technological progress had been made so quickly that cost efficiencies were realized much sooner than anticipated.

With these caveats about forecast uncertainty in mind, we can look at the wider implications of this shift to renewable energy sources. Although

Exhibit 2. Expected Annual Growth Rates of Energy Sources



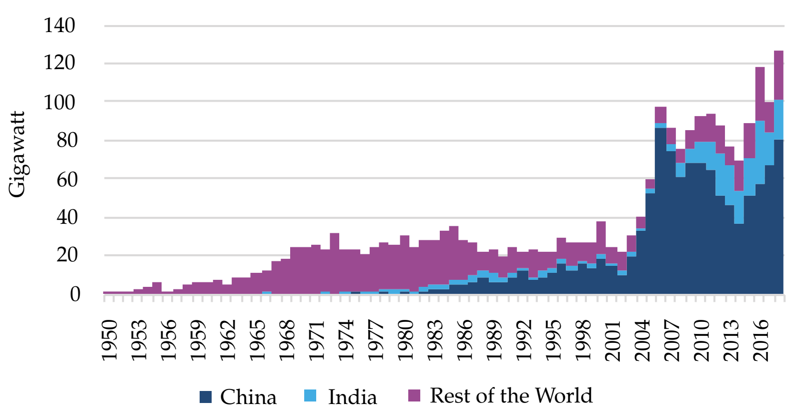
Source: BP (2019).

BNEF projects that 50% of global electricity production will come from wind and solar by 2050, large regional disparities are likely. Europe is taking the lead in this transition. Wind and solar energy are promoted heavily there, with wind energy the preferred source of energy in the United Kingdom and Scandinavia and solar PV in France and southern Europe. BNEF predicts that by 2050, more than 90% of electricity generation in Europe will come from renewable energy sources.

Renewables Have Become the Cheapest Energy Source in Two-Thirds of the World. Meanwhile, China and India will be major players in the renewable energy space, and more than 60% of electricity generated in these two countries in 2050 is expected to come from renewable sources. The carbon dioxide (CO_2) emissions in these countries, however, will continue to rise for several years after 2050. China and India are also the world's biggest users of coal and are responsible for 80% of the coal power plants that have been added in the world in the past five years, as shown in **Exhibit 3**. Even as the rest of the world is phasing out coal, China and India remain hooked on it.

Yet, with its latest five-year plan, China is turning around and increasingly focusing its investments on renewable energy. Between 2016 and 2020, China planned to invest $361 billion into renewable energy generation domestically and create 13 million jobs in the sector (Mason 2017). As we read in chapter 6, China's ambitions with Made in China 2025 and the Belt and Road Initiative concentrate very much on such modern technologies as the generation, storage, and distribution of renewable energy.

Exhibit 3. Coal Capacity Additions, 1950–2019



Source: BNEF (2019).

Today, China is the world leader in renewable energy investment by a wide margin. The result of the country's policy shift is that CO_2 emissions will likely peak in China around the year 2027 and then decline to approximately one-half of current levels by 2050. In comparison, India's CO_2 emissions are not expected to peak before 2038 and will then decline only modestly by 2050. India's CO_2 emissions in 2050 are likely to be 50% higher than in 2018 (BNEF 2019).

In the United States, contrary to the rhetoric of the Trump administration, coal is no longer competitive and will be rapidly phased out. This reality, along with the rise of wind and solar energy, means that by 2050, levels of CO_2 emissions from the US power sector will likely be only one-half of those seen in 2018. Nevertheless, the United States will probably remain a laggard in the adoption of renewable energy. BNEF projects that by 2050, only 43% of the electricity used globally will be produced from renewable sources.

The transition to wind and solar is driven not by politics or ideology but simply by economics. In 2014, renewable energy sources were the cheapest source of energy in only one or two countries in the world. In 2019, the least expensive form of energy in two out of three countries worldwide was either wind or solar, even without subsidies. Coal remains the cheapest source of energy in Poland, Turkey, and Malaysia, while natural gas is the least costly form of energy in Russia and Algeria. Even in the United States, wind produced in the plains of Texas is now less expensive than any other form of energy.

As a result, building new gas- or coal-fired power plants in most countries of the world makes no economic sense. If current price trends persist, then shutting down existing coal power plants in China and replacing them with newly built solar and wind power plants will be less expensive in 2027. In the United States, by 2030, building a new wind farm will likely be cheaper than continuing to run an existing gas power plant.

What keeps renewables from growing any faster than they already do is their significant intraday and seasonal variability. The sun shines only during the day, so solar PV plants can produce power only during that time. Wind is not a constant, and the strength of the wind varies from season to season, so that wind energy provides power only part of the year. What is needed is further development of electricity storage technologies, such as batteries and "peaker gas" plants, which can ramp up electricity production quickly in times of fading renewable energy production. These peaker gas plants are the main reason that demand for natural gas, rather than coal or crude oil, is expected to grow at decent rates over the next decades. They provide a complementary energy source to renewables, with relatively low CO_2 emissions.

Fast-Rising Electricity Demand Creates Challenges

Another major challenge for renewables in the coming decades will be the increasing electrification of our societies. Electric vehicles are still more expensive than internal combustion engine cars and require subsidies and tax incentives to be competitive in most countries. But BNEF estimates that between 2022 and 2025, electric vehicles will become cost competitive with internal combustion engine cars. This is the tipping point after which the adoption of electric vehicles should start to accelerate significantly, as **Exhibit 4** shows.

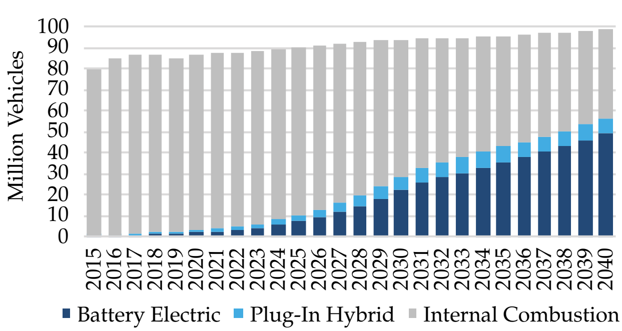
Add to that the increased demand for electricity to power air conditioners in warm, emerging-market countries and the strong growth in GDP and population in those markets, and global electricity demand is expected to increase by 62% over the next three decades. This demand is way beyond the current capacity of power generation and requires estimated investments of $13.3 trillion. How such investments will be financed will be discussed later in this chapter.

Tipping Points and the Inevitable Policy Response

Most forecasters expect the switch from fossil fuels to renewables to be a gradual one, an evolution rather than a revolution. But good arguments can be made as to why we could indeed face a revolution and a rather quick shift in energy use.

Bond (2017) looked at past energy transitions in the United Kingdom and argued that although the new energy source (in these cases, primarily oil and electricity replacing coal) provided only a small fraction of total energy supply, as shown in **Exhibit 5**, investors care about prices, not market shares.

Exhibit 4. Global Car Sales by Type of Drivetrain



Source: BNEF (2019).

Exhibit 5. Historical Energy Transitions in UK Energy

Area	Fuel Change	Year of Peak Old Demand	Market Share Old Energy	Market Share New Energy
Power	Steam → Electricity	1907	84%	3%
Transport	Coal → Oil	1913	94%	2%
Light	Gas → Electricity	1914	69%	3%
Heat	Coal → Gas	1940	88%	6%

Source: Fouquet (2009).

And prices react to marginal changes in supply and demand rather than to secular changes.

For example, BP reported that the world's total energy consumption in 2017 was 13,511 megatons of oil equivalent (Mtoe),[1] but the annual increase in demand was approximately 225 Mtoe—a growth rate of less than 2%. Given these low growth rates, one might be tempted to think that transitioning from one energy source to another will take a long time. But the rate at which consumers switch is determined by the marginal rate of consumption. If the new energy source is cheaper than the dominating one, then marginal supply and demand will be determined by the production costs of that new energy, and the new energy source will quickly gain market share as long as one additional unit of energy from the new source remains less expensive for consumers than one unit of energy from the old source. In 2015, solar and wind already provided 33% of marginal energy supply globally, whereas fossil fuels accounted for approximately 51% (Bond 2017).

As the marginal energy supply becomes increasingly dominated by renewable energy sources, demand growth for fossil fuels is expected to drop quickly, with potentially hazardous consequences for investors. When demand declined by just 2% for coal in recent years, many coal companies struggled to avoid bankruptcy, and some did not succeed. Once the marginal energy supply is dominated by the new, incoming energy source, investments are rapidly diverted to this energy source, and the transition accelerates. Investors stuck with the old energy source face high price volatility with a potentially secular decline in prices.

Another reason the transition to renewables might become a revolution rather than an evolution is that current trends are by no means sufficient to

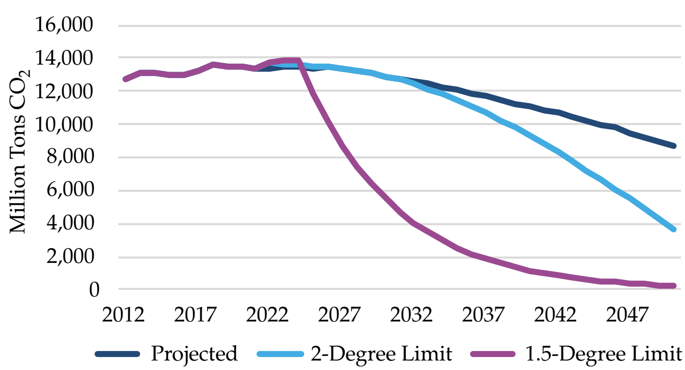
[1]This amount is equal to approximately 157 petawatt-hours per year, or 157 quadrillion watt-hours per year.

keep CO_2 emissions low enough to ensure that the global average temperature warms by less than 2°C, compared with the levels of the mid-1800s. As **Exhibit 6** shows, the current trajectory keeps us on a less than two-degree path for the next decade or so, after which we would need to restrict CO_2 emissions much more than currently projected. So-called phase II renewables, such as geothermal energy, biomass, and carbon capture and storage (CCS) technologies, will have to be deployed on a large scale to keep us within those limits.

The situation becomes even more challenging if we want to keep global warming within 1.5°C of mid-19th-century levels. In that case, we would need to decarbonize the power sector completely by 2050. A radical shift to renewables, nuclear energy, and other zero-carbon power sources would then be necessary in the mid-2020s.

Today, such a drastic policy change seems unlikely, especially on a global scale. The UN Principles for Responsible Investment, however, argued that a point will come when the effects of climate change will become so visible and salient that public pressure on governments around the globe will increase. Pressure could rise to such a level that politicians will need to change course abruptly and embark on a serious policy shift just to keep their re-election chances intact (Principles for Responsible Investment 2018). In a joint publication, the IEA and IRENA (2017) called for an "unprecedented policy effort" to stay below the two-degree limit with a probability of 66% or higher. The reduction in the use of fossil fuels and their replacement with renewables would have to progress at approximately twice the rate we have seen in recent years (IEA and IRENA 2017).

Exhibit 6. CO_2 Emissions of the Power Sector



Source: BNEF (2019).

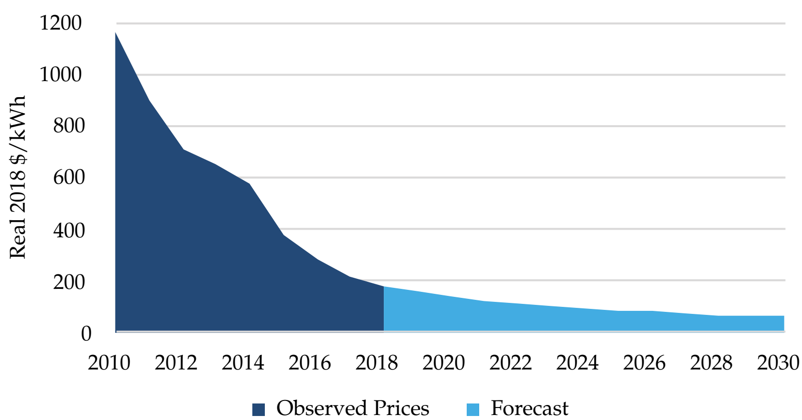
A New Kind of Resource Competition?

Although we could face a drastic shift in climate change policy or investment activity that turns the current transition to renewables into a revolution, we think that looking at the consequences of the current mainstream scenario rather than banking on extreme scenarios is best (see also the rules of forecasting in chapter 5).

One of the areas in which the transition toward renewables might cause geopolitical shifts is in the supply of metals required in solar and wind energy applications. In particular, battery prices have declined rapidly over the past decade and are expected to halve again from current levels by 2025 and then to drop to one-third of current prices by 2030, as **Exhibit 7** shows.

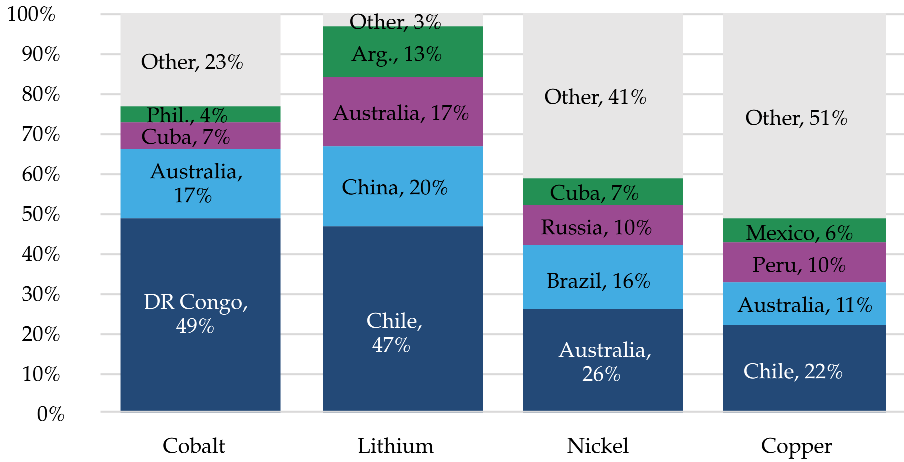
This decline in battery prices creates demand for batteries and, in turn, for the metals used in modern lithium-ion batteries. The most important metals used in the production of batteries are lithium, cobalt, and nickel. Copper, steel, and cement are used heavily in the construction and wiring of solar power plants and windmills. These materials therefore are often the focus of demand analyses in the wake of the shift to renewables. **Exhibit 8** shows the four largest producers of these crucial metals globally. One might ask whether the proliferation of batteries could lead to a geopolitical race for influence in these countries, similar to the race for influence that occurred in the oil-rich Middle East during the 20th century. Especially in the case of cobalt, of which the Democratic Republic of Congo (DRC) owns approximately one-half of global reserves, and Cuba another 7%, these poor countries could possibly become a football in global geopolitics.

Exhibit 7. Lithium-Ion Battery Prices



Source: BNEF (2019).

Exhibit 8. National Origins of Renewable Energy Metals



Source: Månberger and Johansson (2019).

For other materials (i.e., lithium and copper), Chile and Australia are effectively the dominant countries of origin, and the potential exists that a production cartel in these metals could control global prices. As we saw in chapter 4, such cartels in copper and other metals have not lasted in the past and quickly were dissolved as some members of the cartel defected and undercut other members' prices.

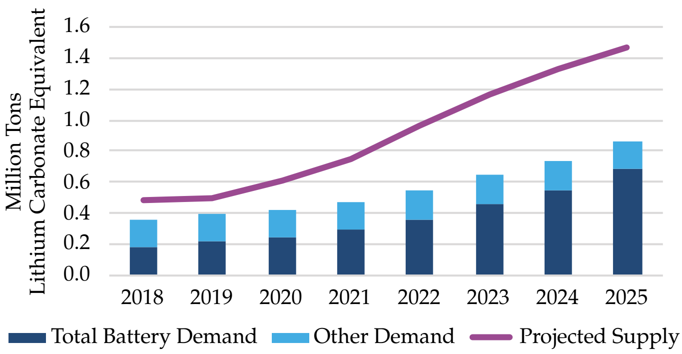
Furthermore, Overland (2019) showed that geopolitical conflict over these resources is not likely for several reasons. Technological progress is fast, and with it comes a declining reliance on such metals as cobalt, lithium, and copper (Månberger and Stenqvist 2018). Increased recycling and the reuse of old batteries will add to the existing supply of these metals. Furthermore, the value of the metals used in batteries and renewable energy applications in general is much lower than the value of oil and other fossil fuels today (Månberger and Johansson 2019). Price spikes in these metals therefore lead to less strain on governments and businesses and, in turn, less push for political intervention to secure access to these resources. Why send an army when you can simply write a check?

The same is true for the eternally misnamed rare earth metals, which are not actually rare and of which China has little incentive to cut supply, despite being in control of more than 90% of the global supply (see chapter 4 and O'Sullivan, Overland, and Sandalow 2017).

Except for Cobalt, an Adequate Supply of Required Metals Is Available. Furthermore, I agree with the analysis in Overland (2019) that geopolitical conflict over metals is unlikely to materialize simply because, well, they are not truly scarce. **Exhibit 9** shows the projected demand and supply for lithium, sometimes called white gold for its dominance in battery production, over the next five years. Global supply of lithium was 35% higher than global demand for the metal in 2018. By 2025, the supply of lithium is projected to be 70% above projected global demand. If anything, investors should expect lithium prices to drop over the next five years.

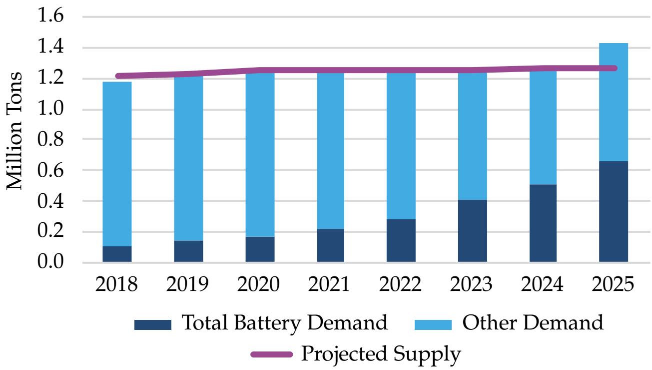
The global balance between supply and demand is somewhat tighter in the case of nickel. **Exhibit 10** shows that until 2025, nickel supply is expected

Exhibit 9. Lithium Demand and Supply



Source: BNEF (2019).

Exhibit 10. Nickel Demand and Supply



Source: BNEF (2019).

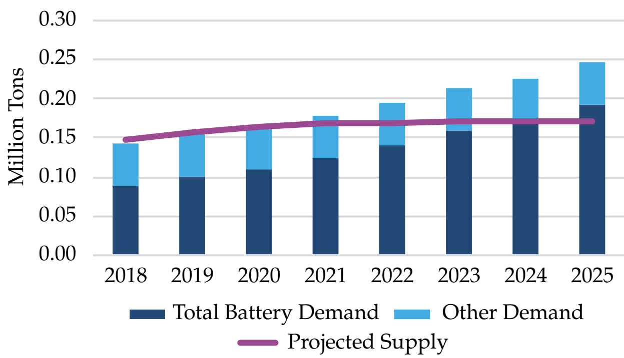
to match nickel demand, which means that prices should remain stable or rise slightly. In the short term, production outages in the world's largest nickel mines in Chile, Peru, and Australia could lead to significant price spikes, but little evidence is available for a systemic shortage of nickel in the next few years that could trigger significant price increases.

The only metal facing significant supply shortages in the coming years is cobalt. **Exhibit 11** shows that starting in 2021, global demand for cobalt is expected to exceed global supply. This means that cobalt prices could increase significantly for a while until the point at which recycling becomes economically feasible on a large scale and new mining capacities come onto the market.

We do need to be aware that modern batteries are using less and less cobalt. A lithium-ion battery with a nickel-manganese-cobalt cathode was developed a decade ago (so-called NMC 333) and contains approximately 20% cobalt by weight. Today's state-of-the art NMC 622 batteries contain approximately 12% cobalt by weight, and the next-generation NMC 811 batteries contain only 6% cobalt by weight (Vergine and Van Hyfte 2018). Yet despite this reduced use of cobalt in batteries, the supply shortage is expected to persist until at least the mid-2040s (Månberger and Stenqvist 2018).

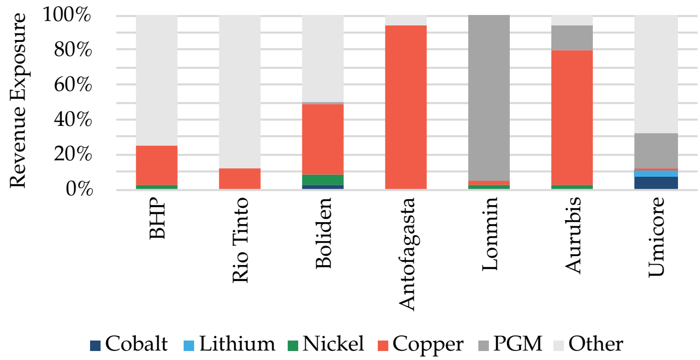
Unfortunately, investors have difficulty getting exposure to cobalt mining because the largest mining companies in the world currently have no cobalt operations. **Exhibit 12** shows that only the Swedish mining company Boliden and the Belgian materials company Umicore have a small exposure to cobalt prices. In the case of Umicore, this is primarily driven by the company's recycling business, which should thrive in a world of persistent cobalt shortages and long lead times to develop new cobalt mines.

Exhibit 11. Cobalt Demand and Supply



Source: BNEF (2019).

Exhibit 12. Exposure of Major Mining Companies to Metals Used in Renewable Energy



Note: PGM = platinum group metals.
Source: Vergine and Van Hyfte (2018).

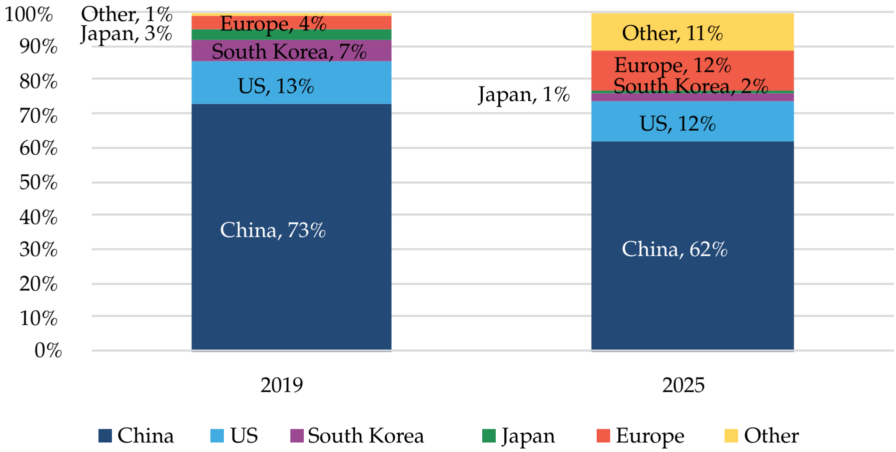
Bazilian, Sovacool, and Moss (2017) concluded that given the realities of supply and demand, the fears of a new resource war centered on metals are overblown. Instead, the focus of geopolitics is likely to shift away from access to resources to increased access to technology and supply chains.

Navigating the Energy-Technology Revolution

If we look at the transition from fossil fuels to renewables, it is evident that this is not just an energy transition. The technologies needed to develop renewable energy are much more complex than the technology needed to pump oil and gas out of the ground and refine it into distillates, such as heating oil, gasoline, and kerosene. The shift to renewables thus can be termed an energy technology revolution (ET revolution) in which the countries with the best technology and access to the best know-how and research will have a competitive and geopolitical advantage over the countries that own the resources. Criekemans (2018) postulated that the balance of power could shift away from the owners of resources and toward the countries that own the technology. The future power base of countries will increasingly depend on the countries' ability to combine technology with the natural abundancy of specific renewable energy sources in their region.

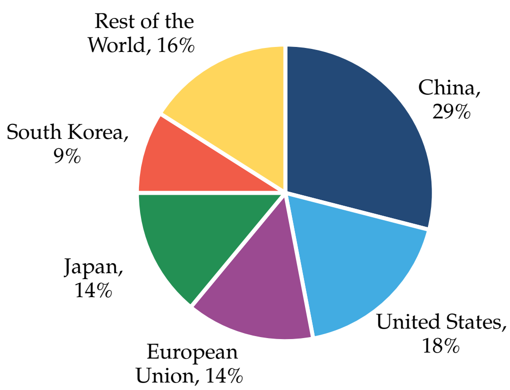
In light of this, it is important to note that with respect to one crucial technology, namely batteries, China has already outpaced the rest of the world. **Exhibit 13** shows that in 2019, roughly three-quarters of global manufacturing capacity for batteries was located in China. Europe and other countries in Asia are pushing hard to build additional facilities, but in 2025,

Exhibit 13. Battery Manufacturing Capacity



Source: BNEF (2019).

Exhibit 14. Share of Renewables Patents



Source: IRENA.

China will still control more than 60% of global manufacturing capacity. China's know-how in batteries and its production capacity are already so dominant that Western car manufacturers are developing new battery technology in research labs in China and rely on Chinese production facilities to drive their future production of electric vehicles (see also chapter 6).

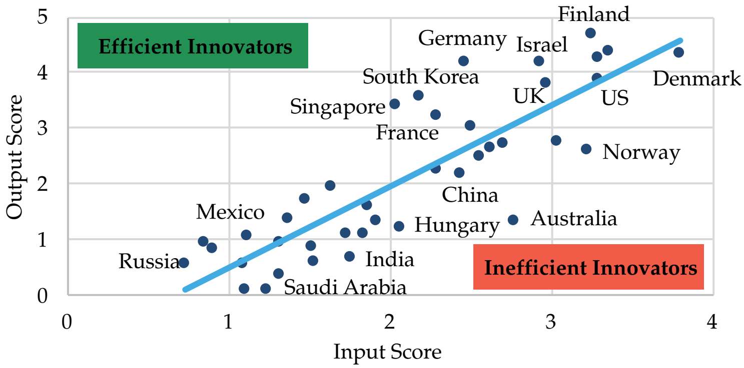
China is also the leader in research and development (R&D) activities in renewable energy. **Exhibit 14** shows that in 2016, 29% of new patents in the renewable energy space were granted to companies and institutions in China, compared with 18% in the United States and 14% in the European Union. China's focus on next-generation technologies means that the country also cooperates intensively with research laboratories and universities in the West to gain access to the know-how there.

China's advantage in renewable energy and batteries, however, might not be as large as the statistics suggest. Arguments have been made that the quality of the patents of Chinese companies is below the quality of patents issued to Western researchers. China still lags the West, and in particular the United States, especially in the area of fundamental research that drives the next generation of breakthrough technologies. The Cleantech Group each year selects the top 100 private companies in the world that are likely to make a significant impact in the coming 5 to 10 years (Cleantech Group 2018). In the 2018 edition, 58 of the 100 companies were based in the United States or Canada and had a combined market valuation of $10.6 billion. In comparison, the United Kingdom had 7 of the top 100 companies, Germany 10, and Israel 5. And China? Three. Of course, this is a statistic about private companies, and the venture capital tradition is simply not as strong in China as it is in the West.

The Cleantech Group also looks at the ability of countries to transform research into economic output in its Global Cleantech Innovation Index (Cleantech Group 2017). It assesses the quality of inputs of innovation such as R&D expenditures, infrastructure for innovation, and government policies to foster innovation in cleantech. The organization then compares these quality measures to a country's output, measured as the number of patents granted, the number of employees in the cleantech industry, the market value of listed and private companies, and the international trade in cleantech products.

Exhibit 15 shows the input score of several countries in the Cleantech Group's 2017 study, along with each one's output score. The higher the score, the more resources available to the cleantech industry in each country. The chart shows that Denmark is the global leader in cleantech innovation, with lots of resources and policies in place to foster cleantech innovation. Yet compared with Finland, Denmark is less efficient in converting these inputs into impactful outputs. The position of the United States on the trend line in Exhibit 15 indicates that the country is roughly average in converting inputs into meaningful outputs. China, on the other hand, is slightly inefficient, as indicated by its position below the trend line. The world's most efficient countries in cleantech innovation are Germany, South Korea, and Singapore, where investors get the best value for their money. In contrast, countries such as India, Australia, and—surprisingly—Norway are among the least efficient countries with respect to cleantech innovation.

Exhibit 15. Efficiency in Cleantech Innovation



Source: Cleantech Group (2017).

From Phase I to Phase II Renewables. The ET revolution depends not only on economic incentives and R&D efforts but also, to a large extent, on domestic policies in different countries. Renewable energy is a catchall term for a diverse set of technologies and can mean different things to different people. In Europe, renewables predominantly mean wind and solar energy. But in France, nuclear power is an accepted complementary technology to reduce CO_2 emissions and fight climate change, while nuclear power is being phased out in such countries as Germany and Switzerland. In other parts of the world, renewable energy can mean predominantly geothermal energy, as is the case for Iceland, or water, as in Norway and Switzerland.

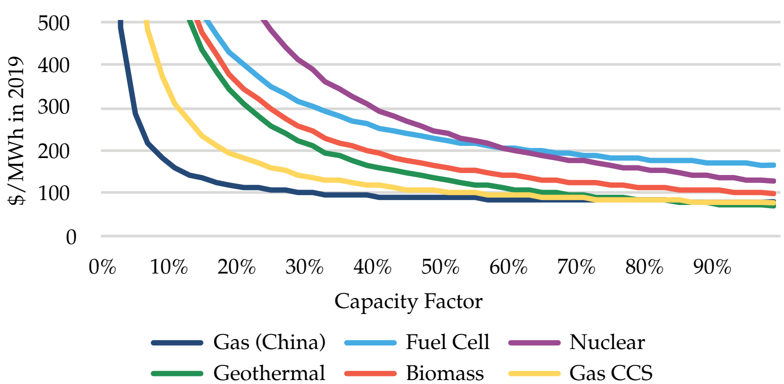
The advantage of wind and solar energy is that it can be produced in a decentralized manner and on different scales (from single-household rooftop solar PV to large, utility-scale solar arrays). The upfront capital needed to build windmills or solar power plants is relatively low, making such investments ideal for private investors. In countries where large corporations and the government can dedicate significant resources to developing renewable energy, other technologies such as CCS and nuclear power are often seen as a valid alternative to wind and solar, especially with respect to avoiding the intraday and seasonal fluctuations of these mainstream renewable technologies (Paltsev 2016).

The variability in power generation from solar and wind also drives the search for phase II renewables. These new technologies are designed to help alleviate the shortcomings of wind and solar and to provide alternative sources of renewable and zero-emission energy. As we have seen, these phase II renewables will become particularly important if the transition from fossil fuels to renewables speeds up. The most important technologies developed in this area are biomass reactors that generate methane and other flammable gases from organic waste, geothermal reactors that use the heat gradient in the earth's surface, and fossil fuel plants with CCS facilities. Additional popular technologies are concentrated solar power reactors, fuel cell reactors (particularly for use in cars), and subcritical small-scale nuclear reactors, of which a meltdown like the one in Chernobyl is physically impossible.

At the moment, none of these technologies are economically competitive with existing technologies. **Exhibit 16** shows the levelized cost of energy production for a selection of phase II renewables in comparison to the levelized cost of energy of running a gas power plant in China. ("Levelized" refers to the lifetime costs of building, running, and decommissioning the plant divided by the energy the plant produces over its lifetime.) The average cost to produce 1 MWh of electricity is plotted as a function of the capacity factor—that is, the share of time in a year when the plant is actually running and producing electricity. As Exhibit 16 shows, geothermal energy and gas power plants with CCS are competitive with a traditional gas power plant when running at full capacity or close to 100%. Biomass reactors are not far behind.

In a world dominated by wind and solar, these phase II renewables would have to work with capacity factors of 30% or less. And for such low-capacity factors, these phase II renewables are still significantly more expensive than natural gas. As a result, for now, natural gas will remain the power source of choice to complement wind and solar energy. But as we have seen in the past decade, technological progress advances quickly, and in 10 years' time,

Exhibit 16. Levelized Cost of Energy of Phase II Renewable Energy Sources



Note: Gas CCS = gas with carbon capture and storage.
Source: BNEF (2019).

CCS technologies or biomass and geothermal energy production might be ready for prime time.

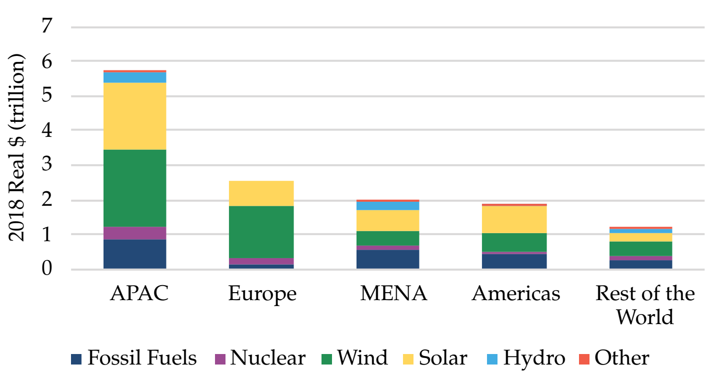
Where Does the Money Come From?

If global electricity demand increases as expected by 62% between 2019 and 2050, who is going to build all the new capacity? And more important, who is going to finance it? According to BNEF (2019), total investments of $13.3 trillion (in 2018 US dollars) will be needed to make this capacity expansion a reality. That amounts to $425.5 billion per year globally. Of this $13.3 trillion, approximately 77% will go to renewable energy sources, primarily solar and wind.

Because energy demand increases most rapidly in Asia, this region will require the most investment. In total, $5.8 trillion needs to be invested in the Asia Pacific region, with China needing $2.9 trillion, India $1.4 trillion, and Southeast Asia $0.6 trillion. Given China's ambitious emission targets, we should expect to see significant resources in that country put to work not only in wind and solar but also in nuclear power, whereas India will be the last major investor in coal power plants and is expected to invest $152 billion in this technology between 2019 and 2050 (BNEF 2019).

In contrast, **Exhibit 17** shows that in Europe, fossil fuels and nuclear energy play only a minor role and are expected to require investments of $135 billion and $171 billion, respectively—nothing compared to the $1.5 trillion investment in onshore and offshore wind. Solar energy investments are likely to amount to only approximately one-half of those made in wind energy, which is understandable given Europe's northerly location.

Exhibit 17. Global Energy Investments by Region, 2019–2050



Note: APAC = Asia Pacific; MENA = Middle East and North Africa.
Source: BNEF (2019).

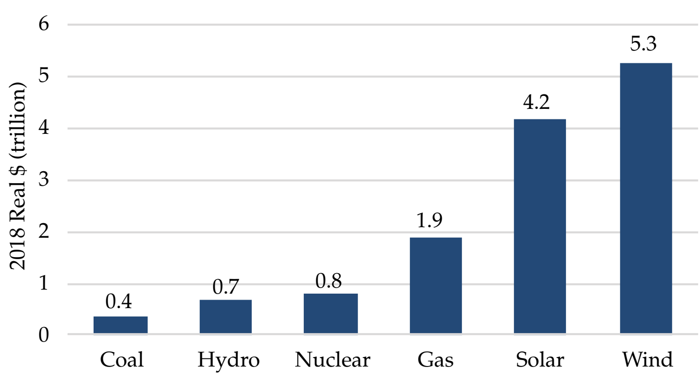
In the Americas, as well as in the Middle East and North Africa, solar power will likely play a more important role, attracting roughly the same amount of investment as wind power (BNEF 2019).

If we look at financing needs by energy source, we see that solar and wind energy require the bulk of financing at $4.2 trillion and $5.3 trillion, respectively, as shown in **Exhibit 18**. This is both good and bad news. The bad news is that the financing needs are quite large, but the good news is that solar and wind power projects are smaller in scale and require less upfront capital expenditure, thereby allowing private and institutional investors to finance individual projects.

The growing shift toward sustainable finance and environmental, social, and governance investing means that private investors are becoming an increasingly important source of capital for solar and wind power plants. A number of firms have listed investment companies similar to REITs that develop and operate wind and solar energy power plants. Like traditional utility companies, such specialized listed investment companies offer stable cash flows and high dividend yields and could become a significant source of investment capital in the future. Private households might also emerge as a major source of small-scale, decentralized renewable energy capacity. Globally, approximately $1.9 trillion is projected to be invested in rooftop solar PV and small-scale batteries by 2050 (BNEF 2019).

What Is the Right Pricing Mechanism? A problem arises, however, with the expansion of wind and solar energy. Because existing solar and wind power plants can generate electricity virtually for free, the expansion of wind and solar power capacity creates downward pressure on wholesale

Exhibit 18. Global Energy Investments by Energy Source, 2018–2050



Source: BNEF (2019).

electricity prices. In regions with a large penetration of solar and wind energy, such as California and Germany, we are already witnessing several days a year when wholesale solar power prices become negative; that is, consumers are paid to use the electricity. In 2017, realized solar PV power revenues were approximately one-fifth below the round-the-clock averages for the year (BNEF 2019). At the same time, a heat wave in California or Australia could lead to a scarcity of electricity generated from solar and wind, triggering massive short-term price spikes. Who would invest in an asset that has low to no income and high cash flow volatility?

Thus far, the solution for producers of solar and wind energy has included a combination of free-market prices to exploit scarcity spikes with long-term fixed tariff contracts wherein utility companies purchase solar and wind energy at a fixed cost and in fixed quantities for several years. This ensures that some of the uncertainty about future electricity prices is rolled over to utility companies, while some of it remains on the books of the producer.

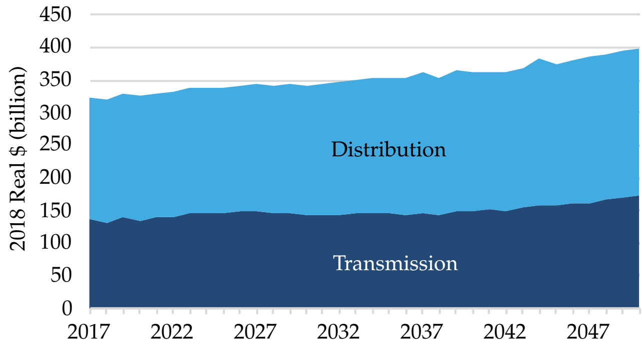
Other forms of price formation will likely have to become part of the market mix in the future to provide reasonable certainty to investors that their investments will create positive net cash flows, at least on average, over time. This does not necessarily mean a regulated electricity market in which prices are fixed by the government or a regulatory body. A feasible solution would be to complement free-market pricing with auctions in which capacity is sold at a fixed price for several years.

Such auctions are already commonplace in many countries around the world. In one version, long-term offtake contracts are sold at auction, providing producers of renewable energy with a stable cash flow, while variable electricity production is sold at market prices. One can also think about the reverse situation, in which long-term market prices are negotiated in an unregulated market but variable capacity is auctioned off at guaranteed prices.

Both models can work and reduce the risk for investors while allowing for competitive pricing of electricity. In the end, the process will be a political one, determining which of these solutions for price formation will be implemented. Without such solutions, however, raising the vast sums necessary to expand the global electricity generation capacity to the required extent over the next three decades seems difficult.

The Bottleneck Is the Electricity Grid. The investment requirements do not stop at the ability to generate electricity. We also need to invest in the infrastructure required to transport and distribute electricity. And here comes the shocker. To deliver this electricity to end consumers, another \$11.4 trillion in infrastructure investments is needed. **Exhibit 19** shows that

Exhibit 19. Global Investments in Electricity Infrastructure, 2017–2050



Source: BNEF (2019).

on average, we must spend $148 billion per year on transmission infrastructure and $205 billion per year on distribution infrastructure. Approximately three-quarters of these investments will be required to replace and refurbish old, existing infrastructure that has reached the end of its useful life.

These investments will be focused primarily in industrial countries where the electricity grid is already well developed. Conversely, in emerging markets, a substantial amount must be spent on new transmission and distribution infrastructure, particularly after 2030, when existing grids hit their capacity limits.

In this respect, investors must be aware of the activities of what can easily be called the biggest investment project one has never heard of, namely, China's Global Energy Interconnection, which was set up by the State Grid Corporation of China (SGCC) in 2016 as part of the country's Belt and Road Initiative. It is about to become the biggest investment project in the world and consists of three pillars: (1) an intercontinental backbone network of transmission and distribution grids; (2) large power bases in polar regions, at the equator, and on every continent to integrate distributed power generation from renewable energy sources; and (3) a smart platform that enables energy trade and resource allocation (Cornell 2019).

In a first stage, China promoted the project globally and sponsored R&D in grid infrastructure. This first promotional and explorative stage was expected to last until 2020. Between 2020 and 2030, countries that participate in the Global Energy Interconnection will develop their renewable energy capacity and connect their grids. Finally, from 2030 to 2050, a total of 126,000 km of transcontinental grids will be installed. Each grid will run ultra-high-voltage (UHV) circuits. These UHV circuits were developed in Europe but have been increasingly used in China. Today, Chinese companies are technology leaders in these UHV grids, meaning that building this global grid will benefit Chinese companies and rely on Chinese technology standards—a major source of economic power for the country.

Developing electric grids between 2020 and 2050 allows China to tap into newly built power generation capacity in neighboring countries in Southeast Asia and India. These renewable energy sources are most likely constructed with Chinese solar panels and digitalized distribution technology, in which Chinese companies are world leaders as well, thus providing ample opportunities for growth for Chinese companies.

Additionally, Chinese companies are increasingly investing overseas to secure access to lucrative markets that support continued growth. Between 2013 and 2018, China invested $452 billion overseas in power transactions. Of these investments, power transmission alone accounts for $123 billion. In the European Union, where no regulator is in place to oversee merger and acquisition activity in the power sector, as the Federal Energy Regulatory Commission does in the United States, Chinese companies can invest heavily in local grid companies.

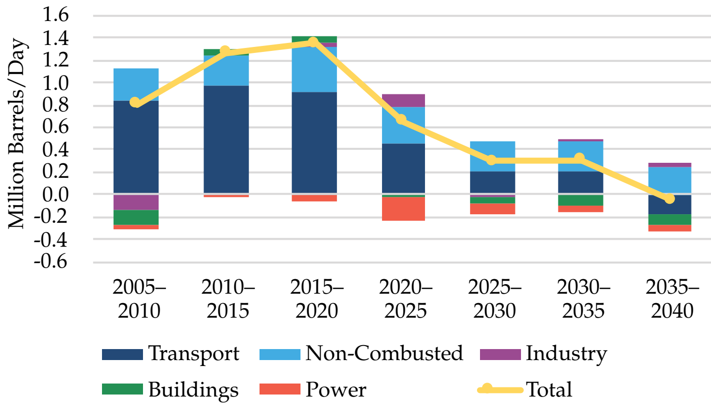
For example, in 2012, SGCC became the largest shareholder in Portugal's electricity grid operator. Chinese state companies own significant grid assets in Italy and Greece, and the country's Three Gorges Corporation wants to expand its stake in the Portuguese utility company EDP (Energias de Portugal). Thus, the Global Energy Initiative is not only a massive investment project that benefits Chinese companies and the recipients of infrastructure investments from China but also a vehicle for soft power that allows China to increase its influence on technological standards and policy making in the areas of infrastructure and global trade (Cornell 2019).

The Decline of Petrostates?

As renewables become more important both in electricity production and transportation, the demand for oil and other fossil fuels is likely to grow at a slower pace. This does not mean that oil demand is going to decline. Most forecasters expect peak oil demand to occur in the mid-2030s, although some think it will not happen before 2060. A typical path of global future oil demand growth is shown in **Exhibit 20** based on data provided by BP.

Demand growth is expected to halve over the next five years, from 1.35 million barrels per day between 2015 and 2020 to 0.65 million barrels per day between 2020 and 2025. The main drivers for this growth deceleration are the decline in demand from the power sector and slower growth in the transportation sector as a result of the greater popularity of hybrid and electric vehicles. By the late 2020s, demand for oil for non-combusted uses

Exhibit 20. Annual Demand Growth for Liquid Fossil Fuels



Source: BP (2019).

(primarily plastics, but also pharmaceuticals, paints, and other products) is expected to become the most important driver of demand for crude oil and its distillates. At that point, annual demand growth for crude oil is expected to have declined to essentially zero.

So far, demand growth in emerging markets is still strong because of strong population and GDP growth in these regions. In industrial countries, however, growth has been slowing since before the Global Financial Crisis of 2008. In member countries of the OECD, oil demand has been declining in absolute terms since 2005 and is today at roughly the same level as it was in 1995–1996. Meanwhile, in the European Union, consumption levels have reverted to levels last seen in the mid-1980s (Van de Graaf 2018).

This decline in the rate of demand growth might already be enough to put oil prices under pressure. As we saw in chapter 3, a 1% to 2% shift in the balance between supply and demand leads to a change in oil prices of approximately 10%. Having demand growth slow from approximately 1.5% per year over the past two decades to approximately 0.5% per year over the next two decades could imply a permanent downward trend in oil prices and a significant decline in the revenues of both international oil companies and petrostates. As O'Sullivan et al. (2017) said, this decline in revenues can either trigger economic and political reform in petrostates or create conflict and, in the worst case, trigger civil strife and international wars if the economy of petrostates is not sufficiently diversified.

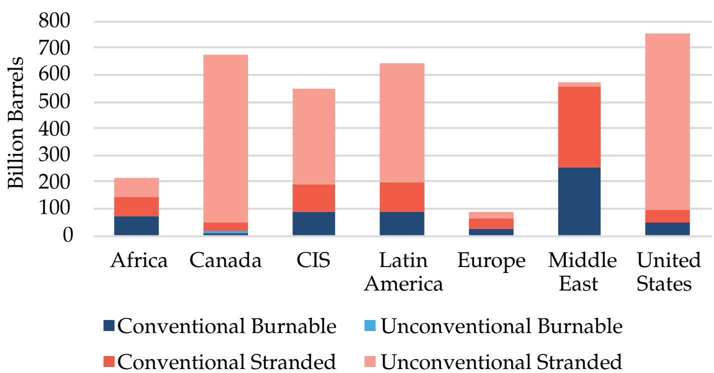
Who Is Left Stranded? The situation becomes even worse if climate change should force a more aggressive policy response globally. Van de Graaf

(2018) calculated that approximately one-half of the global conventional oil reserves and approximately 80% of unconventional reserves would have to stay in the ground forever if we hope to keep global warming at less than 2°C. **Exhibit 21** illustrates this trend. Canadian tar sands, US shale oil, and Arctic and Antarctic oil deposits should all be left unextracted if we want to have a decent chance of keeping climate change under control. Even if we assume the widespread adoption of CCS technology, approximately 30% of conventional oil deposits would need to remain in the ground.

Middle Eastern petrostates are often claimed to be the areas that will be most affected by this shift in energy demand. This might not necessarily be the case, however, because these countries have the lowest production costs for a barrel of crude oil in the world, as **Exhibit 22** shows. Therefore, these countries could produce oil profitably long after other countries have left the market. What matters for petrostates is the amount of money earned by producing a barrel of crude oil, and this in turn depends on production costs as well as on the market price of oil.

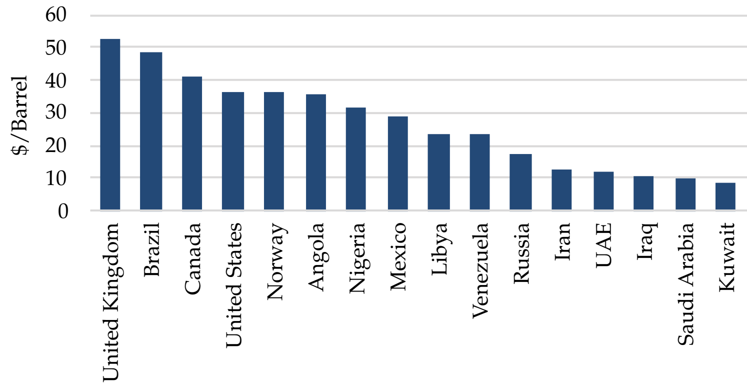
Petrostates essentially have three ways to deal with the challenges of the energy transition and the risk of being left with stranded oil and gas reserves. The first is what Van de Graaf (2018) called "pump and dump." Facing the possibility of dealing with stranded assets, some oil producers—especially those producing at relatively high costs—could decide to sell their oil more quickly than originally planned. Countries that face a high social cost of oil—ones that need oil revenues to finance domestic social safety nets and pension guarantees—also would have an incentive to pump their oil more quickly,

Exhibit 21. Stranded Assets in a 2°C Warming Scenario



Note: CIS = Commonwealth of Independent States of the former Soviet Union.
Source: Van de Graaf (2018).

Exhibit 22. Estimated Cost Of Production for a Barrel of Crude Oil in 2017



Source: Rystad Energy, CNN.

given that they might face social unrest if they have to cut back on their domestic handouts. This is particularly true for autocratic countries, such as Venezuela and countries in the Middle East, that have extensive social benefits financed by petrodollars.

Countries following a pump-and-dump strategy could trigger a surprise increase in global oil supply that accelerates the decline in oil prices. Oil prices in such a scenario would be unlikely to stay above $50 per barrel for an extended period of time. Paradoxically, these lower oil prices could lead to an increase in demand growth for oil in the coming years.

This scenario seems unlikely to materialize for several reasons. First, materially expanding oil production in a country takes time (often years). Today, most countries, with the exception of Saudi Arabia, are producing at or close to their maximum capacity. Therefore, to increase production permanently, new wells must be drilled and new pipelines built, both of which take time. The only source of crude oil that can be expanded quickly (within months) is shale oil, but it is produced at a relatively high price point, so in a pump-and-dump scenario, this source of supply would not be in play.

Russia, however, seems inadvertently caught in a pump-and-dump strategy. The country has a relatively diversified economy compared with other petrostates. Its manufacturing sector is the 10th largest in the world, and the country has a massive defense sector that is financed primarily by oil and gas revenues. Yet to finance its defense sector and diversify the rest of the economy, the country needs additional revenues. So, in its efforts to wean itself off oil, Russia was forced to increase capital expenditure in the oil and gas sector in recent years at a faster rate than in the rest of the economy. On top of that, as a result of the economic sanctions imposed against Russia since 2014, the country relies even more on energy exports. Today, Russia produces not only more oil than 10 years ago, when oil prices were above $100 per barrel, but also effectively pumps as much as it can (Bradshaw, Van de Graaf, and Connolly 2019).

The second strategy for petrostates to follow during the energy transition is to maximize cash flows by controlling production. In this strategy, OPEC would limit production to keep oil prices at moderately high levels to maximize rents while allowing the global economy to continue to grow. This strategy is essentially the one that OPEC+ (OPEC in coordination with Russia) follows today.

In this scenario, oil prices should hover around $50 per barrel. At an upper limit of approximately $60 per barrel, shale oil production becomes profitable quickly, leading to the expansion of US production. The challenge OPEC faces with this strategy is keeping individual member states from defecting. Some OPEC members produce at much higher costs than Saudi Arabia and other members of the Gulf Cooperation Council (GCC), which gives them an incentive to pump more oil than they agreed to.

This situation already happened in the early 1980s when OPEC introduced production limits that were undermined by several member states that continued to produce more than their quota. The result was a continued decline in oil prices that increased the incentive for these defectors to pump even more oil. In 1986, Saudi Arabia finally stepped in and swamped the market with its oil to enforce discipline on the other OPEC member states.

For investors, of course, the result was that oil prices stayed low for another decade or so until China and other emerging markets had created enough additional demand to push oil prices higher. When, in early 2020, Russia tried to defect from the OPEC+ agreement to cut production, Saudi Arabia again employed this strategy, and Russia had to cave within months and get back in line with OPEC to stabilize the oil price, albeit at much lower levels than before it tried to defect.

The third strategy petrostates can follow is arguably the most sustainable. Facing declining oil rents, petrostates could try to diversify their economies and bolster domestic consumption. The problem is that many petrostates have fallen victim to the so-called Dutch disease, a situation in which the oil sector becomes so dominant that other parts of the economy suffer neglect and become uncompetitive over time.[2]

[2]This situation is called the Dutch disease because this kind of scenario occurred in the Netherlands in the 1960s; the Dutch economy has since diversified and prospered.

In these countries, many of which are ruled by an autocratic regime, social cohesion is bought with oil money. To diversify their economy, petrostates need to engage in a long-term strategy to use their wealth to develop their economy rather than spending it on social safety nets and domestic subsidies. If that is not possible, then additional revenues might be raised by selling off some oil assets.

Saudi Arabia tries to follow this diversification strategy. A few years ago, the country introduced Saudi Vision 2030, a strategic plan that aims to increase the role of the private sector in the economy and to diversify the revenues of the state. The IPO of Saudi Aramco was a means to this end. By raising capital from foreign investors, Saudi Arabia could invest the proceeds of the IPO into achieving the goals of Saudi Vision 2030 while simultaneously offloading some of the risks of stranded assets and declining oil rents onto international investors (Bradshaw et al. 2019).

Which strategy each oil-exporting country will take depends on several factors. As Goldthau and Westphal (2019) pointed out, the key variables seem to be the production costs of crude oil and the reserves-to-production (R/P) ratio. Higher R/P ratios imply that a country is forced to be in the oil-exporting business for longer. In this light, recognizing that many of the high-cost producers of oil also have rather low R/P ratios is instructive. Mexico, for instance, is a high-cost producer with an R/P ratio of nine years. Brazil's R/P ratio is 13 years, and Angola's is 16 years. These countries are natural candidates for a pump-and-dump strategy. Other countries with both high production costs and a strong dependence on oil revenues for domestic spending are Venezuela, Nigeria, and Libya.

In contrast, Saudi Arabia's R/P ratio is 60 years, and Iraq's is 90 years (Goldthau and Westphal 2019). Given their low production costs and large reserves, these countries are likely to be in the oil business for the long run. They have an incentive to control output and maximize oil rents while gradually diversifying their economy. Russia is a borderline case. With the lowest production costs outside the GCC and an R/P ratio of 26 years, it could go either way, but as we have seen, for now, the country seems trapped in a pump-and-dump situation.

The irony of these divergent strategies is that OPEC could become more influential again in the future. For decades, OPEC has lacked internal cohesion because different members had different incentives to produce oil. With the transition of the global economy away from fossil fuels, some countries could leave OPEC to follow pump-and-dump and other strategies that they cannot implement under the OPEC quota system. The countries remaining in OPEC most likely would be the low-cost producers of the GCC.

This "core OPEC" would benefit from stronger internal cohesion and thus a better ability to coordinate output and global oil prices.

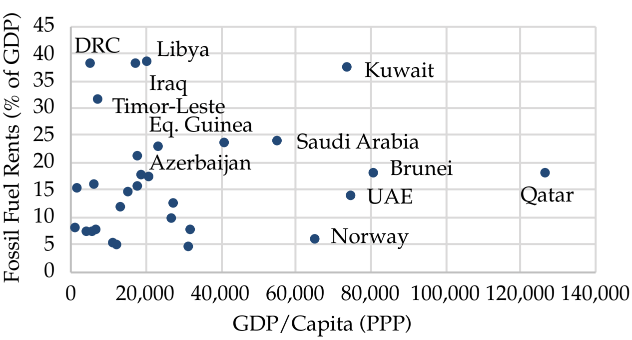
Geopolitical Hot Spots during the Energy Transition

Given the material impact of the energy transition on petrostates, investors need to consider the risks of failure in any one of these countries. What if the strategy to diversify the economy fails and a country remains hooked on ever-declining cash flows from oil and gas exports? What if a country runs a pump-and-dump strategy and then finally runs out of oil?

The vulnerability of petrostates to the energy transformation depends, on one hand, on the share of government income from fossil fuel production and export and, on the other, on the ability of the economy to generate income from other sources. Inspired by IRENA (2019), we have plotted in **Exhibit 23** every country in the world where fossil fuel rents (income from oil, gas, and coal) make up more than 5% of GDP. We compare the fossil fuel rent with the GDP per capita for each country. GDP per capita is used as a proxy for the robustness of the local economy to declining revenues. If a country is very wealthy, declining oil revenues will still hurt, but the risk of widespread poverty that could trigger civil unrest is smaller than in poorer countries. Remember rule 6 of forecasting in chapter 5? "A full stomach does not riot."

Furthermore, a country can usually achieve a high GDP per capita only if its economy has significant sources of income other than the export of oil and gas. The presence of refineries and oil service companies and of businesses in other sectors mitigates the decline in revenues from the production and export of fossil fuels. In fact, as more and more countries around the world introduce carbon trading schemes that increase the cost of CO_2-producing

Exhibit 23. Vulnerability to the Renewable Energy Transformation



Source: World Bank.

activities, some businesses in the energy sector, such as refineries, might shut down in industrial countries and move instead to the Middle East or another oil-exporting region, where the price of carbon is zero or very low—a possibility that will be further explored in chapter 9. Some petrostates therefore would be able to dampen the decline in oil and gas rents with increased income from oil processing and refining.

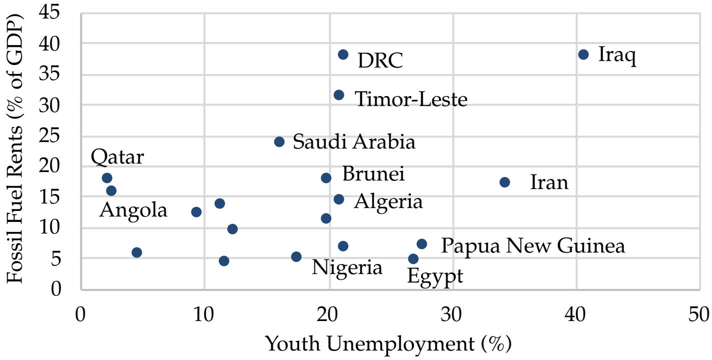
Looking at Exhibit 23, we see that Qatar is probably the least vulnerable petrostate, given its extremely high GDP per capita. Other resilient petrostates are Saudi Arabia, Kuwait, the United Arab Emirates (UAE), and Brunei. Despite their high reliance on fossil fuel rents, they have a relatively high GDP per capita. Arguably, inequality is high in many of these countries, and GDP per capita is not distributed as equally as it is in more diversified economies. This adds additional vulnerabilities that we will address.

For now, it is important to note that the most vulnerable countries seem to be the DRC, Libya, Iraq, and Timor-Leste, which all rely heavily on oil and other fossil fuel exports yet remain very poor. This dynamic provides fertile ground for terrorist organizations and a potential trigger for civil war that could spread to neighboring countries, as we saw in 2011 with the Arab Spring.

The potential for social unrest is particularly high in countries that suffer from high inequality, where, for example, only a small elite benefits from the wealth generated by oil and gas exports while the majority of the population suffers from poverty. The situation becomes even worse when a country experiences rapid population growth and thus has a very young population. As the Arab Spring and so many other civil uprisings in history have shown, it is young men (and it is typically men, not women) with nothing to do all day who are prone to start rioting.

Thus, in **Exhibit 24**, I plot the fossil fuel rents of different petrostates along with the latest available youth unemployment rate. Some countries shown in Exhibit 23 have been omitted from Exhibit 24 because they do not publish youth unemployment figures. Furthermore, in many cases, the youth unemployment figures in Exhibit 24 are several years old and might not be too reliable. With these caveats in mind, Qatar is, interestingly, again relatively immune to the risks of the energy transition because it has very low (official) youth unemployment. Saudi Arabia is a borderline case, with a youth unemployment rate of 16.1%, while countries in Africa, such as Egypt, Algeria, the DRC, and Nigeria, all suffer from youth unemployment rates of 20% or higher. In Iran and Iraq, the youth unemployment rate surpasses 30%, putting these countries at extreme risk of social unrest—or even war—should the economy weaken.

Exhibit 24. Potential for Social Unrest Because of the Renewable Energy Transformation



Source: World Bank.

The Options for International Oil Majors

The energy transition leads to new challenges not only for petrostates but also for international oil companies. After all, international oil majors typically produce at higher costs than do the national oil companies of the GCC. Caldecott, Holmes, Kruitwagen, Orozco, and Tomlinson (2018) ran several war games to simulate the strategic options of international oil companies and the likely impact of each on their share price:

- In the first strategy, oil companies could follow a "first-one-out strategy," in which the company would announce its exit from oil exploration and production, try to sell existing high-cost reserves to competitors, and gradually run down the remaining low-cost reserves. Revenues from oil production would be handed back to investors through dividends and share buybacks. During this transition period, the company would transform itself into an oil services company engaged in midstream and downstream activities, become a renewable energy producer, or simply shut down operations altogether. Theoretically, investors should welcome such a strategy because it would provide growth-style cash flows well into the 2030s and reduce the risk of stranded assets.
- The second strategy could be a "last-one-standing strategy," in which the company tries to accumulate as many low-cost reserves as possible to survive a price war between oil majors. This strategy can work for both the company and its shareholders if the company is financially sound and not too leveraged at the beginning because the acquisition of

additional reserves likely will lead to a substantial increase in financial leverage.

- Under the third strategy, the company could announce a planned transition of its business model away from oil exploration and production to renewable energy or other energy-related services. In this case, committing to this long-term strategy and resisting pressures from shareholders to increase short-term profits is crucial for the company. The transition will likely take years and reduce profitability in the short run, given that costs increase well before revenues and profits from new business areas do. As the transformation progresses, a legal separation of the legacy business and the new renewables business would likely be necessary. Probably the best example of a company following this strategy is DONG Energy, the former Danish national oil company. Renamed Ørsted, the company successfully transformed itself from an oil company into a pure renewables company in recent years.
- Two final strategies are available for oil companies to follow. A "drift strategy" implies that an oil major continues to drift away from high-cost reserves toward low-cost reserves and other fossil fuels, such as natural gas, but makes no plans for a transition or price war. Another option is the "do-nothing strategy" of pretending that all is well and that nothing needs to change. That both of these strategies are disastrous in the long run should be obvious.

Caldecott et al. (2018) reported that in the war games that simulated the fate of different international oil majors based on stylized facts of real-life companies, those that followed a first-one-out strategy had the least amount of stranded assets remaining when oil demand peaked and finally declined rapidly after the 2040s. Unfortunately, the share price of the companies following such a strategy also collapsed because of the rapid reduction of proven reserves on the companies' balance sheets.

That analysts and investors value an oil company largely based on the value of proven reserves, assuming that all reserves eventually will be sold at market prices, is a fact of life. Investors at the moment therefore do not price in the possibility of stranded assets, so a first-one-out strategy is tantamount to shareholder suicide. What companies need for successful implementation of a first-one-out strategy are shareholders who are long-term oriented and take the risk of stranded assets seriously.

In the war games, companies that followed a drift strategy or a last-one-standing strategy saw relatively stable market valuations but were left with the largest stranded reserves at the end of the simulated period. Continued exploration remained profitable until the mid-2020s, at which point demand slowed rapidly, and the price of carbon increased in many countries, rendering impossible the sale of existing reserves at decent prices and the quick transformation of them into a liability on the balance sheet. Thus, investors face decent performance for several years with such companies but run the risk of a catastrophic collapse of the share price if at some point in the future, some or all of a company's reserves become stranded.

Finally, the most successful strategy in the long run was the planned transformation strategy. Although share prices suffered for several years as costs increased and profitability declined, market valuations for these companies increased after a few years as high growth rates in renewables led to higher earnings growth compared with their peers.

War games are a good way to simulate the potential outcome of different strategic options in a competitive environment, but they remain theoretical. Pickl (2019) investigated what some of the biggest international oil companies are really doing.

Royal Dutch Shell seems to be at the forefront of companies following a planned transition strategy. The company no longer calls itself an "energy company" but rather an "energy transition company" and invests $1 billion to $2 billion per year in electricity generation. The company also bought significant stakes in NewMotion (Europe's largest provider of electric vehicle charging stations), First Utility (a UK electricity company), and Silicon Ranch (a US solar developer). With these investments, Shell is among the largest investors in energy transition technologies in the world. Other companies that follow a planned transition strategy are the French oil major Total, which focuses on investment in renewables as well as refining, chemicals, and shipping; Eni in Italy; and the Norwegian Equinor (formerly Statoil).

BP is a special case among European oil majors. The company was one of the first oil majors to invest in renewables, channeling between $8 billion and $10 billion into renewable energy sources in the first decade of the 2000s, although these investments had to all be written off because the projects were too early and could not be made profitable. The reasons were lack of demand and failure to be price competitive with conventional sources of energy. On top of that, the 2010 oil spill in the Gulf of Mexico forced the company to cut costs and exit the remaining renewables projects. Today, the company is caught in what looks like a drift strategy, but management announced in early 2020 that it wants to engage in a planned transition strategy that is more ambitious than the one followed by Shell.

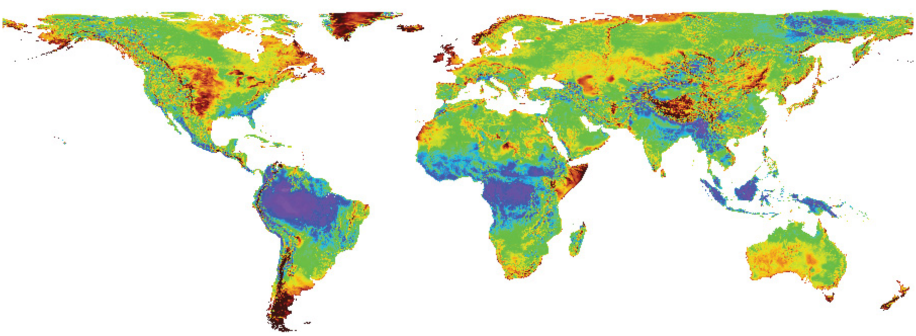
Unlike their European peers, American oil majors such as Exxon and Chevron follow a last-one-standing strategy that focuses on low-cost oil and gas reserves with limited to no engagement in renewables. The only energy transformation technology to which these companies seem to be willing to commit substantial resources is CCS methods of reducing the emissions of gas and coal power plants. Finally, Brazil's oil major, Petrobras, seems to follow a last-one-standing strategy as well. It potentially is exposing itself to sizeable long-term risks, given that Petrobras has significantly higher production costs than Exxon or Chevron and thus seems poised to lose a potential price war.

Energy Independence for Emerging Markets

Historically, the energy transition from fossil fuels to renewable sources of energy such as solar and wind has been driven by industrial countries in Europe. A look at the global wind energy potential, shown in **Exhibit 25**, reveals why. Most European countries are far north and in the middle of steady winds circling the globe from west to east. The west coasts of Ireland, the United Kingdom, and Norway as well as the North Sea and the North Atlantic face steady winds that are ideal for wind farms, both onshore and offshore. As the costs for windmills dropped rapidly, these countries naturally increased the production of wind energy.

The other major opportunity in the Northern Hemisphere for wind energy lies in the plains of Texas and the American Midwest. Rick Perry, the former US secretary of energy and governor of Texas, realized this economic potential and provided significant government incentives to install wind farms in Texas. Today, Texas is the biggest producer of wind energy in the United States, and wind energy from Texas is the cheapest energy source in

Exhibit 25. World Wind Energy Potential



Notes: Blues and greens indicate areas of low potential, and reds indicate areas of high potential. Darker shades of red indicate areas of higher potential for wind energy.
Source: Vaisala, IRENA: Global Atlas for Renewable Energy, Global wind data: VAISALA, 2016.

the country. Houston is no longer just the home of global oil majors but also the home of an ever-increasing number of wind energy companies.

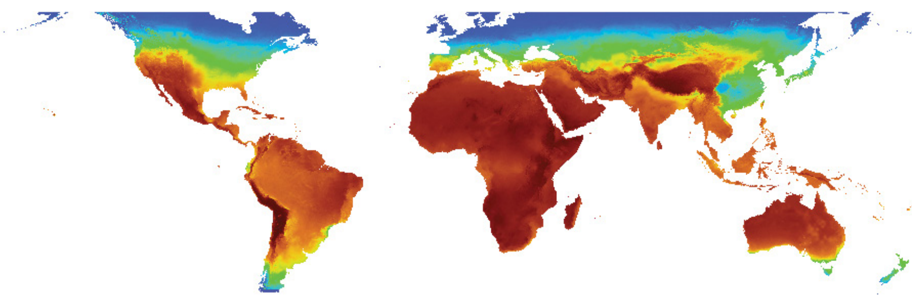
A look at Exhibit 25, however, shows that in the Southern Hemisphere, some of the best places to install wind farms are in emerging markets. The Argentinian Pampas, the Atacama Desert in Chile, and the Horn of Africa are all fertile ground for wind investments. Add in the potential for solar energy, which is obviously highest in the world's deserts and in countries close to the equator, as shown in **Exhibit 26**, and emerging markets clearly have huge potential to benefit from the transition to wind and solar.

BNEF (2018) showed that emerging markets are increasingly driving the transition to renewable energy. In 2017, 63 GW (gigawatts) of renewable energy were installed in industrial countries but 114 GW in emerging markets—mostly in China. And while China, India, Turkey, and South Africa continue to build their coal power capacity, other emerging markets are moving away from coal as a fuel for electricity generation. Investments in renewable energy surpassed $140 billion in 2017, with only $21.4 billion funded from developed countries.

The majority of the funding for renewable energy in 2017 came from local sources. Of 103 emerging markets surveyed by BNEF (2019), only 11 had no official clean energy policy in place. Seventy-four percent of countries had clean energy targets, and 64% gave tax incentives to companies investing in clean technologies. As a share of GDP, the investments in renewable energy in many emerging markets top the investments made in developed markets, such as the United Kingdom and the United States, as shown in **Exhibit 27**.

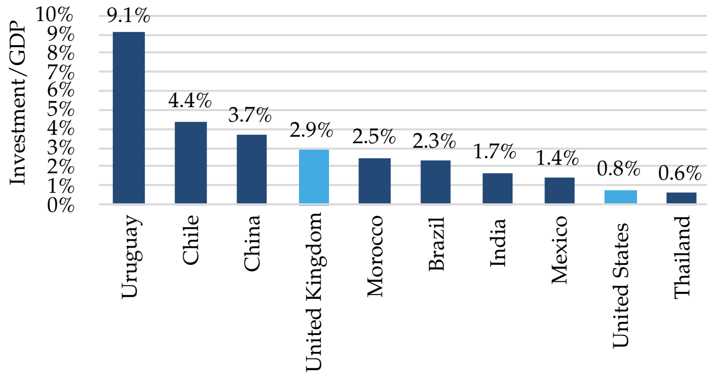
Mexico illustrates how an emerging market can reduce its dependence on fossil fuels and boost investments in renewables. In 2013, the country

Exhibit 26. World Solar Energy Potential



Notes: Blues and greens indicate areas of low potential, and reds indicate areas of high potential. Darker shades of red indicate areas of higher potential for solar energy.
Source: Vaisala, IRENA: Global Atlas for Renewable Energy, Global solar data: VAISALA, 2016.

Exhibit 27. Investments in Renewable Energy, 2013–2017



Note: Dark blue bars indicate emerging markets, and light blue bars indicate developed markets.
Source: IRENA.

liberalized its electricity market. Today, the electric grid is run by an independent operator (CENACE), while power generation is subject to market prices. The country also introduced a goal of generating 35% of its power in 2024 from renewable sources. To help achieve this goal, clean energy auctions were introduced, and clean energy certificates were issued to providers of renewables. The result was a massive increase in renewables investments, from $1 billion in 2013 to $6.2 billion in 2017 (BNEF 2018).

Many countries, however, still face considerable obstacles to the development of renewables. Chile has among the highest potential for both wind and solar energy in the world. The Atacama Desert could become an energy production hub for all of South America. Unfortunately, Chile's electricity grid is run by four different operators that are not linked. As a result, electricity generated in the arid north of the country cannot be transported to the big cities in the south, let alone to neighboring countries. In recent years, multibillion-dollar investments have been made to link the electricity grids of the two largest domestic providers and to connect them to the grid of Peru and other neighboring countries, but much more needs to be done before Chile can meet its potential.

Geopolitical Risks of the Energy Transition

For emerging markets, the energy transition provides many opportunities but comes with its own set of risks. Petrostates, such as many Middle Eastern countries, not only have different incentives than energy importers but also different tools with which to manage the energy transition. And the owners of crucial technologies, most of whom are based in industrial countries in the Northern Hemisphere, fear the loss of intellectual property and cheap competition from emerging markets.

At the moment, therefore, each country manages the energy transition differently and with little international coordination. The UAE, for example, launched its Soft Power Strategy in 2017, which aims to establish bilateral diplomatic links with crucial strategic partners that could become useful during the energy transition (Griffiths 2019).

Although rich in oil, the UAE, like many of its neighbors in the GCC, faces shortages of natural gas supply. Given the area's rapid increase in population, energy demand from private households, much of which is powered by gas, grows fast. Qatar would be the natural hub for local gas supplies because the country has vast gas reserves, but political differences between Qatar and Saudi Arabia, the UAE, and other GCC countries have limited Qatar's ability to deliver gas to its neighbors.

These obstacles have focused the minds of governments in the UAE and other GCC countries, and they are seeking access to gas, nuclear, and renewables technology to develop the countries' domestic power supplies. For example, a bilateral agreement between the UAE and South Korea, in place since 2009, gives the UAE access to nuclear technology. Meanwhile, to increase their influence in the region, both Russia and China are aggressively trying to sell their nuclear technology to Saudi Arabia. In return for access to technology from strategic partners, GCC countries can use their oil as a bargaining chip. No wonder, then, that the strategic partners of the UAE in Asia are China, India, South Korea, and Japan—countries that need Emirati oil and can provide access to crucial technology in return (Griffiths 2019).

Not all emerging markets are as lucky as the GCC and other petrostates. Resource-poor emerging markets must try to improve their economies by building low-cost production centers for renewable energy—in some cases by producing power but also by manufacturing components of solar panels and windmills. Low-cost competition from emerging markets, however, can draw the ire of producers in industrial markets that fear the loss of market share. The tariffs on solar panels that are imported to the United States from China were introduced after the US solar company Suniva filed for bankruptcy in 2017 and complained to the US Commerce Department (see chapter 6).

Because renewables remain a nascent industry, the temptation to introduce trade barriers or protect domestic suppliers from international competition remains high. Thus, the transition to renewable energy increases the risk of a return to government-directed "industrial policies" such as those seen in the 1970s and 1980s.

As Shum (2019) showed, some industrial policies are beneficial and some are harmful. Among the more beneficial policies are those that aim to increase local demand and know-how rather than curtailing supply. Classic examples of such beneficial industrial policies are installation subsidies and feed-in tariffs for renewables. Installation incentives lead to the spread of know-how in renewables technology to small local businesses that install solar panels and windmills. Feed-in tariffs increase demand for solar PV and wind energy that is produced locally and then fed into the electricity grid at subsidized prices. Meanwhile, the question of who supplies solar panels, windmills, and other technology is left to the markets to answer.

The more harmful policies are those that aim to limit supply or protect domestic suppliers against international competition. These policies traditionally take the form of production subsidies and quotas on foreign imports. Under former president Donald Trump, the United States also saw a return to tariffs as a means to protect US manufacturers.

Although such production incentives are politically expedient, they often cause manufacturers to become uncompetitive, then implode once a market is liberalized again, a situation we saw in the early 2010s when European and North American producers of solar panels faced cheaper Chinese competitors and declining domestic demand after government subsidies were curbed. Ironically, in such an imploding market, the temptation to protect domestic manufacturers and jobs becomes even higher for politicians, creating a potentially harmful feedback loop to unwind globalization in the renewables industry. The biggest losers of such a dynamic would be (1) consumers in industrial countries who would have to pay higher prices for renewable energy and (2) manufacturers in emerging markets that would have reduced access to international markets.

Conclusions

In this chapter, we have seen that the rise of renewable energy such as solar and wind has become a fact of life. Wind and solar are the cheapest energy sources (even without government subsidies) in two-thirds of all countries of the world (BNEF 2019). By the late 2020s, wind and solar will likely be cheaper than gas- or coal-powered plants everywhere.

This reality does not mean that we face a rapid decline of fossil fuel as an energy source but rather an evolution in which demand for oil, gas, and coal from the energy sector gradually declines and investments in new capacity are made primarily in the renewables space. Because the transition from fossil fuels to renewables will take many years and peak oil demand is likely to happen only in the mid-2030s or later, investors might be tempted to ignore the energy transition for now.

As this chapter has shown, ignoring the energy transition would be a mistake not just for investors but also for international oil companies and petrostates. Instead, the next decade should be used to diversify the economy of petrostates and the business of international oil majors. Diversification in this context means investing in renewable energy generation that is likely to outgrow oil and gas by a factor of two to three over the next two decades. If this opportunity is missed, geopolitical tension could rise dramatically, particularly in countries that have high production costs for oil and low national income. For international oil majors, not diversifying the business model could even lead to bankruptcy.

The winners of the energy transition will be countries and businesses that have access to the new technologies that drive renewable energy production, because renewable energy production is a high-tech industry. This means that the energy transition is, in reality, an energy-technology transition.

Some countries, including China and Germany as well as those in Scandinavia, have positioned themselves for this energy-technology transition and already have focused their R&D efforts on this industry. The countries that manage the energy transition successfully seem likely to gain considerable geopolitical influence, while the laggards will lose influence. Of course, losing geopolitical influence is not something those countries will take lightly. Instead, we face the risk that countries that are no longer competitive will resort to industrial policies that erect trade barriers or protect inefficient domestic industries from unwanted international competition.

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