July 2019

Energy, Climate Change and Finance: 2019Update

Bradford Cornell
Anderson School of Management, UCLA
Cornell Capital Group
bradford@cornell-capital.com

In *Energy and Investing*, Cornell (2019), I concluded that:

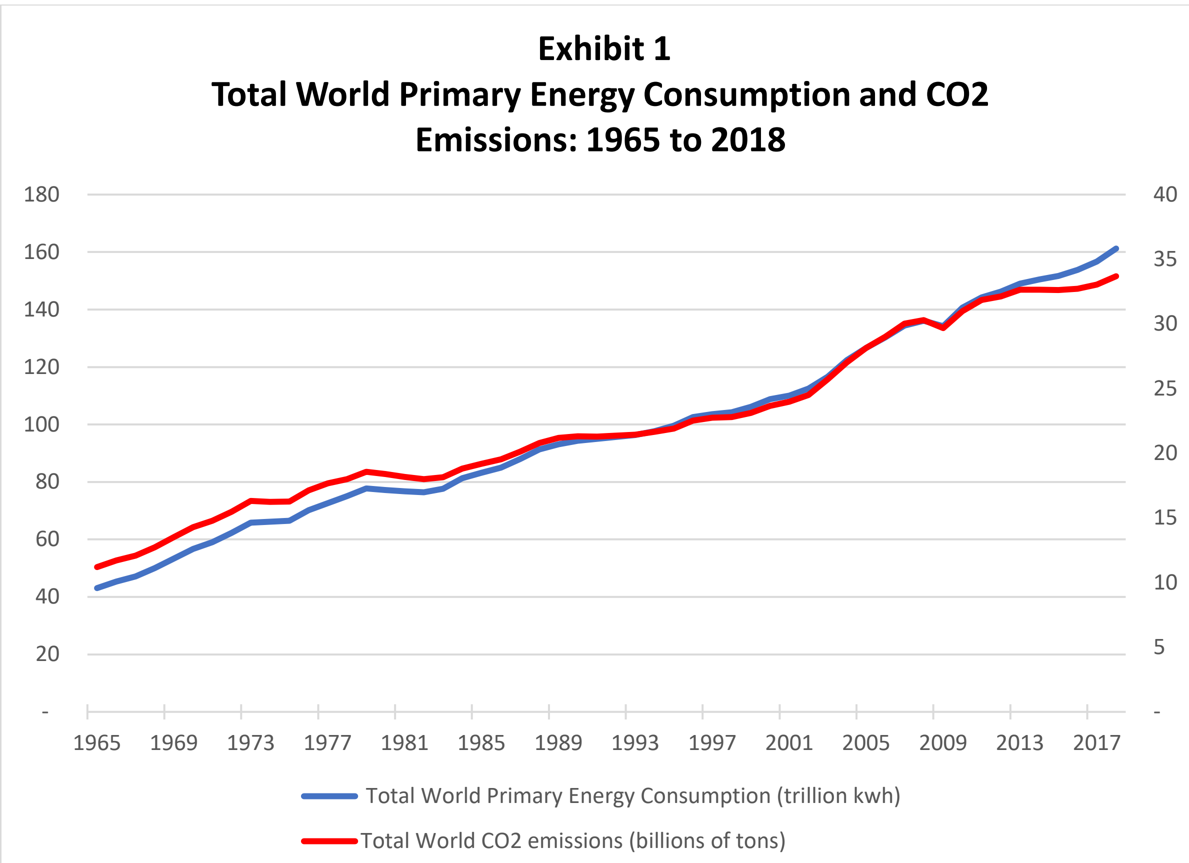
Despite all the publicity given to green energy projects, the inertia behind the use of fossil fuels has continued largely unabated. Driven by a combination of population and economic growth, a huge infrastructure supporting their use, and political roadblocks to rapid change, the use of fossil fuels is widely projected to continue to grow through 2050. In the second half of the 21st century, the great transformation to reliance on renewable sources of energy, primarily via the generation of electricity, will have to begin in earnest. It will entail what may well be the largest capital spending program in human history. Here I have argued that the financing of such a program, if it is to be done outside of direct government control, requires two components. First, a long-term, predictable, carbon tax must be put in place as soon as possible to reflect the social cost of using carbon-based fuels and to provide the proper incentives to invest in alternatives. The predictability must also extend over the long-term given the long life of most energy investments. Any policy uncertainty increases the risk adjusted discount rate investors use to evaluate investments and, thereby, discourages investment.

Second, the size of the required investment and the importance of the ultimate product to people worldwide – namely electricity to power society – has two implications. The first is that electricity will be of such political importance that its price will be tightly regulated, if not controlled directly, by governments. The fact is that there are many more electricity consumers who are voters than there are investors. There will be immense political pressure to keep electricity prices at "fair" levels which means lower returns for investors. The problem is compounded once funds are committed, because governments then have an incentive to behave opportunistically. For low returns to be acceptable to investors, *investment risk – including the risk of opportunistic behavior by the government – must be kept to a minimum. The only feasible way to accomplish that is with government guarantees on a grand scale, an order of magnitude higher than the government guarantees of mortgage securities today.*

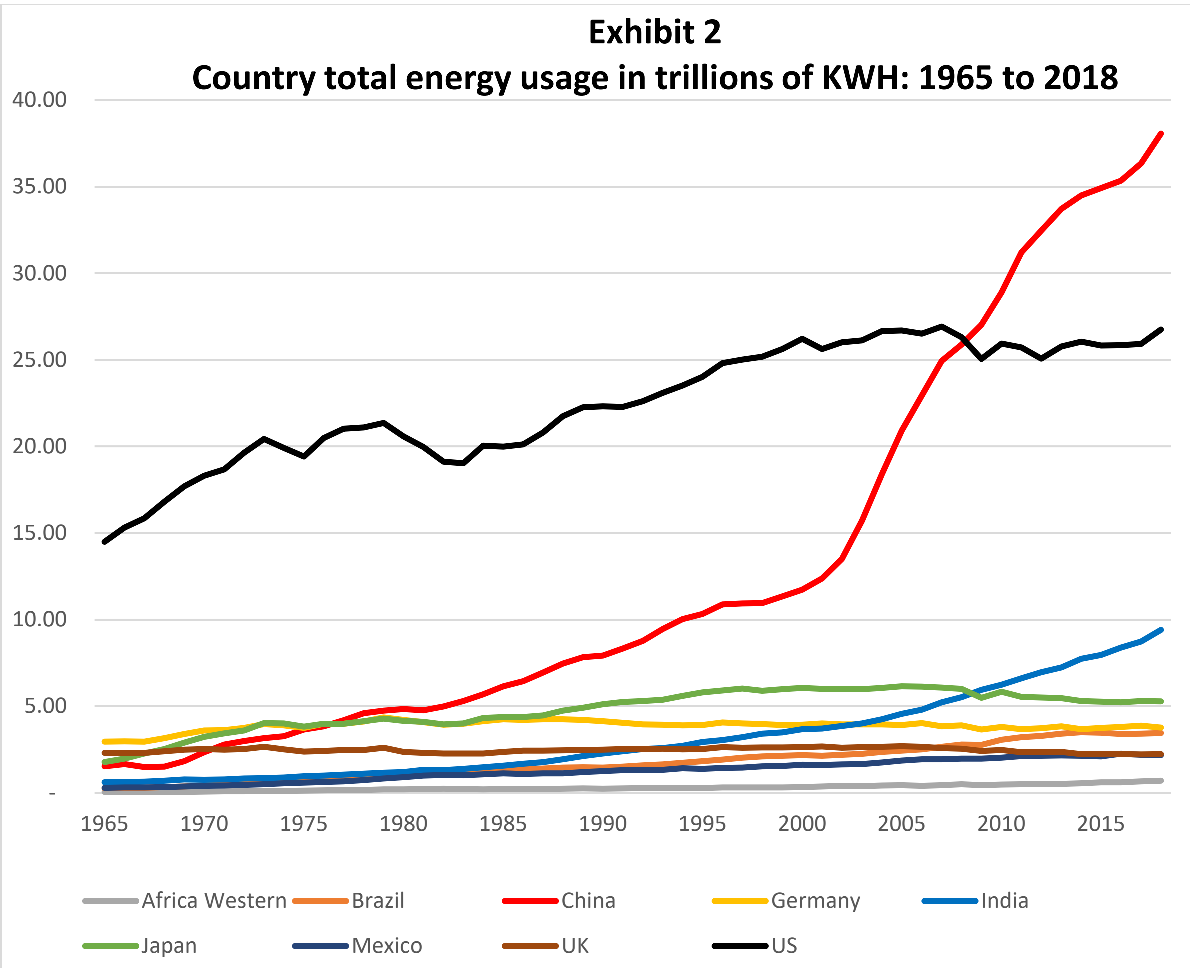
Given that inertia is going to delay the bulk of the great transformation to years beyond 2050, there is time to design the financial structure that will be necessary to fund what may well be the largest capital project in human history. But inertia extends to the financial markets as well. It is time to start preparing for the immense financial requirements of the great transformation.

Data for 2018 are now available and they reinforce the prior conclusions, particularly with regard to inertia. While innovation and adoption continued in the renewal space, it was not sufficient to make a meaningful dent in the dominance of fossil fuels. As documented below, the usage of all types of fossil fuels rose in 2018 along with the associated emissions. Concentration of greenhouse gases in the atmosphere reached record levels. In addition, despite the awarding of the Nobel Prize in Economics to William Nordhaus, a decades long advocate of a carbon tax, there was little movement in the direction of a long-term, predictable carbon tax. There was also little progress made in setting up the financial market structure that will be necessary to finance the great transformation from fossil fuels to renewables. In short, the hurdles to the transformation that existed at the start of 2018 were still in place, largely unchanged if not worsened, at year end.

To briefly review the key data that has recently become available, **Exhibit 1** starts by presenting updated information on global primary energy usage from 1965 to 2018 measured in kilowatt hours. The exhibit also plots annual CO2 emissions measured in terms of millions of tons of CO_2. There are three key aspects to the exhibit. The first, as stressed in *Energy and Investing*, is the sheer size of global energy consumption. In 2018, the world consumed a record 160 trillion kilowatt hours of primary energy. The biggest problem for renewables is reaching anything approaching this scale without causing immense disruption. The second is the continued growth of energy consumption – even of fossil fuels. In 2018, primary energy consumption rose by 2.9%, almost double its 10-year average of 1.5% and the fastest growth rate since 2010. In light of all the talk about advancement in renewable technology, falling prices for green energy, and government proclamations to fight climate change, one might have hoped that all that increase was due to transition to various forms of green energy. No such luck. Consumption of fossil fuels, led by a 5.3% increase in usage of natural gas, rose 2.8%. Oil consumption rose 1.5%. Most surprisingly, global usage of coal



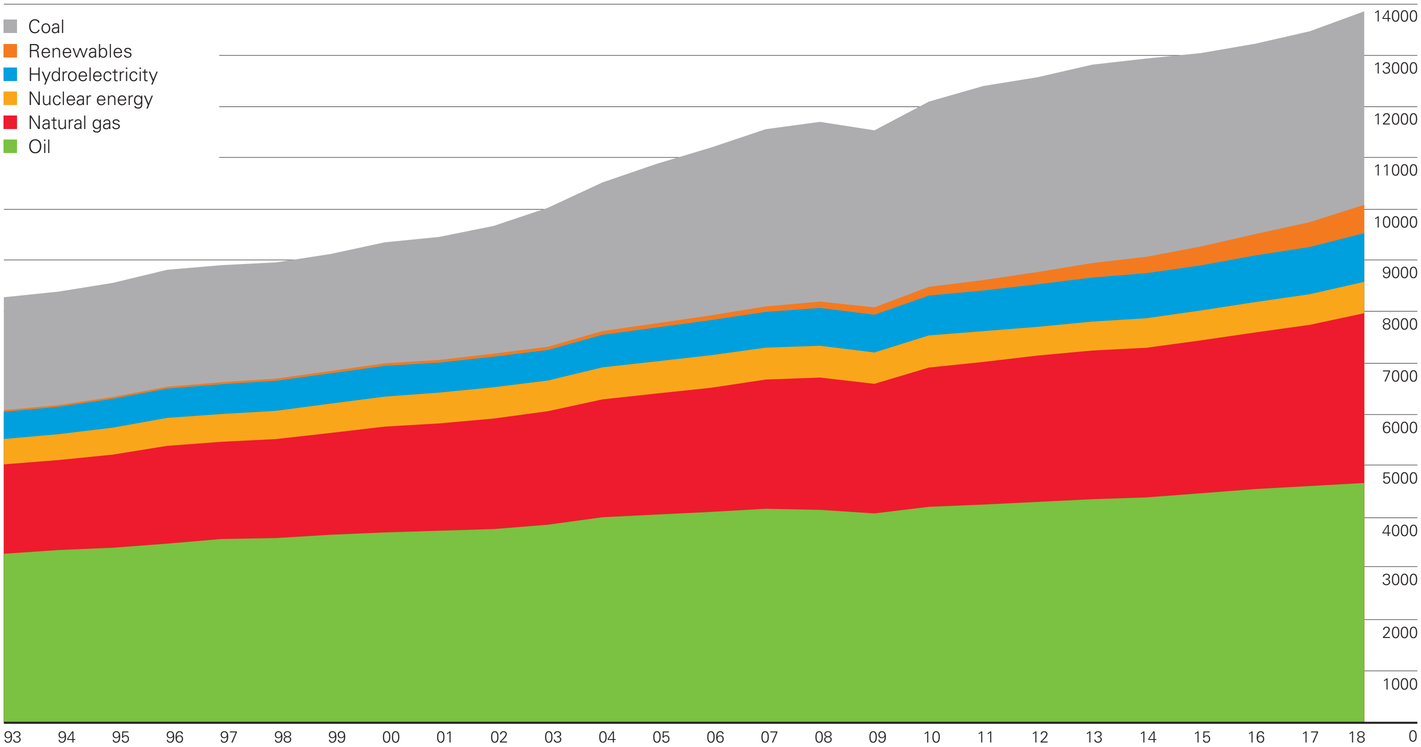
rose 1.4%, double its 10-year average growth rate. As illustrated in **Exhibit 2**, the global growth in energy consumption was largely attributable to three countries: the United States, China and India which together accounted for about two-thirds of the worldwide increase. Consumption in the United States rose by 3.5%, the highest growth rate seen in the last 30 years.



Given these data, it is not surprising that the composition of primary energy consumption barely budged in 2018. **Exhibit 3**, taken from British Petroleum (2019), shows the breakdown of primary energy consumption both globally and by region from 1993 to 2018. The main takeaway is the continuing dominance of fossil fuels which still account for 84% of primary energy. The rise of renewables is visible in the exhibit, but because it starts

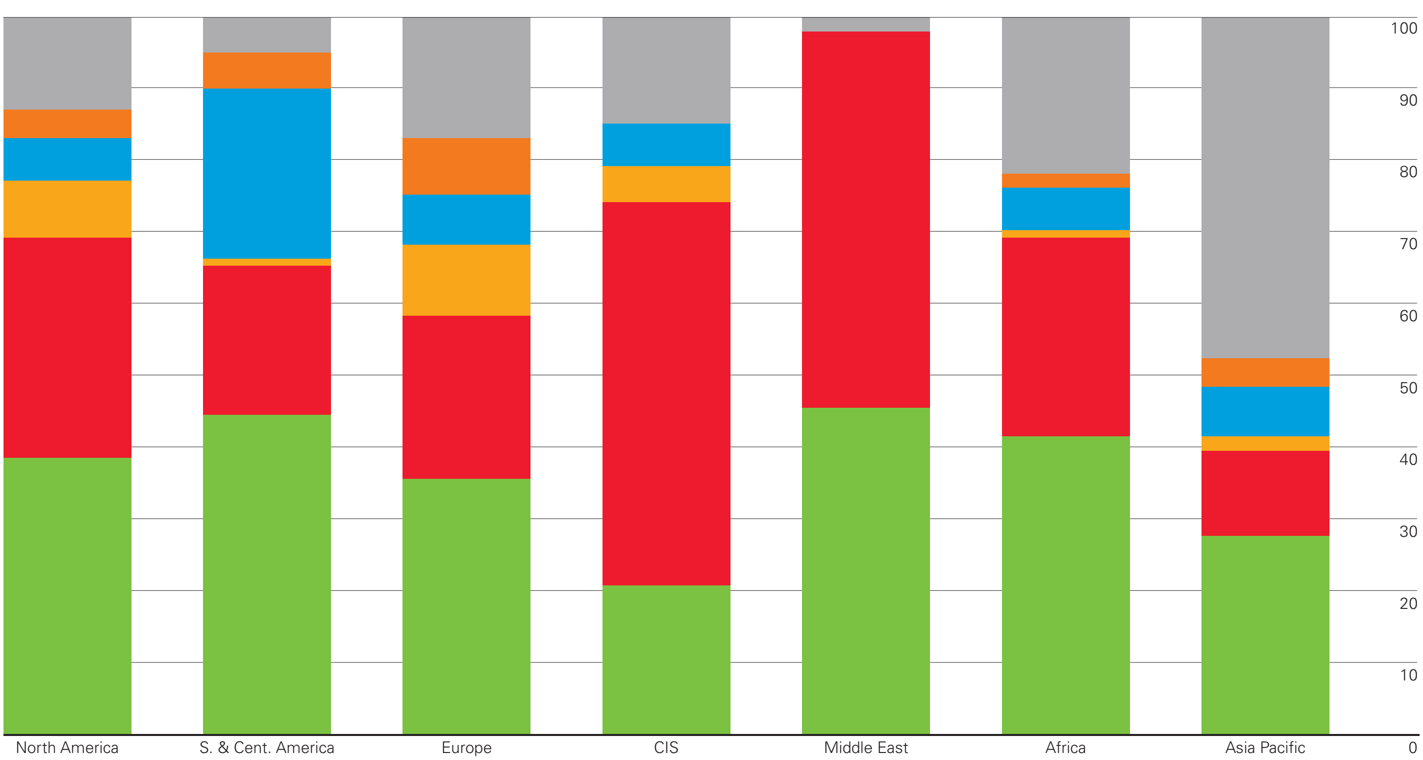
Exhibit 3

World consumption
Million tonnes oil equivalent



Global energy consumption increased by 2.9% in 2018. Growth was the strongest since 2010 and almost double the 10-year average. The demand for all fuels increased but growth was particularly strong in the case of gas (168 mtoe, accounting for 43% of the global increase) and renewables (71 mtoe, 18% of the global increase). In the OECD, energy demand increased by 82 mtoe on the back of strong gas demand growth (70 mtoe). In the non-OECD, energy demand growth (308 mtoe) was more evenly distributed with gas (98 mtoe), coal (85 mtoe) and oil (47 mtoe) accounting for most of the growth.

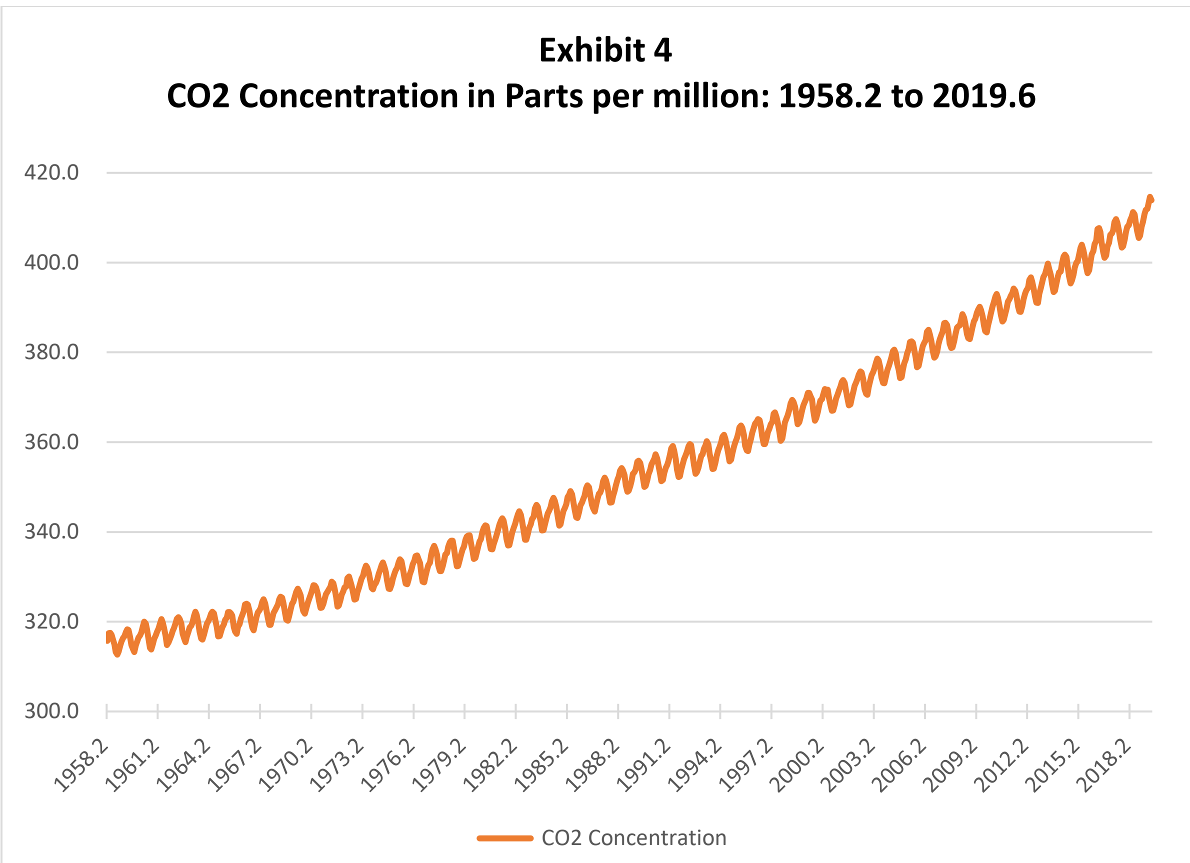
Regional consumption by fuel 2018
Percentage



Oil remains the dominant fuel in Africa, Europe and the Americas, while natural gas dominates in CIS and the Middle East, accounting for more than half of the energy mix in both regions. Coal is the dominant fuel in the Asia Pacific region. In 2018 coal's share of primary energy fell to its lowest level in our data series in North America and Europe.

from such a small sliver the impact of renewables remains small. In some regions such as Africa and the Middle East, renewables have yet to make a dent.

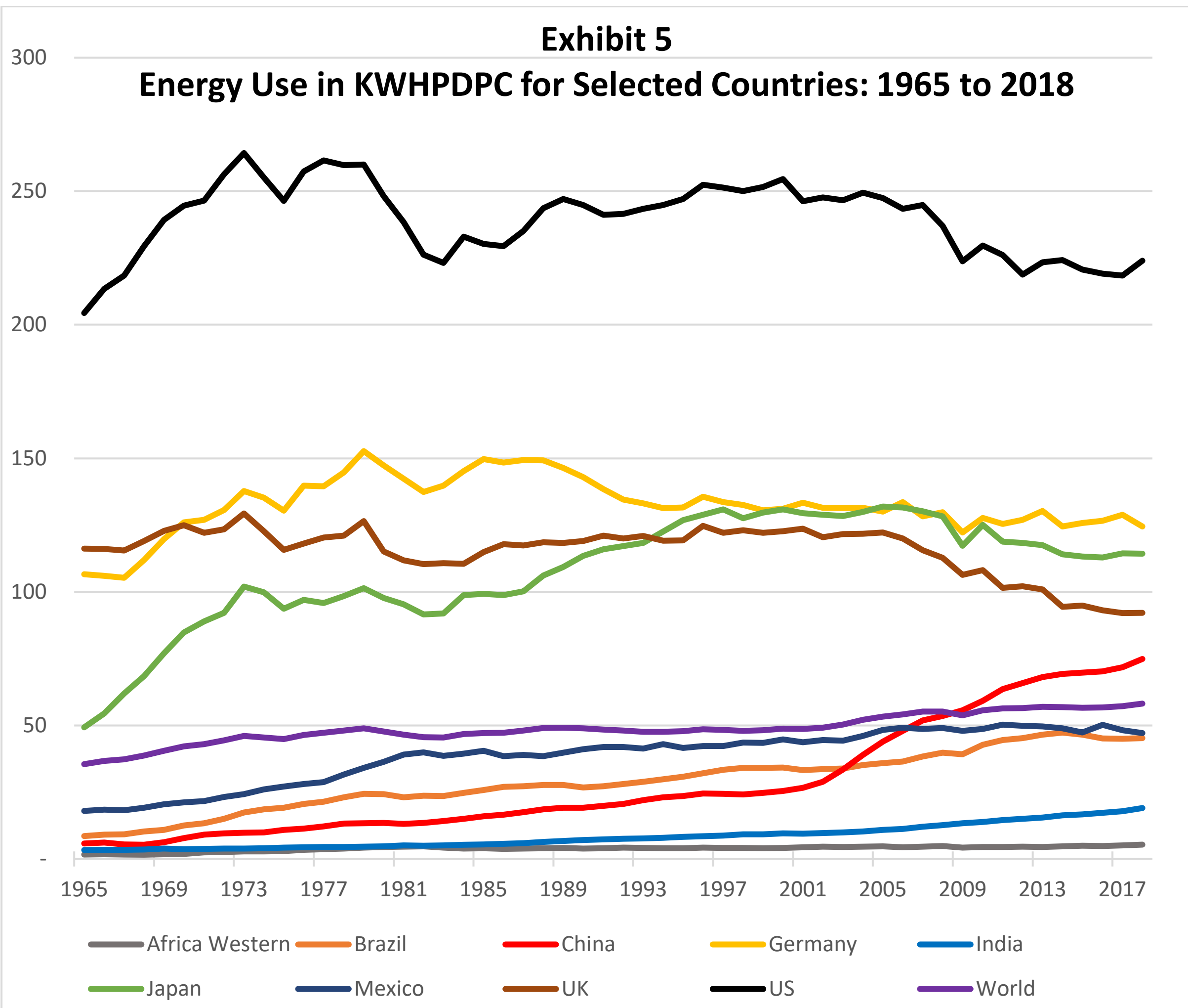
Third, as shown in Exhibit 1, emissions of CO2 track energy consumption almost perfectly. Emissions grow slightly slower due to some movement to renewable sources, but the impact thus far has been minor. In 2018, global emissions rose 2.0% making it all but certain the world will fall well short of the goals outlined in the Paris accords. This is underscored by **Exhibit 4** which plots NASA data on the concentration of CO2 in parts per million from February 1958 through June 2019.[1] By mid-2019, the concentration was above 410 parts million a level not observed since Pleistocene times. Furthermore, there is no evidence of a leveling off of emissions following the Paris accord.



[1] https://climate.nasa.gov/vital-signs/carbon-dioxide/.

On a positive note, the largest percentage increase in energy consumption was 14.5% for renewables. However, that is due in large part to the low base from which the percentage increase is measured. In terms of kilowatt hours used, fossil fuels increased more than renewables. Another bright spot was Europe where emissions fell 1.3%, but this was more than offset by a 3.1% growth in U.S. emissions. Indian emissions rose by 4.8% and Chinese emissions by 2.5%.

As stressed in *Energy and Investing*, cross country comparisons such as the foregoing must be made with care because different countries start from such different places. For instance, **Exhibit 5** updates data on kilowatt hours consumed per day per capita in a sample



of large countries. The exhibit shows that KWHPDPC in India was only 20 compared to approximately 225 in the United States. Given that massive difference, one would expect consumption and emissions in India to grow much faster in percentage terms than in the U.S. Even in China, despite its dramatic growth, consumption in 2018 was about 75 KWHPDPC, still below the "European standard" of approximately 120 KWHPDPC.

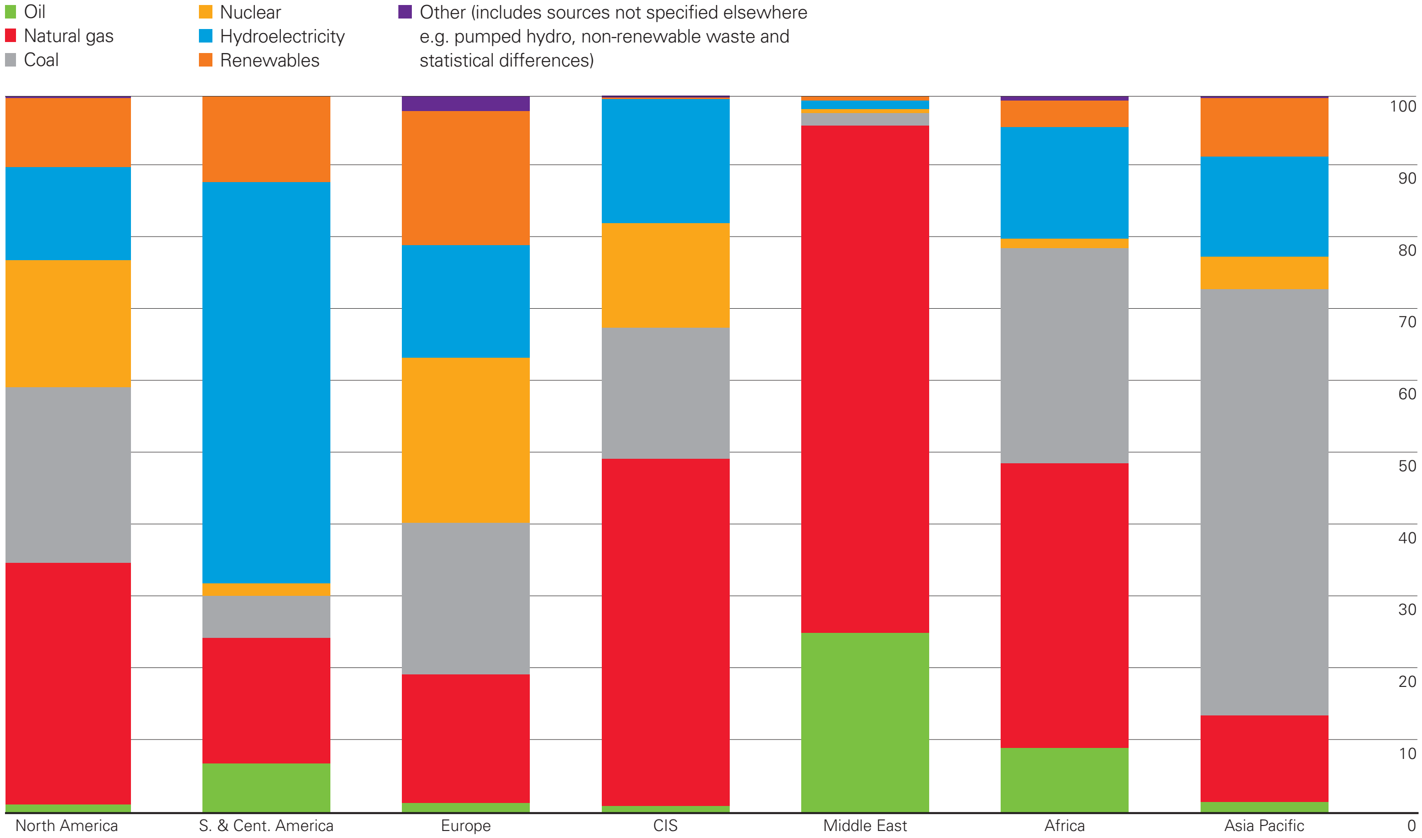
What is perhaps most depressing is that carbon emissions from the power sector are estimated to have risen by 2.7% in 2018, despite the highly publicized efforts to transition electricity generation to renewables. This failure illustrates that thus far it has not been possible to decarbonize the power sector quickly enough to offset the growth in demand. To have maintained emissions from the power sector at 2015 levels given the growing demand, renewable generation would have needed to grow at twice the rate that it actually did. These observations are underscored by **Exhibit 6**, again drawn from British Petroleum (2019), which breaks down the fuels used for electricity generation from 1986 to 2018. The good news is the rise in renewables and the decline in the use of oil. However, despite being the "dirtiest" fuel, coal has remained stable generating about 40% of global electricity. The decline in oil has been largely offset by the rise in natural gas so that the share of electricity generated by fossil fuels has remained relatively constant.

Projecting the continued rise in renewables is hazardous. As long as renewables account for only a small fraction of total generation, the intermittency and storage problems can largely be solved by ramping up fossil fuel plant generation. When renewables start to account for a sizeable fraction of total generation, this will no longer be feasible. At that point, future expansion of renewable generation will become significantly more complicated and expensive.

Regional electricity generation by fuel 2018

Exhibit 6

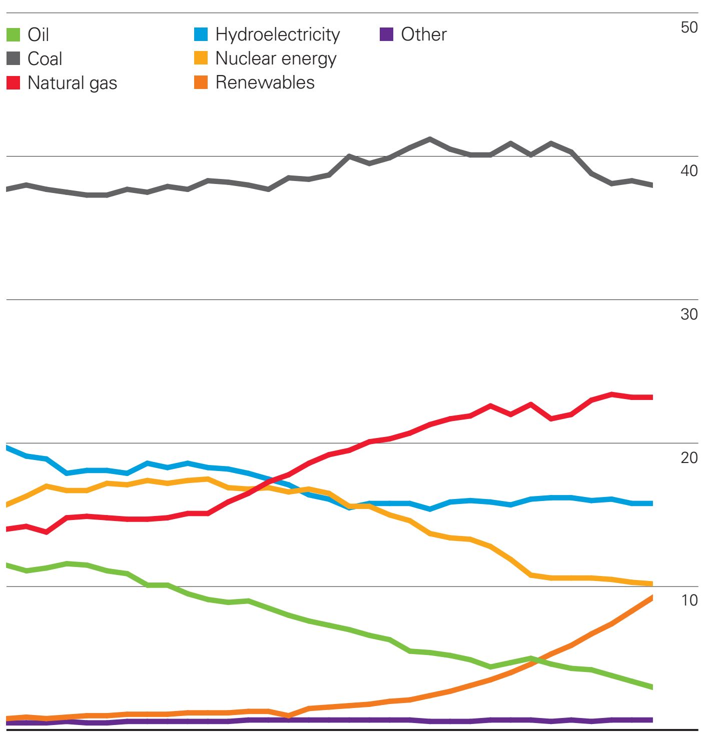
Percentage



Natural gas is the dominant fuel for power generation in North America followed by coal. In South & Central America, hydro accounts for more than half of power generation. In Europe nuclear, coal, renewables and gas all have a prominent role. In CIS and the Middle East, natural gas is by far the most important fuel for power generation. In Africa, natural gas and coal account for almost 70% of the electricity generated. Coal remains the most important fuel in Asia Pacific.

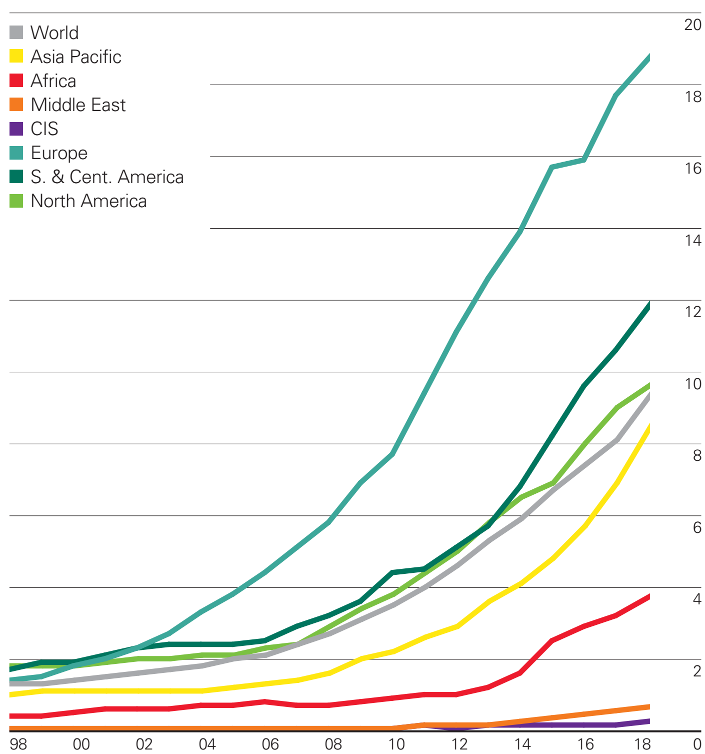
Share of global electricity generation by fuel

Percentage



Renewables share of power generation by region

Percentage



At the global level, coal is the dominant fuel for power generation, accounting for 38%, the same share as 20 years ago. Gas is the second most used fuel with a share of 23.2%, higher than in 1998. The share of oil and nuclear has declined substantially over the same period. The share of renewables is 9.3%, up from only 3% 10 years ago. Regionally, there is significant variation in the penetration of renewables: Europe has the highest penetration at 18.7%, followed by South & Central America at 12%.

One unfortunate and growing aspect of the politics of energy is that it is taking on an increasingly moral tone. Those who historically have relied on or produced fossil fuels are implicitly seen as having been immoral. This is either an unfair characterization or, if true, is true of all of us. For instance, how many of us have availed ourselves of air travel, one of the most profligate and environmentally damaging uses of fossil fuels, in the past year? The simple fact is fossil fuels helped drive the industrial revolution and the accompanying economic growth we have enjoyed because two billions years of life on earth provided carbohydrates in great abundance and because fossil fuels have some remarkable properties that make them ideal sources of useable energy. Here I briefly review the two of the most important benefits. The first is energy density.

Energy density

Compared to batteries or renewal production, the energy density of fossil fuels is remarkable because it is stored in the chemical bonds of every single hydrocarbon molecule. Pound for pound, the maximum potential energy stored in oil molecules is approximately 1,500% of the maximum that can be stored by lithium batteries. To store the energy equivalent of one barrel of oil costing about $75 and weighing 300 hundred pounds requires $200,000 of Tesla quality batteries weighing 20,000 pounds. It the high energy density of fossil fuels that makes air travel practical.

Energy density also plays a critical role in electricity production. The problem with the two main forms of renewal energy – wind and solar - is that they have very low energy density, particularly after accounting for intermittency. Both windmills and solar panels produce energy, averaged over a year, about 25% to 30% of the time. Consequently, one needs to build about 3 kW of wind/solar capacity to replace 1 kW of fossil fuel capacity.

What is more Smil (2016) reports that wind farms produce on average about 2.5 watts per square meter and solar farms about 10 watts per square meter. Using those numbers, Cornell (2019) calculates that the land required to switch all the fossil fuel-based electricity generation to wind and solar is almost three times the surface area of Massachusetts. Furthermore, there are strict physical limits on how much this energy density can be improved with solar topping out at about 20 watts per meter and wind at about 5 watts per meter in real world situations. In comparison, the energy density associated with the procurement of fossil fuels and their use in thermal electricity generation plants is on the order of 10 to 100 times greater. This reduces land requirements by a corresponding factor.

Intermittency, transportation and storage

The second benefit of fossil fuels is related to intermittency, transportation and storage. As noted above, wind and solar farms product electricity only 25% to 30% of the time. In comparison, conventional thermal power plants operate between 80% and 95% of the time. Given the intermittency of renewable power generation, their widespread adoption requires a method for storing electricity during the downtimes. That is not easy and will not be cheap. As Mills (2019) notes, "Astonishing quantities of batteries will be necessary to keep country-level grids energized – and level of mining required for the underlying raw materials would be epic. . . The $5 billion Tesla Gigafactory in Nevada is currently the world's biggest battery manufacturing facility. Its total annual production could store three minutes' worth of annual U.S. electricity demand." It remains to be seen how sufficient storage will be provided. The key point from the standpoint of finance is that it will be expensive, and investors will demand a fair rate of return on the required capital.

Added reliance on renewables also means that dramatically better energy transport will be required. There are large parts of the country where the wind does not blow, and the sun does not shine for prolonged periods of time. It may seem that compared to carbon fuels electricity is easier to transport because it moves through wires, but that is not, in fact, the case. Long-distance transport of energy by wire is twice as expensive as by pipeline.[2] Building out and reengineering the grid will be another incredibly expensive project.

The foregoing list is far from complete, but it drives home the point. We have been aggressively using fossil fuels not because we have been tricked into it by some political cabal, but because they are so useful. It is for the same reason that the usage of fossil fuels has such tremendous inertia. Therefore, it makes little sense to cast dispersions at anyone, even fossil fuels companies. They sold us fossil fuels because we wanted to buy them. The problem is all of us and all of us must be the solution as well. Unfortunately, in that regard 2018 was not an auspicious year. Insufficient progress was made in the transition away from fossil fuels, emissions rose yet again, and there was little financial innovation of the type that will be necessary to fund the great transformation. Hopefully, 2019 will be a better year in all respects.

---

[2] See, Bonneville Power Administration and Northwest Gas Association, “Comparing Pipes & Wires,” undated.

References

British Petroleum, 2019, *BP Statistical Review of World Energy for 2019*.

Cornell, Bradford, 2019, Energy and investing, *Cornell Capital Group*, https://cornell-capital.com/blog/2019/02/energy-and-investing-a-cornell-capital-report-on-renewable-energy.html.

Cornell, Bradford, 2019, Some green new deal financial arithmetic, *Cornell Capital Group*, unpublished work paper.

MacKay, David JC, 2009, *Sustainable energy: Without the hot air*, UTT, Cambridge, England.

Mills, Mark P., 2019, The new energy economy: An exercise in magical thinking, *Manhattan Institute*, https://media4.manhattan-institute.org/sites/default/files/R-0319-MM.pdf

Smil, Vaclav, 2016, *Power densities: A key to understanding energy sources and uses*, MIT Press, Cambridge, MA.

World Bank Population Data through 2018, https://data.worldbank.org/indicator/sp.pop.totl