Energy Transitions and Carbon Neutrality by 2050?

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The world's economy has expanded considerably over the last three decades, underpinned by the rapid emergence of its most populous nations – China and India – as well as other developing economies. In fact, global GDP, in real terms, has more than doubled since 1990. This has driven substantial increases in global energy demand, with most of the growth over the last thirty years coming from developing economies. Notably, this has occurred concomitant with growing pressures to reduce CO_2 emissions, which is, to put it bluntly, challenging because fossil fuels make up the majority global energy use.

Economic growth, expanded access to energy services, and environmental sustainability are among the world's most pressing challenges. This has always been true to varying extents in different parts of the world, but international discourse has recently galvanized around environmental sustainability, with a particular emphasis on carbon neutrality, especially in the developed nations of the Organization of Economic Cooperation and Development (OECD). This begs two fundamental questions, "Is carbon neutrality by 2050 possible? And, if so, how can it be achieved?"

We do not portend to answer these questions herein. That story is still being written and there are likely to be multiple twists and turns in the plotlines that unfold. Rather, we will examine the current energy landscape in its context of recent history in order to identify some important vectors for consideration. This will allow a rationalization of what may be achievable, and obviously raise some important questions.

Energy Transitions – What Does Recent History Tell Us?

Make no mistake, energy systems are changing, and they will continue to do so with an inexorable inevitability. The *pace* of change, however, is an open question that will influenced by a multitude of factors – economics, policy, technology, regulatory and legal environment, etc. – that extend well beyond aspirations. That stated, the global energy system of 2050 will look very different than the global energy system of today. But that is not a particularly bold statement. The energy system of today looks different than it did in 1990, and the global energy system of 1990 looked very different than it did in 1960, which looked very different than it did 1930, and so on. The point? Energy is always in transition.

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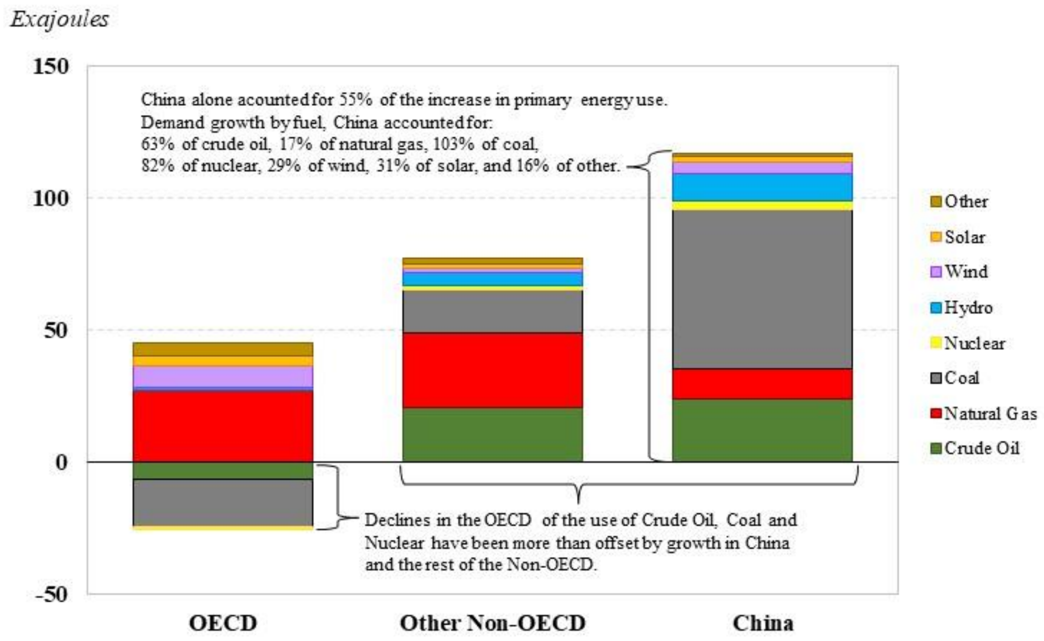
Two primary factors have always driven this – economic growth and technological change. Consider the last 30 years and ponder the two largest drivers of change in the global energy system over that period: (1) energy demand growth in China and (2) the shale revolution in the U.S. Driver #1 is the result of rapid economic growth, and driver #2 is the result of innovation driving commerciality of a previously inaccessible oil and gas resource base.

From 1990 to 2020, China alone accounted for over half of the total increase in global energy demand. The impacts include a redirection of global energy trade, substantial investments in new energy resources (both fossil and renewable) and infrastructures to support expanded supply chains, and a shift in global geopolitics. Moreover, the observed growth in demand has been primarily fossil fuels (see Fig. 1).

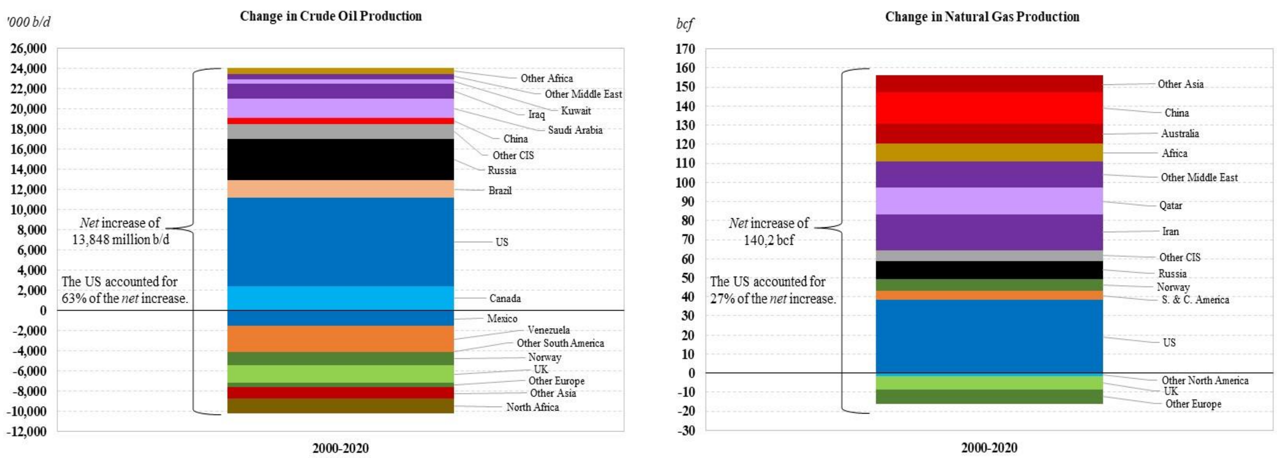
The shale revolution in the U.S. has driven equally dramatic shifts to global energy markets. As recently as 2000, the U.S. was the largest energy consumer on the planet, was positioned to become a major importer of LNG, was already a major importer of crude oil and petroleum products, and relied on coal for 24% of its energy mix. But the rapid growth of shale oil and gas production substantially altered the US contribution to global oil and gas balances over the last 20 years (see Fig. 2). Other regions also saw expansion to meet growing global demands, but the so-called shale revolution was transformational. In less than 20 years, the US became a net exporter of natural gas, a major player in the global LNG export market, a net exporter of crude oil and petroleum products, and saw a substantial reduction in the use of coal domestically. Altogether, this has held dramatic implications for global energy trade and geopolitics.

Fig. 1 The Impact of China on Global Energy, 1990-2020



Source: Data obtained from the BP Statistical Review of World Energy 2021

Fig. 2 The Impact of the US on Global Oil and Gas Production, 2000-2020



Source: Data obtained from the BP Statistical Review of World Energy 2021

What does this mean? To begin, the changes themselves, while impactful on the global energy ecosystem, are not the main point. Rather, the *drivers* of change are. The notable shifts in global energy demand toward China and the rest of the developing world are being driven by *economic growth*. And, the dramatic production increases of oil and gas in the US, a result of shale development, have been driven by *innovation* in the upstream. Regardless of one's view of the next 30 years, it can almost certainly be stated that economic growth and innovation will drive the future of global energy!

Energy Transitions – Carbon Neutrality by 2050?

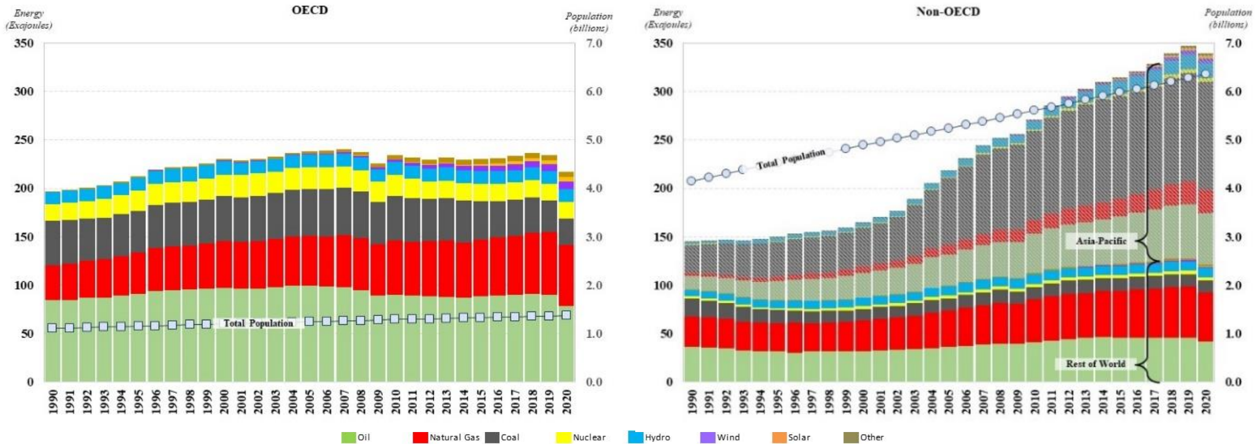
Despite the rapid growth in energy demand in developing countries over the past 20-30 years – which has triggered a shift in global center of gravity in energy toward developing nations in the Asia-Pacific region (see Fig. 3) – the world of energy remains a world of 'haves' and 'have-nots'. This is particularly noticeable when one compares the per capita energy use across regions – the populations across the OECD, on average, consume roughly 3 times the amount of energy per person than populations of non-OECD nations, with some differences even more striking on a country-by-country basis.

The nations of the OECD are home to about 1.3 billion people and generally enjoy reliable and consistent access to modern energy services. In contrast, the nations of the non-OECD collectively represent about 6.4 billion people, about half of whom still lack *reliable* access to modern energy services.[1] Of course, each non-OECD nation is different, with some having rapidly ascended over the last 30 years (especially those in the Asia-Pacific region) and others still lagging far behind. Any status quo paradigm that leaves such a sizeable portion of the world's population in

[1] See J. Ayaburi, M. Bazilian, J. Kincer, T. Moss, "Measuring "Reasonably Reliable" access to electricity services," *The Electricity Journal*, Volume 33, Issue 7, 2020, https://doi.org/10.1016/j.tej.2020.106828.

the dark is neither sustainable nor acceptable, and meeting energy demands for such a large, and growing, fraction of the world's population presents a non-trivial challenge to global carbon neutrality.

Fig. 3 Energy Demand by Primary Source and Population by Region, 1990-2020



Source: Data obtained from the BP Statistical Review of World Energy 2021 and World Bank

The widespread access to energy services in the OECD is a product of massive capital investments in energy infrastructure over multiple decades. Therein lies a fundamental challenge. Namely, the *scale* of energy infrastructure required to support modern economies is enormous, and once in place it establishes a *legacy* of infrastructure and fuel choices that do not change rapidly. In well-developed economies, such as those in the OECD, new energy technologies – such as wind, solar and batteries – must compete for market share against well-entrenched incumbents. And, they must do so against a backdrop of little to no growth in total energy demand (see Fig. 3).

In order to deliver reliable access to modern energy services to populations in developing non-OECD nations, a scale of capital investment in energy infrastructure never before seen must occur. This means that the size of the global energy system will certainly expand. Not only must *existing* energy systems see a significant reduction in the use of fossil fuels while also continuing to deliver energy services reliably, *new* energy demands must be met primarily with low carbon energy sources, a trend that has yet to be seen in developing nations (see Fig. 3). Consider a case where global energy use rises by one-third from 2020 to 2050, representing a 0.96% average annual growth rate, which is well below the 1.64% rate seen from 1990 through 2020.[2] Simply holding the use of fossil fuels constant at their 2020 levels requires the fossil share to fall from 83.1% to 62.4%. While this may not be insurmountable, it translates to a three-fold increase in all other energy sources globally. If we assume all non-fossil demand will be met by wind and solar,

[2] Note this simple exercise does not account for the fact that energy use declined in 2020 due to the economic malaise triggered by responses to the COVID-19 pandemic. Arguably, demand will rebound in line with 2019 as the pandemic subsides, but, for simplicity, we construct this example using 2020 as the reference year.

an almost 13-fold increase in wind and solar energy must occur over the next three decades, just to keep fossil energy use flat. To achieve a much more ambitious carbon-free energy portfolio, such increases would have to be significantly larger, unless, of course, we significantly reduce the growth of energy demand. But that would complicate, to say the least, efforts to increase reliable access to modern energy services outside the OECD.

Closing Remarks

The above discussion is not meant to downplay efforts to transition the global energy system. Energy will transition. It always has and always will, but the pace of change is uncertain. In the end, the future of energy is NOT an OECD story; it is about developing economies. It will be challenging to meet the expanding energy needs of a growing population in the developing world, while also decarbonizing energy systems in the developed world. Any movement to achieve carbon neutrality by 2050 must be facilitated by a full portfolio of potential solutions – from carbon capture, to nature-based solutions, to expansion of renewables and hydrogen, to rethinking the role of nuclear and hydro power, to technologies that have not yet been fully developed, including potential advances in material science that create a "carbon-to-value" proposition through the development of advanced carbon materials.[3] Nothing can be left off the table. If policy attempts to define a subset of the potential portfolio through various measures, failure is inevitable.

Writer's Profile

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[3] See, for example, K. Medlock and R. Meidl, "The Advanced Carbon Economy: A Sustainable Hydrogen Pathway," available at https://doi.org/10.25613/v58t-pm38.