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Global Future Council on Energy 2016-2018

Transformation of the Global Energy System

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Contents

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Introduction

As an integral part of the World Economic Forum System Initiative on Shaping the Future of Energy, the Global Future Council on Energy provides vision and thought leadership. Since 2016, the Council has been looking at the forces transforming the production, demand and impact of the energy industries. It has focused on the profound technological changes, which may completely transform the energy system, creating opportunities along with significant challenges. Here the Forum offers insights into what has been learned, along with four specific actions that its community might consider in coming years to help corporate leaders and policy-makers grapple with the implications of massive technological change.

Over a few decades, centred on the year 1900, energy systems underwent their most profound transformation. The internal combustion engine and electricity found niche markets in wealthy industrialized cities before spreading and sending shock waves through modern economies. New types of energy created new forms of architecture and urban planning (air-conditioning and elevators made high density working and living possible, even in hot climates), transport (buses and cars were much cleaner than horses) and the means of production across nearly every major industry. Economic growth boomed for a century.[1]

An innovation tsunami has the potential to wash over the world's energy systems. With it, disruption and transformation throughout the world economy could be as profound as the shocks of electricity and oil a century ago.[2] The size and scope of today's energy systems create powerful inertia, but tsunamic forces could swiftly upend businesses and also profoundly alter the outlook for how energy systems affect emissions and sustainable development.

Anticipation of this tsunami has been a source of tremendous anxiety. Some firms and industries fear survival. Others foresee riding these powerful waves into new markets. The energy system's predictability has decreased while the risks and opportunities for investors have risen. Considering these issues over two years, those involved learned a number of things, the key points of which are briefly outlined in this report.

The future shape of the energy system

Out of this uncertainty, several patterns are emerging. First, the century-long process of electrification is likely to continue and accelerate. Moving energy by wire is hugely advantageous when flexibility and cleanliness are at a premium, such as in cities. Pressure for decarbonization will likely accelerate electrification since the ability to generate power with little or no carbon gradually becomes competitive. Today, approximately 19% of final energy is electricity; some studies see that portion doubling by 2050 with deep decarbonization.[3]

Second, growth in total energy demand is likely to slow as economies shift in structure, efficiency improves and economic growth moderates. There are countries and regions where primary energy demand will continue to grow significantly, such as India, but what is most striking is how many countries have made transitions to lower demand growth at rates that are relatively rapid considering how infrastructure-intensive the energy system is. Between 1965 and 1975, total global demand for energy grew almost 4.5% per annum; since 2007, it has averaged just 1.8%.[4]

Third, coal faces significant problems globally. Some niches for growth are possible, but the overall picture puts the industry on the brink of flattening demand and contraction. Oil continues to occupy invaluable roles in transport and petroleum chemicals, which plausibly plateau total demand for liquids at levels not much higher than current amounts. Gas is the big "wildcard", in particular for use in electric power. With the right technologies and policies, total demand for gas could grow substantially. Without them, markets that are seeking deep cuts in emissions will squeeze conventional natural gas.[5] Technology is the key to deciding whether or not gas will be a transition fuel.

Fourth, decentralization of energy systems is under way, in particular with the rise of self- and locally-generated power. This possibility, which is spoken about more than observed, is most striking in the ways in which rural and low-income populations obtain electricity. Approximately 1.2 billion people lack access to electricity, a number that remains stubbornly high.[6] Perhaps one-half of these people can gain access to electricity from decentralized micro-grids and solar power generators, rather than traditional extension of grids.[7]

There is a lot of good news in these trends, but plausible transformations do not necessarily align with the goals that societies are setting for their energy systems. A large-scale rise in efficiency, a shift toward natural gas and pervasive deployment of renewables are not putting the world on track for stopping global warming below 2 degrees Celsius limit.[8] The UN's Sustainable Energy for All goal of universal access to modern energy services by 2030 will require an unprecedented spread of electricity to the most remote areas of the world that, so far, have remained very hard to electrify, despite new decentralized technologies and business models. The UN target of providing everyone with clean energy for cooking and heating may prove to be even more difficult to achieve.

Business and government must become much more adept at talking about these realities. Tsunamic technological change could bring profound improvements to how society uses energy. Yet, improvements are still likely to lag far behind society's expectations.

The system has become less predictable

A system on the cusp of radical transformation is also one that is much more difficult to forecast. The roots of this unpredictability are in four areas. First, large parts of the energy value chain are becoming decentralized, flat and open. This shifts authority and influence away from incumbent firms and infrastructures towards new entrants and even consumers. Many of those entrants, by definition, do not exist, making their impacts on the system difficult to anticipate.

Second, the most profound effects of large-scale innovation come from interactions of systems. For example, many power markets are seeing much higher penetrations of wind and solar without much impact on total cost, an outcome that reflects several factors. These include: innovations in the materials and methods used in solar and wind generators; innovations in management of complex stochastic power supplies; more ubiquitous information available to customers and grid managers; changes in business models that unleash new supplies of capital; and innovations in creating more responsive demand and storage. By themselves, each factor is hard to forecast, while together the interactions in these systems of systems run the full spectrum. This partly explains why mainstream energy forecasting is so poor on penetration of new technologies, such as solar.[9]

Third, the energy industry has tended to focus on the inertia of a large (size and capital intensity) system as a source of stability and therefore predictability. However, that system depends on continued investment. Pervasive uncertainty is making firms wary of deploying capital. In the oil and gas industry, by some estimates $1 trillion in previously viable projects is on hold because of uncertainty about future prices and industry structure. The power industry has seen similar reluctance to make capital intensive upgrades because of the question of who will pay for the grid. New firms and policies aimed at promoting change have also disrupted the business models and policy credibility needed for long-term investment. The result of chronic under-investment may be more intense cycles in price and behaviour, creakier infrastructures and more crisis-driven policy-making.

Fourth, many sources of new ideas and technologies lie outside the energy industry. New market designs and technologies, such as distributed ledgers, arose from banking and IT. Yet these innovations could allow much more efficient peer-to-peer transactions that undermine traditional energy suppliers and marketers while also eroding the capacity of government to supervise and tax energy services. Renewables have emerged, in part, from advances in semiconductors. Similarly, radically improved batteries stem from advances in material science, and demand for power storage in computing.

These sources of profound innovation, for the most part, are far outside the realm of familiarity and forecasting skill for the energy industry. They tend to be less responsive to the normal market forces of supply and demand within the industry. The explosion in information and communications technologies that are central to the large-scale changes that are taking place appeared on their own and did not emerge in response to changes in oil or power prices. Tesla, a leading disruptor in electric vehicles, has never made a profit and, by the end of 2017, will have lost nearly $4 billion since its inception. This is even as its market capitalization exceeds $53 billion (the more disruptive, the greater the losses), which is not familiar territory in the energy industry. Many observers failed to forecast even profitable innovations in the industry, such as the shale boom, because they arose from niches.

Exacerbating the situation is the fact that the most disruptive innovations arise from short-lived start-ups whose survival in the search for capital and market share depends, in part, on hyperbole that drives valuation. The ecosystem of disruptive innovation – where everyone and everything claims it will disrupt exponentially – is noisy, making it hard to assess which ideas will survive. As in much of the Fourth Industrial Revolution, the business model for this democratic, decentralized mode of innovation tends to yield a large-scale churn in ideas and a few “blockbuster” success stories. Success is typically equated with prescience when luck often plays the bigger role. Parts of the media exacerbate these problems of finding signal in all the noise, often reporting as truth what the new class of billionaires says without scrutiny.

The problem of forecasting has practical implications for corporate leadership and policy-makers:

– There is a need to rely less on traditional methods, such as large-scale scenario analysis, which often hides the factors that are driving underlying change and generates broad outcomes, obscuring insight. Different methods include focusing on clusters of pivotal innovations, such as electric vehicles (EVs), storage and decentralized controls, to make it easier to probe scalability and synergies.
– Energy firms, NGOs, regulators and policy-makers need to improve their ability to reliably incorporate ideas and people from industries outside their realm of experience. Energy firms, NGOs, regulators and policy-makers need to improve their ability to reliably incorporate ideas and people from industries outside

their realm of experience, for instance from incubators and through engaging in technology scouting. As the supply of new ideas grows rapidly, traditional firms also need to become much more adept at determining failure modes so they can abandon or redirect dead ends. The challenge is to spot the few gems that lie within a large and shifting pile of new solutions.

– The industry must better address the reality that around its social licence to operate, it will face goals that are impossible to meet. When uncertainty plagues forecasting, it is easy for goal-settings on futures where "everything goes right". Targets such as zero emissions or stopping global warming at 2.0 degrees Celsius are rooted, in part, in this kind of thinking. Yet energy firms must keep producing energy and are on the front lines politically and financially when new technologies do not scale, business models for critical low-carbon technologies fail to scale quickly, and when needed policy support proves unreliable. This gap between what society expects (and convinces itself is feasible) and what firms and energy markets actually deliver, creates constant tension and the perception that industry is falling short.

Steering change

Reflecting the potential for large-scale technological change, many different stakeholders want to ride the potential tsunami and its effects.

The Forum has undertaken an extensive review of the energy policy pronouncements of all the major international organizations that work in this area, from the International Energy Agency (IEA) to the International Renewable Energy Agency (IRENA), the Business 20 (B20) and many others. There is a striking consensus in what policy-makers and analysts think actually works.[10] Yet many of the ideas – such as the need to shift towards market-based control of pollution and away from costly and inflexible regulation – are routinely ignored.

Efforts to steer change can rest on three pillars.

First, tremendous opportunity lies with the fact that decarbonization overlaps with other goals that are much more pressing in most of the world, such as cutting local air pollution. Indeed, by one estimate about one-quarter of today's global emissions come from countries whose climate-related policies are principally motivated by concerns about climate change. Since 1990, that fraction has declined by one-half, which suggests tackling the problem of global climate requires engaging countries whose energy policies are rooted in other policy concerns.[11] Making climate change policy politically realistic in most of the world requires linking this policy to other topics that command more long-term concern.

Second, whether a future with fossil fuels is also one consistent with deep decarbonization hinges on how the existing oil, gas and power industries respond to the opportunity. There are many ways in which to cut emissions even while using substantial amounts of fossil fuel – notably with the pivotal clusters of technologies around carbon capture and sequestration (CCS) and hydrogen. Collective efforts such as the Oil & Gas Climate Initiative (OGCI) are a start, as are the small, but growing number of CCS projects in planning and operation. According to estimates from the IEA and the Global CCS Institute, required investment outweighs actual investment by 300 fold. Closing that gap requires not only technological advances, but also reliable and well-designed policy support.

Third, governments and firms have become much more adept at deploying resources that will enhance the supply of basic knowledge, which is the foundation for technological innovation. For governments, there are now many good models for doing this, drawn from the experiences in the US (e.g. ARPA-E), Europe (e.g. Horizon 2020), Japan (e.g. Top Runner) and others.[12] These programmes have varying degrees of emphasis on fundamental innovation and market-deployment. Most striking is that many emerging economies (including the People's Republic of China, Mexico and the Republic of Korea) now have their own, effective efforts to improve national systems for energy innovation and deployment.

The markets for new ideas and viable technologies are now global, which means a measure of global cooperation is needed to realize the benefits of these global public goods. In this regard, the Mission Innovation (MI) initiative from 2015 is important, and there are many other related efforts, such as the International Solar Alliance, Oil and Gas Climate Initiative (OGCI) and the Breakthrough Energy Coalition, which have varying degrees of public- and private-sector focus. What remains much more uncertain is which of these international efforts will actually mobilize new resources and help governments and firms spend them efficiently.

What we don't know

It is customary in short papers to focus on areas of confidence. Discussions in the Global Future Council on Energy have given much attention to the opposite. Here is our short list (roughly in order) of important areas where experts diverge in opinion and where, in most cases, divergence is growing:

- The future for demand. Radical, but possible combinations of assumptions could almost cut demand for oil in half by 2050 period; other assumptions see oil largely unaffected, continuing to grow.[13] Similar, if less profound, uncertainties now plague forecasting of electricity demand.
- The role of the consumer. A host of new innovations such as smart meters, small-scale renewables, and blockchain give consumers more authority to make their own choices. What is unclear is whether consumers will make marginal changes in behaviour when they have new choices, nudges and information. Alternatively, will they drive transformative change given the emergence of new norms and expectations for energy and capacity to take direct control over energy supplies?[14]
- Shape of the transportation system. At no time since perhaps 1900 has the transportation system been more in play. Oil dominates freight, personal transportation and aircraft, but the future could be very different. EVs are on the rise, but combustion engines are also improving radically. A suite of hydrogen-based technologies are emerging as well, albeit more quietly than faddish EVs. Biofuels, plausibly, are starting to realize their potential as conventional corn-based ethanol stagnates and other methods of generating drop-in replacements for oil rise in importance.
- The nature of work. Wholesale change threatens to destroy and shift the location of labour. What will these people (as workers, consumers and in most of the world, voters) do, and how will they learn skills and find employment?[15] Large-scale changes to the energy sector will likely impact many country's politics, potentially exacerbating the sense of disenfranchisement that people are feeling.
- The future of the utility. Much of the talk about new business models and technologies in power generation implies that traditional utilities will decline in importance. Indeed, old revenue models are exposed to "death spirals" as demand flattens and generation shifts to smaller decentralized units and grids. That might be true, or utilities might prove even more indispensable as the stewards of intelligent wire systems that interconnect and help manage all these decentralized components.

These unknowns are sobering. How we learn to manage them could help in crafting the narratives about futures that are attractive and feasible.

Managing the innovation tsunami

A revolution in energy systems seems to be on the horizon. In many ways, these potentially radical changes are just in time for societies that want continued economic development in a sustainable manner on a planet that will have 30% more people and with a global GDP three times current levels by 2050. The tsunami brings hope, but it has also generated fear and uncertainty, with tangible effects on the level and direction of investment.

The Forum should help chart courses by working on at least four fronts.

First, the energy industry could do a better job of understanding the root causes of diverging projections for demand in oil, gas and electricity. Convening the forecasting groups from the major firms and identifying the assumptions that create variance and developing metrics to track them could help create a stronger, shared understanding of how demand may actually unfold. Some such efforts are under way, but the Forum could help highlight the key uncertainties and how they play out into the future of the energy industries.

Second, central to the most profound effects of the innovation tsunami is the idea that new business models will emerge in tandem with new payments systems, greater consumer empowerment, better mechanisms for rewarding efficiency, and atomization of energy supply chains. Some of this will happen; other parts of the vision are much more speculative. The Forum could help convene stakeholders focused on which of these business models are actually scaling and how quickly they disrupt old orders.

Third, industry and policy makers need to become much more articulate about why pivotal technologies such as CCS and hydrogen still command little investment outside niches. A study and series of activities on how to fix the orphan technology gap could help. In CCS alone, the 300 to 1 disparity in actual and necessary investment is a key talking point, but what can really close it?

Fourth, business and government have a strong interest in making effective, collective efforts to promote innovation and deployment, such as MI. As the global community begins analysing whether the Paris climate agreement is working, the industry could helpfully organize a similar effort to assess collaborative innovation and deployment, including the ability of public programmes such as MI to mobilize private capital. Big firms and governments could volunteer to have their own efforts scrutinized, with the Forum helping to steer a process aimed at increasing the overall effectiveness of the innovation effort.

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