2017 FORUM ON GLOBAL ENERGY, ECONOMY AND SECURITY

ABUNDANCE AND RESISTANCE

A REPORT FROM THE
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GLOBAL ENERGY, ECONOMY AND SECURITY

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THE ASPEN INSTITUTE
ENERGY & ENVIRONMENT
PROGRAM

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FOREWORD

The global energy market is complex. Every nation is vying for resources to grow their economy, feed their people, and light their homes. Some enjoy riches of resources, whether it be huge reserves of coal, oil or natural gas, or the technological and financial means to deploy innovative technologies like wind, solar, and electric vehicles. In a recent year, 10% of global GDP was spent on energy; therefore, when a group of experts gather in Aspen, Colorado to discuss "global energy, economy, and security" it can seem to be a daunting task.

Mary Landrieu served three terms as United States Senator from Louisiana and is now a Senior Policy Advisor with Van Ness Feldman. Marvin Odum was the President of Shell Oil until 2016. We are grateful that both chairs dedicated their time and considerable expertise to make this among the best Global Forums held by this program.

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Over the last four decades, the direct impact of the Forum on policy-making has always been difficult to quantify. However, the true lasting and ultimately more important influence of the Forum has likely been on individuals who attended – and how they have carried what they learned about issues and themselves in Aspen into the broader policy and business arenas. Forum participants gain perspectives, test ideas, participate in thought provoking discussions, make predictions (often proven wrong), and are inspired to act on key issues. Many of the key learnings and connections have occurred outside of the meeting room, with important professional and personal relationships established over meals, during free time, or on hikes. The Aspen Forums have fostered both knowledge and friendships, and they will surely continue to do so for many years to come.

David Monsma
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EXECUTIVE SUMMARY

The global energy system is always changing, as new supply resources come online, demand drivers shift, infrastructure needs develop, stewardship concerns intensify, and technological innovations emerge.

While transitions in the energy sector typically take decades, energy production in the United States has transformed in a very short period of time, not least because of the shale revolution. Fracking has taken off in North America in recent years due to a confluence of developments, including horizontal drilling and improved understanding of frack propagation. The cost structure has also come down, giving companies greater license to innovate and experiment and enabling them to be more profitable in lower-price oil environments. The shale revolution has made supplies of U.S. natural gas abundant and reliable, which will enable U.S. liquefied natural gas (LNG) to be some of the lowest-cost exported gas in the world – changing the global energy balance of power and making natural gas more commoditized on a worldwide basis. Similarly, growing production of natural gas liquids (NGLs) and liquefied petroleum gas (LPG) will be more than the U.S. market can consume and will have to be exported.

The shale revolution has also upended the scarcity model that underpinned global strategies on oil and gas reserves. The entire industry has long been structured around the idea that oil and gas reserves would be depleted, meaning reserves underground were more valuable in the future than in the present. Now, the ability to produce tiny particles of oil and gas from source rock means that supplies might as well be infinite, which means it no longer makes economic sense to wait to produce. At the same time, however, the risk of supply shocks seems to be growing, with geopolitical instability in many spots around the world. Energy markets could be headed into some rocky times – raising questions about the role of the Strategic Petroleum Reserve and about how fast U.S. shale can respond to a major disruption.

The shale revolution has also upended the scarcity model that underpinned global strategies on oil and gas reserves.

Several factors beyond geopolitics could affect levels of production as well. Investors, for instance, are sending conflicting messages to companies about strategies to pursue (i.e., growth versus returns). In addition, the Trump Administration's deregulatory push might affect the levels of U.S. energy production and export at the margins, though prices and market conditions will be far more important. Data analytics, machine learning, and other emerging technologies, however, could have big impacts on improving production, such as by helping companies understand and optimize the downhole physics of their systems.

Given the abundance of energy supplies, it is likely that energy markets in the coming years will be driven more by demand than by supply. Demand for energy is expected to rise over the next couple of decades, with most of the growth occurring in developing countries. Global gas demand appears to be rather bullish and may even be under-forecasted, whereas some forecasters (but not all) are projecting the potential for global peak oil demand. There are clearly potential drivers of demand destruction out there, particularly in the transportation sector (e.g., electrification, shared mobility, automation, vehicle-free urban centers, efficiency gains). Still, demand for U.S. LNG appears to be strong in Europe (as an alternative to Russian gas supply) and potentially elsewhere, and demand for gas is also rising steeply in the U.S. power sector at coal's expense. U.S. defense, meanwhile, is a source of large, relatively consistent energy demand, both for installations and operations, and the Department of Defense's focus on mission has driven its initiatives on energy efficiency, renewable energy, and alternative fuels.

Energy supplies cannot meet energy demand without midstream infrastructure to move energy resources from where they are to where they need to go. New infrastructure development in the United States is mostly concentrated in the Northeast and West Texas; other basins have been in a deep freeze for a couple of years and already had too much pipeline capacity. Most Northeastern and Permian production is headed for the Gulf Coast, but billions of dollars of additional investment is needed in infrastructure to move gas there. Beyond pipelines, vital energy infrastructure includes rail, trucks, ships, ports, and storage capacity. Human infrastructure is also essential; finding, training, and retaining the right people is a constant struggle for the energy sector, and the recruitment challenge has been made more difficult by the Trump Administration's actions on immigration. The Achilles heel of the industry, though, may be that people are increasingly resistant to construction of necessary infrastructure – from pipelines to coal export terminals to intermodal infrastructure – whether because the infrastructure will negatively affect them personally or because of opposition to using fossil energy generally (i.e., the keep-it-in-the-ground movement). It is getting more difficult to get permits for anything now, and opposition to hydrocarbon infrastructure will only grow more intense, especially in the absence of serious climate policy.

It is likely that energy markets in the coming years will be driven more by demand than by supply.

Climate change is just one of a suite of stewardship issues that are becoming central to the future of the energy sector. Companies have to focus on investing in technologies and solutions that will contribute to real stewardship results. Dealing with produced water, for instance, is an increasingly important job for the oil and gas industry, requiring a range of infrastructure and technologies not only for transporting and storing water, but also for recycling and reusing it (though it is essential to understand what the produced water will be used for and to make sure it is cleaned to be fit for that purpose). Leaks from oil and gas development, transport, and distribution – from major pipeline incidents to releases of fugitive emissions – similarly could place the industry's social license to operate at risk. The value of inspectors and preventative maintenance cannot be overstated, and advanced sensors and other technologies (e.g., machine learning, data analytics) could lead to a revolution in predictive maintenance that improves operational integrity and environmental performance. Perhaps the largest threat to the industry's social license to operate is the issue of climate change, which is drawing increased attention from shareholders, civil society, and policymakers. While the Trump Administration has no plans to address climate change, the industry will fundamentally be stuck with the energy policies currently in place, which were developed with an eye towards energy scarcity instead of energy abundance, until a way is found to address the climate issue. It is conceivable – though a very long shot – that there may be a narrow path forward for a carbon tax, particularly as part of broader tax reform efforts, as some Republicans in Congress begin to look for a more constructive approach to dealing with climate change.

ENERGY PRODUCTION

Global energy production is always changing, with new resources coming online, new technologies, and new demand drivers. Transitions in the energy sector typically take decades, but the changes that have taken place – and that are projected to continue – in the United States are like turning the entire energy system on a dime, with ramifications for global energy markets.

THE SHALE REVOLUTION

The U.S. Energy Information Administration projects that natural gas production and renewable energy generation in the United States will grow rapidly through 2050, U.S. crude oil production will rise sharply over the next decade and then plateau, and U.S. coal production will decline sharply. This represents a staggering turnaround. The current rhetoric of the Trump Administration to "unleash" domestic energy production seems not to recognize the extent to which it has already been growing, not least because of the shale revolution over the past decade.

Through a uniquely American story of technology, innovation, entrepreneurialism, capitalism, markets, property rights, and contract law, U.S. energy production – which was written off for dead a decade ago – has changed the landscape of the world's energy future.

Hydraulic fracturing, in some respects, goes back to the 1940s and started growing in the 1980s and 1990s. In recent years, however, fracking has really taken off in North America due to a confluence of developments, including horizontal drilling (which can go 20,000 feet), a shift from delineating fields to optimizing wells, gel fracks, improved understanding of frack propagation, and greater proppant use per well. The small innovators that have driven the shale revolution have done so in a state of constant disruption, and companies are trying new technologies on virtually every well. Companies are pumping massive stimulations, conducting lots of downhole science, and drilling longer and longer horizontal wells. The cost structure has also come down over the years, giving companies greater license to innovate and experiment and enabling companies to be more profitable in lower-price oil environments. (In the Permian, there are many resources that could break even at $35/barrel, which has forced other asset classes to compete and spurred some governments to reduce their take to keep capex flowing to their projects.) Through a uniquely American story of technology, innovation, entrepreneurialism, capitalism, markets, property rights, and contract law, U.S. energy production – which was written off for dead a decade ago – has changed the landscape of the world's energy future. The resource revolution may just be getting warmed up. There are tremendous amounts of remaining resources in the United States; many undiscovered plays (more gas than oil) are still out there.

The shale revolution has had significant economic, geopolitical, and environmental consequences. It spurred economic growth and lower energy prices as the United States came out of the 2008 recession. U.S. gas exports are starting to have important geopolitical and foreign policy effects, enhancing the security of supply for U.S. allies around the world. The substitution of natural gas for coal in power generation has been a key driver of reductions in U.S. carbon dioxide (CO2) emissions to date. The shale revolution has also changed the vulnerability of the U.S. economy to high oil prices; it used to be that high oil prices were bad for the U.S. economy because of the impact on consumers, but now high oil prices would provide enough economic benefits to the U.S. oil-producing states that the overall effect of high oil prices on the U.S. economy is relatively neutral. With very low oil prices now as bad for the U.S. economy as very high oil prices, U.S. policymakers ought to significantly rethink their views on energy security.

There are some real limiting factors and problems to deal with, however. Cash flow, for instance, is a challenge; while investments are profitable, cash flow is low due to the lower commodity prices. Logistics are another challenge, in terms of getting the millions of pounds of sand, hundreds of thousands of barrels of water, and all the other resources on location when needed to drill wells. Environmental impacts from energy production are always a serious concern. In addition, there is the risk of fuel price volatility; it is hard to guarantee that the type of significant volatility natural gas prices have had historically could not happen again. Even though few market actors actually do it, financial economics would suggest that equalizing the risk between natural gas on the one hand and renewables and energy efficiency, which have no such volatility, on the other would require adding the market price of fuel volatility to the spot price, which raises the price of gas.

Although shale basins exist all over the world, growth of similar markets in other countries seems unlikely in the short term. There is a reason most shale development has occurred in the United States. The Permian Basin, for instance, has not only great rock, but also land ownership that is aligned with company interests in terms of making money and placing needed infrastructure. The United Kingdom has the rocks, but the Crown owns the gas, so there is no similar alignment of interests there. Shale deposits in China and the Middle East will be fairly high-cost. Places in North Africa that are relatively well-endowed are politically unstable, which means off-takers cannot rely on them. Argentina may have issues with access to services, domestic gas pricing mechanisms, and high-cost labor. Shale development is a very complex equation that goes beyond just the resource itself. At the end of the day, companies will make financial decisions to allocate capital and will look at whether a location has good rock, good economics, and good geopolitics.

LNG & NGLS

Due to the shale revolution, supplies of U.S. natural gas are abundant and reliable. The world may not fully understand the size of the U.S. shale resource base, how easily and safely it can be produced, and the range of ways it can benefit the world.

The United States today is the lowest-cost producer of natural gas, with most basins able to produce for less than \$1/MMBTU, which means gas can be at the Gulf Coast for less than \$2.50. That will be some of the lowest-cost exported gas in the world. By around 2020, U.S. exports are expected to supply about 20% of the global liquefied natural gas (LNG) market, with more than 80 cargoes per month leaving the United States for destinations around the world. U.S. LNG exports will change the global energy balance of power and the way the global energy market operates, bringing more flexibility and liquidity to the market and making natural gas more commoditized on a worldwide basis. U.S. LNG will also bring the opportunity for cleaner air to polluted cities.

Similarly, the U.S. production outlook through 2022 suggests continued growth in natural gas liquids (NGLs) – the molecules that are the basic building blocks of petrochemicals, which are at the heart of manufacturing and goods produced throughout the world. By 2022, U.S. production of NGLs is expected to be around 6 million barrels a day; it was not so long ago that the number was 2 million. About half of that production is ethane. There are numerous ethylene plants under construction in the United States that will have the capacity to cumulatively produce

28 billion pounds of ethylene a year, and that volume could easily multiply further when new crackers come online. Derivative plants are also being built. The U.S. market cannot consume all the hydrocarbon production expected in the next few years, and a lot of the ethane will be exported.

Liquefied petroleum gas (LPG) produced from NGLs is also being deployed around the world. LPG – a relatively clean fuel that can be carried – is replacing wood, dung, and other dirty fuels in places such as Nigeria, India, and China, and demand is growing rapidly. Since U.S. demand for LPG is flat or declining, the growing LPG production has to be exported; without exports of the growing LPG volumes, the entire oil and gas value chain would be clogged. This means production is now dependent on exports.

RESERVES & SUPPLY SHOCKS

The technological innovations that have been deployed in the oil and gas industry have implications for global oil and gas reserves that are not yet well understood. For decades, the entire industry has been structured around the idea that oil and gas reserves in non-OPEC countries would be depleted, after which the cost for oil and gas would increase. This created an incentive to hold on to reserves, wait for maximum depletion, and then get higher prices per barrel; reserves underground were more valuable in the future than in the present. Technological innovation, however, has thrown this future reserves scarcity model into question. With the ability to produce tiny particles of oil and gas from source rock, instead of having to look for reservoirs, supplies might as well be infinite. Countries holding decades of oil and gas underground in reserves can no longer count on depletion to appreciate the value of those reserves; the value could even depreciate. There will still be boom and bust cycles, but the trend is now assumed to be towards lower oil prices.

This fundamentally changes how one views the net present value of the resource – and requires changes in strategy, as limiting production to hold oil prices up only enables others to produce first. The recent OPEC production cuts, for instance, did not have the expected effect, as others simply increased production. Recognizing that it is now probably better to produce than to wait, many oil-producing countries have ambitions and plans to grow production going forward, including Kuwait, Iran, Iraq, Russia, and others. This means even greater increases in global supply.

Given the potential supply disruptions around the world, there are questions about how fast U.S. shale can respond to a major disruption – and about the role of the Strategic Petroleum Reserve (SPR).

At the same time, however, the risk of supply shocks seems to be growing. Venezuela could explode at any time, and there is the potential for sanctions targeting the energy trade with the country. Conditions in the Middle East, with almost a third of the world's oil and gas, are worse than at any time in recent memory, and the United States is losing influence in the region. Trump signed a sanctions bill targeting Russia, and the low world oil price and the change in natural gas availability seem to be among the factors driving more aggressive Russian mischief making. The White House debated whether to certify Iranian compliance with the nuclear deal, and it is clear that Trump wants to find a way not to. There is the potential for increased sanctions against North Korea. Overall, although global conflict is currently the lowest it has ever been, the past is not predictive, and energy markets could be headed for some rocky times. Whether Iran, North Korea, Syria, Afghanistan, Russia, China, or elsewhere, there are all kinds of potential risks and concerns right now that could have implications for energy supply, and the United States is still dependent on the global oil market.

Given the potential supply disruptions around the world, there are questions about how fast U.S. shale can respond to a major disruption – and about the role of the Strategic Petroleum Reserve (SPR). The Trump Administration has been hearing that the SPR is no longer needed, which is worrying. Shale cannot ramp at the same rate as the SPR and does not replace the SPR in terms of spare capacity. In addition, the reason the United States has the SPR is as part of an energy security agreement with International Energy Agency (IEA) partners to maintain a 90-day stockpile, not just for domestic use but also for the mutual aid of others. Maintaining the SPR is a real cost to the public, though. While eliminating the SPR is inadvisable, the price responsiveness of shale oil and gas could be a reason to shrink it, as the time has been reduced between the price shock and significant production coming online. One could also imagine a system where private oil inventories could be on call as part of the SPR. The SPR could be modernized as well, to address not only volumes but also quality and the accessibility of volumes when needed. There are legitimate conversations to be had about the SPR, which has a pretty mixed track record, but those conversations are not happening. Outside voices need to keep validating to the Trump Administration the importance of the SPR as a strategic asset to temper price spikes from major disruptions for a period of time.

Debates centered on shale's price responsiveness are playing out in other areas as well. For instance, the industry appears divided between projecting an oil price spike at the turn of the decade and thinking that rising tight oil production in response to higher prices will prevent a price explosion. The global oil market is tighter than many appreciate, given the natural decline in production and the trillion-dollar cut in capex for longer-cycle conventional projects, which reduces future oil production; much of the world is seriously underinvested. Shale's growth and ability to ramp up production could help a bit with some of that supply crunch, but probably not enough to avoid an oil price spike.

INVESTOR INFLUENCE

Beyond global supply shocks, other factors could affect levels of production as well. Investors, for instance, are sending conflicting messages to companies about strategies to pursue. Current markets have seen a rotation out of growth and a move towards returns, but the markets may not remain that way.

Very short-term investors (e.g., hedge funds) want companies to grow and borrow, putting the pedal to the floor. Private equity, which has flooded the business, is also generally short-term, making decisions with an exit within five years in mind; private equity investors have pressured public companies to do reckless things, resulting in bankruptcies. Despite knowing nothing about the industry, they want to tell companies how to run their businesses.

Long-term investors, in contrast, want companies to be prudent, manage the balance sheet, and pursue full-cycle productivity; having core, long-term, predictable investors such as index funds can provide companies with a higher level of comfort. If investors reward businesses – and businesses reward executives – for growth, then the result will be growth; if investors prize cash flow and dividend yield, then the industry would get more discipline on cash flow. It would be helpful, though incredibly challenging, to educate Wall Street to take a hard look at the resource endowment and decide whether to spend time and attention trying to optimize development of resources as opposed to growing acreage. Ultimately, there is plenty of capital around, and capital will continue to flow, even with a short-term focus among investors.

IMPACT OF CHANGES IN U.S. POLICY

The actual impact that the Trump Administration will have on energy production is unclear. The Trump Administration's rhetoric has focused on American "energy dominance" – which the Administration has defined as the United States being self-reliant, secure, free from geopolitical turmoil, and an exporter to other markets, thereby increasing global leadership and influence. Much of this definition is problematic or incomplete. The United

States will not be self-reliant any time soon; even with big increases in domestic production (which have already been occurring), the country is still a massive net importer of oil. The United States will also continue to be part of an integrated global oil market, whether it imports a little or a lot, which means it will still be vulnerable to global geopolitical disruptions. Global leadership and influence, meanwhile, go beyond just fossil energy production to encompass things like climate negotiations, trade negotiations, and leadership in clean energy (which is the fastest growing segment). As for being an exporter, the country will continue exporting to markets around the world – a trend that was already underway – but "dominance" may not be the best marketing slogan if the goal is to boost U.S. exports.

The Trump Administration's view seems to be that, under the Obama Administration, the pendulum swung too far towards supporting renewables and hindering domestic fossil fuel development, so the Trump Administration's energy policy largely appears to consist of trying to swing the pendulum in the other direction. The Administration is trying to remove all potential barriers to producing and exporting as much domestic energy as possible. It is pulling out of the Paris Agreement and has reversed the stream protection rule. It is also seeking to scale back domestic regulations (e.g., the Clean Power Plan, methane emissions, coal leasing on federal lands), expedite permitting and National Environmental Policy Act reviews, open new areas for offshore drilling, and ease fuel economy standards. At the Department of Energy (DOE), efforts could be focused more on things like carbon capture and storage (CCS), work on methane hydrates, increasing recovery from shale, and promoting regional efforts on NGLs – though the 2018 budget request included big cuts to DOE's Office of Fossil Energy.

The United States will also continue to be part of an integrated global oil market, whether it imports a little or a lot, which means it will still be vulnerable to global geopolitical disruptions.

All of these efforts are noteworthy, but their effects on energy production should not be overstated. The Administration is still in its honeymoon phase and has not filled many key jobs in agencies, who in turn help leadership draw on the expertise of the career staff in the government who actually execute what is coming out of the White House. In addition, while the regulatory and policy efforts may help on the margin here and there, prices and market conditions will be far more important for determining the levels of U.S. oil and gas production and export than most of these changes.

Companies invest long-term, taking at least 10-20 year views, which means they often invest through both economic and political cycles. Many companies that have to make bets on the direction of the energy system as they make investments and respond to regulations see the possibility of the Trump deregulatory and fossil-focused agenda being a four-year blip in the longer-term trajectory of society and the policy environment. The Trump regulatory rollbacks do not change the fundamentals much at all for big companies, and the companies are not reacting knee-jerk to the regulatory rollbacks.

The Trump agenda, though, does change perceptions; companies feel like the pressure is being relieved, even if the economic impact of rolling back regulations is small. Supporters of the Administration's deregulatory agenda believe that the Environmental Protection Agency (EPA) should be brought back to earth and feel that the beating has stopped. Some in industry are also very interested in removing some of the layers of regulations that have created bottlenecks for infrastructure. There is a political base pushing the Trump Administration's actions. Still, regulations help protect public health and air quality and can reassure people that the industry is acting responsibly, furthering the industry's social license to operate. Going too far on regulatory rollbacks could have a range of negative implications for the industry and the public.

ROLE OF TECHNOLOGY IN FURTHER EXPANDING PRODUCTION

Data analytics and machine learning are emerging technologies that can have a lot of impact on energy production. Data has always been a big part of the industry, but the volume of data has exploded in the last few years; some companies have collected more data in the last year than in the prior 70. Data is also now coming from many sources. Seismic data is high-def and has a lot more information embedded in it than it did before. There are more sensors downhole and on the surface collecting more data in real time. A lot of old analog instrumentation is becoming digital, creating yet more data. The industry is swimming in data. There is enormous, valuable information embedded in the data that the human mind cannot easily process, but there is now unprecedented computing power to process and analyze that data, anywhere and anytime.

Apps can bring different disciplines together that have historically been siloed capacities within companies. For instance, subsurface knowledge – the earth model that defines the reservoir – can now be tied to the surface systems; real-time production data can be used to refine the earth model using seismic data. At the same time, companies can use the earth model to drive production optimization, reduce costs, and reduce water waste. There is huge opportunity around the integration of subsurface and surface data. Autonomous drilling is another example of how machine learning can aid the industry. These types of advances mean companies need fewer geologists and geophysicists, as some of what they used to do has been automated. Still, humans working in interdisciplinary teams in concert with machines produce even better results; the technology is a facilitator, but people are still required.

The Trump regulatory rollbacks do not change the fundamentals much at all for big companies, and the companies are not reacting knee-jerk to the regulatory rollbacks.

The industry is still in the early stages of deploying these technologies. Sometimes it feels like the industry adopts technology in geologic time; complete no-brainers still take a really long time to penetrate. Impediments to deployment include cash flow constraints, restrictions (especially outside the United States) on data flows crossing national boundaries, and a disconnect between workers and decision-makers at the top of companies regarding comfort with and confidence in the technologies. Furthermore, increased digitization and use of data analytics may increase vulnerability to cyberattacks, which have very quickly become a high priority disruptor within the industry; the industry is under attack, with hundreds of thousands of hits on the system every day, including a small but not insignificant number of attempts to get into digitized control systems. Some companies have strictly segmented office IT systems and control systems, with firewalls that only go one way so that data goes out of control systems but nothing goes in.

Overall, though, the industry is likely to embrace these technologies. There will be a divergence among oil and gas companies between those who believe technology and science are just a manufacturing, logistics, and management play and those who recognize that technology and science can improve production. Most companies have great wells, but the key difference will be which companies understand and optimize the downhole physics of their systems. Those that do will create a new level of attraction for young people to join the industry, marrying the best of geoscience with the best of computer science.

There have to be efforts, however, to include regulators in educational efforts around new technologies. It does not make sense for regulators to enforce rules that do not apply anymore. Regulators need to know the direction industry is headed, what the smart things are to upgrade, and what data they should (and should not) be asking for. For instance, most of the industry has already moved to the point where it is easier to email a blockchain file than paperwork, but regulators are nowhere close. (Federal and state regulatory agencies are far behind the industry in terms of upgrading their IT systems.)

ENERGY DEMAND

Given abundant supplies, it is likely that energy markets in the coming years and decades will be driven more by demand than by supply.

DEMAND FORECASTS

By 2040, the world is projected to add almost 2 billion people and almost 3 billion middle-class consumers (about 1 billion each in China and India and another billion across the rest of the developing world). Those people will start to buy things that require energy and petrochemicals, profoundly impacting demand for oil and gas over the next couple of decades. Demand for energy is expected to rise 25% over this timeframe (while global GDP is expected to double), with most of the demand growth occurring in non-OECD countries, particularly in Africa and Asia. Significant increases in energy supply are expected to be needed over the next couple of decades to meet this increased demand. Oil is expected to grow and remain the largest source of energy for transportation (especially heavy-duty transport, aviation, and marine, where energy density is hugely important) and for industrial uses (e.g., as a feedstock or for high heat). Natural gas is expected to grow even more quickly, both as the preferred fuel for power generation (mostly displacing coal) and for industrial uses. Coal demand is projected to peak and decline. Solar and wind are projected to grow faster than anything else, though scale ends up being a limiting factor in the speed of their penetration. Long-term projections, of course, are just projections, and different projections are more or less bullish on the future roles of oil, natural gas, coal, renewables, and other fuels. Forecasts tend to involve smooth, broad trends, but the reality in local markets is much more disruptive.

Global gas demand appears to be rather bullish. It has historically grown at a fairly steady pace, around 1.75%, at which rate the industry would have to bring on another 7 bcf/d of new gas every year to meet demand. Global demand for natural gas, however, could well be under forecasted. In China, only 3% of power generation and 6% of total primary energy consumption are from natural gas, but for each percentage point that China adds of gas as primary energy, gas demand grows 4 bcf/d. There have also been significant reforms in several countries to create more competitive gas markets. India, for instance, in addition to experiencing strong growth in renewables and coal, is trying to reform its domestic gas markets, have auctions for onshore and offshore gas leases, and build more refineries. India has almost infinite demand for cheap gas and almost no demand if the price gets high. Pre 2000, no one anticipated Chinese energy demand growth, and India may be a similarly underappreciated wild card in global energy demand growth; energy outlooks do not anticipate China-like growth in India.

As for projections of oil demand, there are two narrative camps shaping up in the industry – one led by the typical "authoritative" experts (e.g., IEA) and one led by more insurgent outsiders that forecast peak oil demand. These two camps are speaking about different things in different languages. Both sides have shortcomings.

The authoritative camp is very data driven, incorporates past patterns, and is inherently conservative; it is basically set up to miss disruptions. The rigor of the data it relies on also should not be overestimated; there are major data integrity issues. The insurgent forecasters of peak demand, on the other hand, are looking for patterns of historical disruption (e.g., in telecomm) and for telltale signs that a pattern of disruption is emerging; when explicitly looking for such signs, it is not hard to find them, but there is an inherent chance of reading too much into them. Peak demand forecasts also tend to have an extreme U.S.-centric emphasis on the personal transportation part of the market, but the potential for replicating U.S. developments in other geographies is not clear. (The increase in speculation about peak gasoline demand is taking place during a time of big gasoline demand growth in places such as China and India, where there is increased deployment of cars, roads, filling stations, and other infrastructure that will last for decades; even in OECD countries, where gasoline demand was declining, there has been a big rebound in demand, in part displacing diesel demand.) Furthermore, peak demand forecasts do not pay enough attention to the other 75% of the barrel, which goes towards buildings, petrochemicals, power generation (e.g., diesel gensets), heavy-duty transport, marine and aviation transport, and other areas.

POTENTIAL DRIVERS OF DEMAND DESTRUCTION

While the debate about peak oil demand is still wide open and requires more research, there are clearly potential drivers of demand destruction out there. Three revolutions in passenger transport will affect long-term oil demand: electrification, shared mobility, and automation (i.e., self-driving). The existing literature is mixed regarding how those three factors will affect oil demand over the next few decades; depending on the modeling, for instance, automation and shared mobility could add more transportation trips and increase demand or could eliminate virtually all oil demand in the transportation sector.

Three revolutions in passenger transport will affect long-term oil demand: electrification, shared mobility, and automation.

Electric vehicles (EVs) are projected to have most impact on the light-duty vehicle (LDV) fleet, which accounts for about 20-25% of total global oil demand. Projections vary but generally show marked growth in EV penetration over the next couple of decades, and those EV estimates seem to be revised upward every year. Adoption seems to be happening faster than many think (but also slower, in terms of the overall turnover of the existing fleet, as cars are now lasting longer). There are reasons to think EV deployment could happen still faster. India, for instance, has a national strategy calling for complete electrification of personal mobility by 2030 (though administrative ability to implement policies is a big constraint). On the manufacturing side, Volvo and others have said they are boosting their EV production – or offering only EVs within a few years. Every car company also offers plug-in hybrid cars with small batteries, and much of the driving that people actually do will be on those batteries, as most driving is very short-range; plug-in hybrids could eliminate some oil demand as well. Even given how large the global oil market is, tight markets for oil mean relatively small changes in demand spurred by EVs could upend things. Whether conversion to EVs actually occurs, especially in a relatively short period of time, will depend on the public's ability and willingness to change and their trust in the new technologies, which could vary based on consumers' ages and geographic locations (e.g., rural versus urban). While EVs are growing in various parts of the world, it is worth noting that conventional vehicles are growing even faster.

Other transportation developments could be drivers of oil demand destruction as well. Scenarios suggest that switching freight to natural gas, electricity, hydrogen, or other fuels, improving logistics via digitization, and ridesharing could peak oil demand by 2040. Demand could drop further if cities move more toward having inner-city pedestrian centers (i.e., excluding trucks and vehicles). Increased mass transit and automated EVs could accelerate the decline in demand, while biofuels policy could further reduce oil demand in the LDV space. Efficiency could also be a much greater disruptor on the demand side than the oil and gas sector realizes. Gains in fuel economy are projected to displace twice as much oil as electrification in the near term. A little longer-term, the combination of electrification with ultra-lighting could lead to demand destruction several times greater than EVs alone. There is also greater heavy truck and airplane efficiency potential remaining to be tapped. Efficiency potential worldwide – and across sectors – may be so large that producers of fossil fuels may have more unsellable than unburnable reserves; they may be more at risk from market competition with efficiency than from climate regulations.

Gains in fuel economy are projected to displace twice as much oil as electrification in the near term.

Beyond transportation, the potential for supply shocks should also be taken into account when thinking about demand. Historically, big contractions in demand – some lasting – have come as a result of supply shocks. Given the high risk of disruptive events in the current geopolitical climate, constraints on supply could have a big impact on demand.

The industry could also accelerate demand reduction for its own products through its accidents. For instance, the Aliso Canyon leak in California – which was a product of poor maintenance practices – led the state to accelerate permitting for more than 100MW of solar with battery storage, fast-tracking deployment that otherwise could have taken years. The industry let technological change in the front door through its own failure. The Macondo Gulf spill similarly changed public perceptions of the safety of offshore oil development. Economics will maintain fossil fuel reliance in the near future, but things going wrong could change the industry's social license to operate and thus the outlook for both supply and demand. If people perceive the traditional technologies as ineffective or dangerous, other technologies exist that now offer flexibility.

EUROPEAN GAS DEMAND

Europe's energy consumption since 1990 has shifted to involve less coal and oil and more gas and renewables. The European energy story now centers around worries about gas supply security. Russia accounts for a sizeable percentage of gas supply to the EU, and there are big concerns about that dependency. Given multiple instances of Russia cutting gas supplies to Europe over the past decade, the European Union has taken a policy-led view of where energy markets should go; European energy policy is driven from Brussels based on security and environmental concerns.

The EU is pursuing an Energy Union that has several dimensions, one of which is security, solidarity, and trust, with a focus on diversifying sources of energy. (Other dimensions include a fully-integrated internal market, energy efficiency, decarbonization, and researching low-carbon technologies.) The United States has been saying for decades, across Administrations, that it has a lot of natural gas it can export and that both Eastern and Western Europe should have alternatives to Russian supply. EU and UK regulators are extremely interested in getting deliveries of natural gas to give themselves optionality and to counter-balance Russian gas influence; they are also looking to drive down the cost of energy for their consumers. U.S. natural gas exports given them options to meet both of those objectives.

U.S. LNG exports to Europe to date have been around 0.47 bcm. U.S. LNG export capacity is growing rapidly, and Europe is building out its LNG receiving capacity at the same time. Much of Europe's existing LNG import infrastructure is located in Western Europe, particularly in Spain, which is kind of isolated from the rest of Europe (and is not supplied by Russia). A lot of the planned expansion of LNG import capacity is occurring in Eastern Europe (e.g., Poland, Lithuania, Croatia) to enable diversity of supply and reduce dependence on pipeline gas from Russia. In the meantime, countries that have built import terminals and said they would buy from the United States when U.S. prices are lower have been able to negotiate lower prices in Russian gas contracts.

With LNG exports, natural gas is becoming a global commodity, which means the key is to be the lowest-cost provider. U.S. LNG can compete in Europe with pipeline gas on a market basis. Just based on the cost of production, LNG can be delivered to Europe for less than $3.50, though that would not involve much return on capital. If Europe is buying on the spot market, the price of U.S. LNG could sometimes be higher or lower than Russian gas. U.S. LNG could also go to other places where the prices are higher; there are some long-term contracts for U.S. LNG in place, some to bring LNG to Europe and some destination-flexible. For instance, U.S. LNG exports could play a big role in satisfying the growth in energy demand expected in Africa and Asia over the next couple of decades, but as in Europe, infrastructure will be needed in countries to receive the product. (For international markets, an inexpensive option is to put a re-gas terminal in place on a ship, which can be moved to where it is needed.) All in all, these new markets will represent a massive change for the natural gas industry – supplying countries not on a baseload basis, but rather on an intermittent basis based on constant competition.

It is not a given, however, that U.S. LNG will be what satisfies energy demand in Europe and elsewhere. It took years for the United States to instill confidence in governments around the world that they could commit to U.S. LNG (and make the associated infrastructure investments) – to reassure them that the shale resources are real, the United States will let LNG be shipped to them, and the United States will not back out of that commitment in the future. The current Trump Administration hyperbole around trade agreements, energy supplies, and relationships with other countries risks undermining the confidence that had finally been built in other countries that the United States would not stop sending them its hydrocarbons. (Similarly, the Trump Administration's efforts to renegotiate the North American Free Trade Agreement raise questions about what North American energy policy will be and the extent to which Mexico will continue relying on supplies of natural gas from the United States; Mexico is exploring greater production of its own oil and gas resources, as well as increasing its production of renewable energy.) For governments to commit to invest in infrastructure on the receiving side, they have to have confidence that a steady supply is coming. It is vital to remember that energy policies are not the only policies consequential for the energy sector and that trade policy, sanctions and other foreign policy, tax policy, R&D policy, and many others are hugely consequential as well.

DEMAND IN THE U.S. POWER SECTOR

Demand in the U.S. power sector is changing. Coal's role in U.S. power generation peaked in 2007 and has since dropped dramatically, while natural gas has been on a steep rise. Gas overtook coal in 2016. Nuclear's share of generation has been relatively steady but will likely start to decline. Among renewables, hydro's buildout level has been steady for a long time, while wind and solar have been growing steeply.

Competitive markets are about marginal cost, and fuel-free renewables have zero marginal cost, which means renewables shift the whole bid stack, lowering prices for everyone.

The decline in U.S. coal use was caused primarily by cheap natural gas, declining electricity demand, and cheap renewables. For instance, in competitive markets, when natural gas was expensive (say, around $8), then it set the marginal price, and the bid stack included nuclear, then coal, then natural gas. When gas prices dropped, prices for electricity went down, and gas switched places with coal. Now, in the United States, renewables are displacing coal (because coal is on the margin) and cutting into the market share of natural gas. Competitive markets are about marginal cost, and fuel-free renewables have zero marginal cost, which means renewables shift the whole bid stack, lowering prices for everyone. In short, solar and wind have the lowest marginal price and beat everything, while cheap gas beats coal and nuclear.

In addition to prices, demand in the power sector is also changing because of environmental factors, such as regulations to address NOx, SOx, mercury, and particulates. These types of regulations have had more impact than carbon in shutting down coal plants, though environmental regulations have played a small role overall in the decline in U.S. coal use. (Accordingly, implementing all of Trump's regulatory rollbacks will not bring coal back as long as natural gas prices stay low.) Water, too, is a rising concern in the power sector, especially in arid climates. Natural gas is half as water-intensive as conventional coal on a lifecycle basis, while some zero-carbon options, such as nuclear power, are very water-intensive. Wind and solar tend to be the best in terms of being low-carbon and low-water, along with perhaps small modular nuclear with dry cooling and a few others. In general, as environmental standards tighten, the winners in the power sector tend to be wind, solar, and natural gas, with nuclear power as something of a wild card. Longer term, because gas is low-carbon but not zero-carbon, demand for gas could be seriously affected if carbon policies get more serious; this means it is possible that the industry is overbuilding gas delivery infrastructure (e.g., pipeline projects into the northeastern United States) to serve power market needs that may not persist.

DEFENSE DEMAND

U.S. defense is a source of large, relatively consistent energy demand, even when not in a time of war; training and readiness, too, are energy-intensive. The U.S. Department of Defense (DOD) is a global energy consumer, and it tries to buy its energy as close as possible to where it is needed. The armed forces require energy for both installations and operations.

In terms of installations, DOD has 28 million acres under management, with 500 bases and 300,000 buildings, and most of its energy bill is for heating, cooling, lighting, and the like. These installations are almost totally on the commercial grid, including in other countries, raising concerns about grid security. Water is also becoming an increasing area of focus at installations, as DOD water use can be disruptive to potential civilian users of water rights.

Most of DOD's energy demand is in operations, almost all in the form of demand for petroleum fuels. The product consumed most is jet fuel, which is used not only in aircraft but also in generators; there is mission benefit to dealing with a single fuel. DOD also consumes other products, including some boutique niche fuels, and the security of supply for those fuels is incredibly important to DOD. While DOD's installations work is mainly about getting the best yield possible (like any other business), its operations work is all about mission. It is about keeping installations and operations running that have to keep running no matter what.

That mission orientation has been the main driver for DOD's relatively long-standing interest in energy efficiency and alternative fuels. For instance, DOD has an interest in reducing the need to carry fuel to difficult places to supply its forward deployed forces and outposts; energy efficiency and solar generation can promote DOD's mission by minimizing fuel supplies and reducing opportunities for adversaries to target supply lines. In addition, on-base renewable energy provides increased security and resilience, enables bases to securely run real-time battle operations remotely, and allows bases to provide support to surrounding communities during a disruptive local event. DOD's scale and ability to do long-term purchasing and agreements make it easier to promote energy efficiency and renewables at its bases, and DOD has also been compelled to pursue efficiency and alternative fuels by various laws and executive orders.

Climate change is not a primary motivation for DOD's efforts on renewables and efficiency, although DOD interacts with the issue of climate change in several ways. Some of its bases, particularly coastal bases, are clearly affected by climate impacts such as sea level rise. The melting Arctic, once it is more navigable, will change the military's approach to northern defense. Humanitarian and disaster relief missions have been on an uptick, and, looking more long-term, there are regions where water and/or food disasters will drive instability and mass migrations. At the leadership level, there are people whose job is to think about the ramifications of climate change, but the more basic, operational, mission-driven concerns are what drive DOD's work.

DOD energy demand is not peaking. Many of its new platforms – ships, vehicles, aircrafts, and other platforms for weapons – that are coming into service consume more fuel than what they are replacing, which is problematic. A countervailing trend is also underway, however, with new capabilities and platforms (e.g., unmanned systems, artificial intelligence, machine learning) that could change the consumption picture radically and impact the way fighting occurs. Still, energy demand for defense is likely to be consistent or higher in the future.

ENERGY INFRASTRUCTURE

Energy supplies cannot meet energy demand without infrastructure to move energy. The resources have to be able to move from where they are to where they need to go. Midstream is the aspect of the industry that historically has gotten the least attention, but it has also become perhaps the biggest challenge for the industry.

INFRASTRUCTURE DEVELOPMENT

The only places in the United States where development of infrastructure is really occurring – where the U.S. shale revolution is currently alive and well – are the Northeast and West Texas. Natural gas pipelines are being built to add takeaway capacity in the Utica and Marcellus, while infrastructure for natural gas, NGLs, and crude is being developed in the Permian to handle growing production (adding to the hundreds of thousands of miles of pipe that Texas already has). Even in these regions, state regulators have been waiting on upgraded pipeline rules from the Pipeline and Hazardous Materials Safety Administration (PHMSA) for at least a couple of years. Regulators are also dealing with some other challenges, such as the increased standard dimensions of pipe, which require bigger rights of way.

More than $100 billion of additional investment in gathering, processing, long-haul transport, and other infrastructure is needed to move gas from the Eastern Seaboard and the Permian to the Gulf Coast.

In contrast, other basins, such as the Bakken and the Niobrara, have been in a deep freeze for a couple of years. Even with signs of life stirring, there is not much infrastructure development happening, as there was too much pipeline capacity developed there in the first place. (The situation in Europe is similar, with very low utilization rates across European pipelines, raising the question of the need for adding additional pipeline capacity such as Nord Stream 2.)

Price makes a big difference in the adequacy of pipeline capacity, as it affects anticipated levels of production and thus expected throughput for pipelines. High versus low oil prices could translate to a million barrels a day difference for Permian crude production by 2022. Similarly, while gas production in the Utica and the Marcellus is projected to grow even in a low-price scenario, there is a 13 bcf/d difference between a high- and a low-price scenario. Depending on which price scenario comes to pass, there could be lots of pipelines with insufficient capacity.

Producers are not just trying to get molecules out, but rather to get them from markets where they are worth less to markets where they are worth more. Currently, that is the Gulf Coast; that is where most Northeastern and Permian production is headed. Some is headed straight to ships for export, while some is going to refineries to be converted. The United States has very cheap gas to produce, at least at the wellhead, but more infrastructure is needed to cheaply get the gas where it needs to go. More than $100 billion of additional investment in gathering, processing, long-haul transport, and other infrastructure is needed to move gas from the Eastern Seaboard and the Permian to the Gulf Coast.

Energy transport infrastructure does not just mean pipelines. Pipelines only go where they go, whereas railcars, trucks, and ships can take product to a range of markets. Rail, for instance, was a key enabler of shale development in the Bakken, when there was inadequate pipeline capacity there. Rail also hauls oil, coal, ethanol, LPG, wind turbines, and more. Rail is about three times more efficient than trucking – it ships a ton of freight 500 miles on one gallon of diesel – and is experimenting with powering itself with other fuels, including hydrogen, LNG, and electricity. Trucking remains a vital element of local energy transport. Ships, too, are a key form of energy transport, and ports need to be dredged and upgraded to allow very large ships to come in and be completely loaded. Inadequate port infrastructure can be a barrier to getting LNG and other products to market.

Vital energy infrastructure also does not just mean transport infrastructure. Storage capacity has to be part of the energy infrastructure conversation as well. There has not been much appreciation of the growth in storage in the country, but the significant energy storage capacity in the United States gives the country more flexibility to handle changes in supply and demand.

TRANSPORTING FRACK SAND

One of the essential items that has to be transported to facilitate shale development is frack sand. Until recently, almost all the sand used in fracking came from Wisconsin, with a bit from Minnesota and Illinois. Demand for frack sand has grown from about 25 million tons in 2010 to around 75-80 million tons in 2017, and demand is estimated to exceed 100 million tons in 2018. Half of that is expected to be used in the Permian.

Most of the cost of frack sand comes not from production but from transport (and service company fees). Sand that has production costs of $20/ton at the mine could cost end users $150-200/ton. Trucking the sand is costly and inefficient, and given the volumes and distances involved, could have significant impacts on road quality. Much of the long-distance transport currently occurs by rail.

Using locally produced sand would be far cheaper. Local sourcing of sand would lead to local jobs in sand mines and in trucking. The industry could also deploy technology to substantially reduce the amount of sand required.

HUMAN INFRASTRUCTURE

People are a constant limiting factor for the energy sector. The industry struggles with finding personnel who will stay long-term. For instance, companies are having trouble finding people to drive trucks who will stay on the job; those jobs currently are not attracting people.

Many of the people the industry needs to hire for infrastructure projects – such as trained welders, sophisticated electricians, and other skilled trades – also are not available. This means the industry has to convert or train other people – which takes time, energy, initiative, and money – or somehow find those people elsewhere. Trained people all around the world could fill the boom of workers needed for infrastructure projects, even as the industry trains its own people in skilled crafts. The current immigration policy situation, however, makes it very hard to bring in talent from around the world. Rational, balanced immigration policy will be needed in order to bring in the right trained crafts the industry cannot find locally.

The industry depends on attracting the talent it needs for both its current and future workforce. Universities are already seeing foreign enrollment drop significantly. American universities used to attract the best and brightest from around the world, but top talent in other countries is now preferring to stay home or go to Canada. Trump Administration immigration policy is making it hard to recruit the best students and faculty, and those who are already in the country now cannot travel home. U.S. competitiveness and the oil and gas industry have benefitted from attracting the best talent; constraining the flow of that talent will come at a price.

On the other hand, not all workers necessarily have to be on-site anymore. People can be located anywhere around the world. Given the difficulty of getting visas for workers, technology can allow for a world without walls (to an extent). In addition, when there is enough money on the table, the industry finds ways to solve problems such as availability of people.

RESISTANCE TO INFRASTRUCTURE

The Achilles heel of the industry may be that people are very resistant to construction of necessary infrastructure. There is increasing opposition to all sorts of infrastructure, from pipelines to coal export terminals to rail and inter-modal infrastructure. It is increasingly difficult to get permits for anything now. The industry has not done a good job of protecting its social license to operate and dealing with those hostile to the industry.

It is important to recognize that there are different forces and motivations leading to infrastructure opposition. Some of the challenge relates to NIMBY (Not in My Back Yard) and local community concerns. Building pipelines, for instance, is a challenge because people do not want them in their backyards and do not want their land taken. If people have personal negative impacts from infrastructure, it is normal for them to oppose it. The web of gas pipelines is also super-dense in some places, raising the question for some people in those areas of why the industry would need to build more.

There is a separate contingent of opposition that consists of people who believe that the country should not be using fossil energy and are working to prevent all infrastructure development. This contingent is commonly known as the keep-it-in-the-ground movement.

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The industry generally seems to view the keep-it-in-the-ground crowd as a bunch of anti-growth fanatics that hypocritically still use fossil fuels and petrochemical products, deny hundreds of millions of people around the world access to energy, and never offer actual solutions. The industry, however, may be misunderstanding at least some aspects of the keep it-in-the-ground movement. It is entirely legitimate to analyze the implications of major new energy infrastructure investments to ensure the investment is compatible with keeping safe climate options open; indeed, it would be irresponsible not to. In addition, keep-it-in-the-ground is a tactical movement designed to hasten rational climate policy by making the status quo unbearable to those in power; it is not yet unbearable – more of a nuisance – but part of the idea is to make the status quo not be fine.

The opposition to hydrocarbon infrastructure will only get more intense, regardless of which party is in power nationally. Outside of Texas, it is possible that Dakota Access will be the last big pipeline built in the United States. Opposition to pipelines is rampant and strong. The climate test for new fossil fuel infrastructure that President Obama announced is currently in the Democratic Party platform. Opposition to pipelines is not just from the liberal left. Members of Congress from the Northeast are downright antagonistic to efforts to advocate for new pipelines, and members of both parties have voted against eminent domain for pipelines. With support from Democrats and Tea Party types, it is conceivable that the Natural Gas Act could be amended to eliminate the power of federal eminent domain for pipelines, which would mean no more interstate pipelines get built.

There is a major divergence in possible solutions to the inability to permit infrastructure. One option is reflected in the current deregulatory and fast-track permitting efforts of the Trump Administration. The other approach is to actually pursue more regulations and good climate policy that make keep-it-in-the-ground a less legitimate argument. There is greater focus on infrastructure opposition when there is less serious climate policy to talk about, so the keep-it-in-the-ground element can be cabined a bit when there are more effective climate policies to focus on.

Companies in the industry are beginning to shift more advertising to social media in efforts to better get out their message, and they should listen to the rather unadulterated comments they will get in response to figure out what opponents are trying to say. Companies should also empower their employees to get out into communities and talk to people; they are companies' best ambassadors. Industry needs to be talking and sharing data with regulators, researchers, and communities as well.

STEWARDSHIP

It is increasingly difficult to have a conversation about the future of the energy sector without addressing the impact of the industry on the environment and communities. Issues related to stewardship – including water, leaks, and climate change – are becoming matters of critical concern.

CORPORATE COMMITMENT

Adoption of stewardship concepts in the industry is still in the early days. The big challenge is in-house – in getting leadership to associate good business with corporate commitment to stewardship. Efforts on sustainability and stewardship have to start at the top of the organization; only when leadership is totally bought in and fully and credibly pushing for stewardship will the concepts move down into the core staff.

Companies have to do more than just make social contributions. Many people in companies are anchored in the old ways, but they need a good understanding of the rapidly evolving landscape of risks and mitigation practices. Companies have to focus on investing in technologies and solutions that will actually contribute to stewardship results. At the very least, pursuing efficiency is absolutely critical, as it contributes to sustainability and improves profitability; lots of inefficiencies still persist in the oil and gas domain, and the industry is lagging others in that regard.

Achieving real results and making real internal commitments are very important to multiple constituencies. For instance, today's young talent is very savvy at seeing through greenwashing, and real actions and results are required in order to recruit young people to the sector. Similarly, sizable percentages of investors already look at environmental, social, and governance (ESG) factors in deciding whether to invest, and the intensity of the wave of ESG focus will continue to increase. ETF and index fund companies have rule-based criteria for voting their proxies, and if industry companies have inadequate female representation on their boards or do not take the issues of stewardship, health impacts, and the like seriously, the funds will vote their proxies against the companies. This is not just political correctness; companies with better stewardship and diversity tend to outperform.

PRODUCED WATER

Water handling will become an increasingly important aspect of the oil and gas industry, as dealing with produced water is and will continue to be a huge problem in the Permian and everywhere that fracking is done. Moving that water around is sometimes handled by large numbers of trucks, but the more trucks there are running through communities, the more challenging relations with communities will be. There are also many pipelines on the surface, both long-term and temporary, for transporting produced water. Large surface facilities are required as well for storing produced water, or produced water can be stored in underground reservoirs and then pulled up on demand, which also requires huge facilities. One day, the industry will have as many produced water storage facilities as it has natural gas storage facilities. They will need to be regulated, and innovation will be needed to ensure the water is stored carefully and protects freshwater supplies.

The cheapest option for dealing with produced water is to dispose of it, but seismicity has been a highly visible challenge with disposal of produced water, particularly in states such as Oklahoma. Mitigating such risks has required building broad and diverse coalitions (including stakeholders who disagree), being open and transparent, and focusing more on what stakeholders do than on their motivations for participating in the conversation. The resulting rules restricting the volumes allowed down disposal wells has reduced the attendant seismicity.

There is a need for other solutions, and there has to be research undertaken on other uses for produced water. Many startups, however, want to own proprietary technologies and become super-rich. Similarly, university researchers are patenting every little thing, driven by federal research grants. Instead, the key should be building technologies, proving them, making them safe, and making sure they can be done at scale. Federal R&D efforts and grants will be essential to figure out how to address produced water; state governments do not have enough resources, and though private industry is investing in it, it is hard for any individual company to fully realize the benefits of such R&D. However, the energy-water nexus is a cross-cut program that sits in several different DOE offices, which runs the risk of getting stranded in terms of funding. The Administration's broader push to only focus on early-stage R&D is also problematic, as there is a need to get the next generation of technologies piloted, demonstrated, and scaled.

Federal R&D efforts and grants will be essential to figure out how to address produced water; state governments do not have enough resources, and though private industry is investing in it, it is hard for any individual company to fully realize the benefits of such R&D.

The industry should focus on handling produced water well within the industry, and there is a commercial case for doing so. Larger companies implementing water recycling and reuse have seen great environmental and economic benefits. The industry has learned that it can use almost any kind of water for fracking, including produced water; it has to be cleaned up and treated, but with developments in water chemistry, that can be done efficiently. Water reuse and recycling can be a particularly valuable approach in regions in drought. The cost of water recycling, however, is a huge barrier to getting small producers to adopt a recycling approach, and others in the industry will need to redouble efforts to convince and teach small operators to recycle water. There are also regulatory impediments to water reuse and recycling that vary state by state, as each state has its own regulations in place about disposing of oilfield waste. Changing regulations fast enough to embrace technological solutions is difficult, though some states, such as Texas, have enabled private companies to pursue a lot of experimentation and new technologies.

Even when produced water can be reused in the next frack, there will still be a lot of water left over that has to be addressed. Moving produced water from one play to another is a possibility, though it could involve large transportation costs (which could perhaps be somewhat reduced by repurposing old pipelines). There has also been talk of using produced water for agriculture or to create freshwater (though those looking to create freshwater would do better to start with brackish water than with produced water).

It is essential to understand what the produced water will be used for and to make sure it is cleaned to be fit for that purpose. The challenge is having a common understanding of what the scientific criteria are in terms of what is appropriate to protect public health and the environment. A consensus even on test methods would be good, much less what the standards should be coming out of the tests. It is vital to understand the constituents in produced water, their impact on health and the environment, and what acceptable levels are for particular purposes; that science remains undone at this point. Using water within a basin might require one set of standards, putting it into a second basin raises a whole separate set of issues, and using produced water for something outside the industry raises an entirely different set of concerns. There is no way to say anything intelligent right now about what clean water looks like for that last set of uses, nor really for the second set. California is using recycled produced water for some crops, but that is a big test case forced by regulators, and the state really does not seem to know what it is doing. Understanding the toxicology and researching ways to reduce the energy costs of treating water are critical, and DOD, DOE, and the National Academies all have research programs that could facilitate research for states into water toxicology.

LEAKS & FUGITIVE EMISSIONS

Leaks from oil and gas development, transport, and distribution – from major pipeline incidents to releases of fugitive emissions – risk breaking public confidence and trust. The industry's failure to take a responsible attitude toward infrastructure maintenance and fugitive emissions could place the industry's social license to operate at risk.

Leadership in the industry, in dialogue with responsible advocates for public health and the environment, should be encouraging inspectors and promoting other efforts to track and minimize fugitive emissions of methane, olefins, ethane, benzene, and other gases and vapors. Leakage prevention can clearly be done better, as made clear by the fact that the industry already does it better for sour gas. The costs of prevention are not high, and most leakage can actually be abated at profit; preventative maintenance can increase industry productivity. The value of inspectors and preventative maintenance cannot be overstated.

The industry's failure to take a responsible attitude toward infrastructure maintenance and fugitive emissions could place the industry's social license to operate at risk.

With regard to methane emissions, between 60% and 70% of emissions from the oil and gas supply chain come from something other than production. A lot of emissions are associated with the gas gathering systems, but there are no good publicly available inventories of such systems in many places. Processing facility locations are known, but not where the web of pipelines is. The rules PHMSA is working on may not be as comprehensive as needed to really understand the web of pipelines. At the distribution end, gas utilities are starting to deploy more advanced technologies to identify methane leaks in distribution systems.

Automation, machine learning, increasingly affordable and available sensors, advanced analytics, and other technologies will in fact have huge roles to play in preventing leaks and advancing well integrity and operational integrity. A lot of leaks and emissions from the industry today are attributable to events that seem random, but as more data is acquired and analyzed to determine where events happen and why, there could be a revolution in predictive maintenance – changing out equipment and doing maintenance so events never occur. For instance, apps are being developed for smartphone- and tablet-type devices with amazing sensors built in that could tell if something is wrong with pipeline flow by sound. (Similarly, sensor technologies could anticipate downhole issues, preventing threats to water quality by figuring out where risks are before they develop into problems.) There are also efforts to look at how smartphones can be used to sense air quality in real time; surrounding communities could tell industry when it has a methane or other air emission problem. Drones could look for leaks and minimize the number of trips and people heading out into the field. Instruments could tell technicians what the problem is, where, where the equipment was made, and where to get help to fix it. With connection to the cloud, all of this content and capability will be accessible anywhere in the world. Technologies, therefore, are not just about making the industry more efficient but also about addressing one of the industry's clear challenges: environmental performance.

CLIMATE CHANGE

Climate change is an issue that will continue to grow in prominence for the oil and gas sector. While some corporations are incorporating internal carbon prices into their decision-making, several companies in the sector lost shareholder resolution votes recently focused on testing the businesses against and seeking financial analyses about climate risk. For instance, it is conceivable that reduced volumes of petroleum and natural gas in the future – as projected in some scenarios with aggressive climate policies – could affect the payback on infrastructure investments. This shareholder activism space is intensifying. In addition, there is a pretty aggressive divestiture movement, in which people are making moral, not financial, decisions.

Civil society is also looking for other ways to pressure the industry to address climate change. One way may be tort litigation against fossil fuel producers for the damages associated with the use of their product, such as the case filed this summer in the California state courts by some California counties and cities against 37 fossil fuel producers. The case asserts eight causes of action and seeks both compensatory and punitive damages. Whether or not this particular suit is successful, potential tort liability is a serious risk for fossil fuel producers. Cumulative emissions continue to rise, it is possible to calculate the number of tons associated with fossil fuels, the science of climate impacts is getting more robust, and the prospect of really serious weather events will bring ever more public attention to the issue. Litigation is likely to increase, and not just in the United States, and it is not clear that fossil fuel producers have a plan in place to manage that liability risk.

The more off-track humanity is for achieving safe climate objectives, the more pressure there will be on the industry.

The industry needs to take greater action to address climate risks and facilitate climate solutions. For instance, there is a need to reduce emissions in the transport process (e.g., trucking). CO2 pipeline networks may also need to be developed for a low-carbon future, not just for carbon capture and storage for coal and natural gas plants, but also for bioenergy with CCS (BECCS) plants and for industrial processes. CCS pipelines need to be close to the basins where the CO2 can be injected, close to demand, and close to places where pipelines can get permitted – which probably means the Gulf Coast. As learned with injection of produced water, geology matters when putting things in the ground, and CO2 injection is a better idea in some geographies than others. There is a need to further assess where a CO2 pipeline network belongs and to ensure right-of-way issues are addressed. More broadly, while CCS is not a silver bullet, it is a vital technology that all sides – industry and climate advocates – ought to be pushing to make a reality.

The more off-track humanity is for achieving safe climate objectives, the more pressure there will be on the industry. Taking into account countries' commitments submitted under the Paris Agreement, CO2 intensity is projected to be cut almost in half by 2040, while energy-related CO2 emissions are projected to peak sometime around the 2030s. (The OECD peak occurred around 2007-2008, while China is expected to peak its emissions around 2025 or a bit earlier.) These projections do not meet a 2°C target, however. The U.S. commitment under the Paris Agreement (which Trump is pulling out of) was to reduce its emissions 26-28% by 2025. The suite of policies under the Obama Climate Action Plan would have gotten the country pretty close to that target (around 21%), but assuming the various Trump proposals and rollbacks come to pass, U.S. emissions are projected to decline by only about 15-18% -- and by even less if fuel economy standards are weakened. Emissions are still projected to decline under Trump, but not as steeply as they would have.

Changing technologies, market trends, and consumer desires will not be enough to get to 2°C. Policy will be a necessity. The Trump Administration, however, does not think of climate change as a priority to solve, or even as a problem at all. Whether because of climate denial or resentment about perceived abuses of executive authority, the Trump Administration will dismantle its predecessor's work as much as it can; the courts will be the only limitation. Until a way is found to address the climate issue, though, the industry will fundamentally be stuck with the energy policies currently in place, which were developed with an eye towards energy scarcity instead of energy abundance; the issue of climate change has disrupted the usual cycles of energy policy legislation in Washington. Until there is legislation on climate change, energy legislation will be largely inconsequential, and there will simply be large oscillations between executive actions taken under different Administrations.

It is conceivable that there may be a path forward, albeit a narrow one, for a carbon tax. A carbon tax is incredibly unpopular among a section of the country, including the group of people in charge. Key people in the Administration, including the President, deny that human caused climate change is even happening, and it is likely pointless to try to change the minds of people, such as the head of the EPA, who have staked their reputation on being climate deniers. There appears to be consensus on the need for tax reform writ large, including on areas where cutting taxes may be desirable. There is not agreement, however, on how to pay for those cuts, and a carbon tax could be one way to do so. While a carbon tax may not have bipartisan appeal on its own merits, it is conceivable that using it as part of a revenue neutral tax swap and as a replacement for some climate regulations could be a path forward.

Some Republicans are desperate to find money to reduce taxes, while others are persuaded by the national security implications of climate change. Some would prefer market-based approaches over regulatory approaches (though that argument did not work to get Waxman Markey through, when there actually was a regulatory onslaught potentially coming). Republican supporters of coal may begin to recognize that a carbon price is likely essential to ramping up CCS and dealing with CO2 in an economically viable way. Some – particularly younger, more recently elected Republicans – are uncomfortable with the climate denier stance of the party and are seeking conservative solutions. Slowly, some Republicans in Congress are looking for a more constructive path forward. This summer, a bipartisan group in the House defeated an attempt to remove climate provisions from the Defense authorization bill.

Still, there are many fine lines to walk between various ideologies, viewpoints, and constituencies, and getting it done is a long shot. One should not underestimate the power of Evangelical Christians in their growing push on stewardship of the earth, and the business community can wield powerful influence over elected officials when it wants to. It might also help if Democrats would stop beating up on industry so much and talk to them like partners. On the other hand, a lot of the politics around the environment generally and around climate change in particular are driven by the local independent producers, who are the ones talking to Representatives when they go back home to their districts. These producers tend to have a focus that is short-term and centered around cash flow. Getting climate policy enacted may require getting this group to see how they materially benefit from it.

Within Congress, there are at least four blocks that are important: the corporate tax cutters, the anti-regulation Freedom Caucus, moderate Democrats, and Democrats heavily aligned with the environmental community position. The environmental community will likely push for a political strategy that isolates the Freedom Caucus and seeks a combination of carbon pricing and a sensible suite of targeted regulations that set performance standards for key sectors. Regulation done well is important, so figuring out which specific tradeoffs make sense and could garner support is advisable; it is not too early to begin conversations about what regulatory relief would be acceptable to garner additional support. The risk appetite of the environmental community in terms of regulatory tradeoffs will be directly related to how transformative the proposed alternative is. At the end of the day, the benchmark for an effective carbon policy is that it starts to get the country to where it needs to go to remain within the 2°C threshold put forth by the scientific community.

The specific details of carbon pricing policy design will really matter. This includes the level of the price, distributional concerns, and how the revenues are used. There will have to be some threshold that excludes smaller emitters, as well as detailed rules for how the carbon emission accounting gets done. While the details will have to be worked out, the first step is to get people to intellectually engage with the issue, appreciate the policy implications, and agree to even have a discussion.

APPENDICES: AGENDA

MONDAY, JULY 24

Opening Session	**Introduction**	**David Monsma**, Executive Director, Energy and Environment Program, The Aspen Institute
	Welcome	**Mary Landrieu**, Senior Advisor, Van Ness Feldman **Marvin Odum**, Former President, Shell Oil Company
	Overview	**Michael Webber**, Deputy Director & Professor, Energy Institute, The University of Texas at Austin

SESSION I: **The Global Energy System in Transition**

Forecasts and predictions in the energy sector are often off in the longer term and tend to underestimate the impacts of technology development. In an energy system filled with transition and unpredictability, what are the different forecasts companies and governments should consider when making long term strategy?

Moderator: Marvin Odum

Discussants:

Peter Trelenberg, Manager, Environmental Policy and Planning, ExxonMobil
Amy Myers Jaffe, Executive Director for Energy and Sustainability, UC Davis
Meg Gentle, President & CEO, Tellurian Inc.
Jason Bordoff, Professor & Founding Director, Center on Global Energy Policy, Columbia University

SESSION II: **Energy Transport**

Whether transported by pipe, wire, rail, ship, or other means, the ability to move energy is key to economic development. What are the opportunities and challenges in different modes of transportation of energy and where can improvements be made?

Moderator: Mary Landrieu

Discussants:

Matthew Rose, Executive Chairman, BNSF Railway Company
Christi Craddick, Chairman, Railroad Commission of Texas
E. Rusty Braziel, President & CEO, RBN Energy, LLC
Robert Rasmus, CEO, Hi-Crush Proppants LLC

TUESDAY, JULY 25

SESSION III: **Next 25 Years of Supply – Expanding the Pie**

Investment in new resources has been lower since the price downturn. With supply recovering, where will the next discoveries of oil and natural gas be? How do technology and developing international markets impact development of supply?

Moderator: Bill White, Chairman, Lazard

Discussants:

Jay Pryor, Vice President, Corporate Business Development, Chevron
Thomas Jorden, Chairman, CEO & President, Cimarex Energy Co.
Jim Teague, Director & CEO, Enterprise Products Partners L.P.
Arshad Matin, President & CEO, Paradigm

SESSION IV: **Energy Demand**

One of the biggest questions global energy markets face is determining future demand. Will the increase in demand for petroleum in developing nations continue the increasing role of oil globally? Will the various natural gas and LNG markets become a global market? How do the policies of big users of energy, such as the US military, impact energy demand?

Moderator: Marvin Odum

Discussants:

Antoine Halff, Fellow, Center on Global Energy Policy, Columbia University
Evan Fuery, Vice President Political & Public Affairs, Statoil
Michael Webber, Deputy Director & Professor, Energy Institute, UT Austin
Sharon Burke, Senior Advisor, International Security Program, New America

WEDNESDAY, JULY 26

SESSION V: **Policy and Infrastructure Uncertainties and Risks**

Policies with regard to energy development, infrastructure development, and license to operate continue to evolve in the US and abroad. How does corporate engagement impact stakeholder reaction to new development? How can policy makers respond to crises when they happen, and what is the role of non-regulatory policy mechanisms in energy policy development?

Moderator: Mary Landrieu

Discussants:

Jean-François Poupeau, Executive Vice President Corporate Engagement, Schlumberger
Alex Flint, Executive Director, Alliance for Market Solutions
Michael Teague, Secretary of Energy and Environment, State of Oklahoma
Doug Hollett, Acting Assistant Secretary, Office of Fossil Energy, US Department of Energy

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Joe Lima, Director of Global Environmental Sustainability, Schlumberger

Amory Lovins, Co-founder & Chief Scientist, Rocky Mountain Institute

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Jan Mares, Senior Policy Advisor, Resources for the Future

Arshad Matin, President & CEO, Paradigm

Nancy Meyer, Director, Climate Strategy, IHS Markit

David Monsma, Executive Director, Energy and Environment Program, The Aspen Institute (*Moderator*)

Richard Newell, President & CEO, Resources for the Future

Bob Nussmeier, Vice President, Business Development, Kiewit Energy Group Inc.

Marvin Odum, Former President, Shell Oil Company (*Co-Chair*)

Heather Palmer, Partner, Bracewell, LLP

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Lucian Pugliaresi, President, Energy Policy Research Foundation, Inc.

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