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Energy Policy Challenges for a Secure North America

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Rapporteur's Summary

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The views expressed here are not the author's, rather the rapporteur's effort to reflect the discussion.

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The Aspen Institute's Congressional Program convened a conference in Vancouver, Canada from August 15-19, 2018, to consider the topic of Energy Policy Challenges for a Secure North America. Eighteen members of Congress engaged with sixteen American and Canadian scholars on a number of policy issues pertinent to U.S. energy needs. A former National Security Council official, a former Federal Energy Regulatory Commission Commissioner, and an executive from a major U.S. utility company also addressed participants.

The conference began with a discussion of the opportunities and threats for the U.S. in the age of energy abundance enabled by the shale revolution. As U.S. energy diplomacy adapts to this newfound energy abundance, the traditional objectives of maintaining the smooth functioning of the energy market, encouraging allies to diversify sources of energy and influencing policy change in other countries will be easier to realize. However, the U.S. must be careful to avoid weaponizing its energy resources to avoid being seen as an unreliable energy supplier and undermine these objectives. As the week progressed, members were able to discuss a broad variety of topics including energy technology, the role of research and development, the impacts of climate change, and the international framework for energy policy.

The Role of Technology and Consumer Choice in Energy Supply and Demand

In the first session, conferees discussed the role of U.S. investment in energy research, development, and demonstration (RD&D) and the role of public and private research in bringing energy technologies to market. Historically, the U.S. has been a leading innovator and investor when it came to energy technology, resulting in solar, nuclear, and wind technologies. Public-private partnerships have resulted in the development of disruptive technologies such as hydraulic fracturing and directional drilling, which together enabled the shale revolution. These technological innovations create major benefits for the nation including cost savings for consumers, jobs, and exports such as natural gas turbines. While these benefits are hard to monetize, it has been estimated that the $7 billion invested by the Department of Energy (DOE) in energy efficiency and fossil fuels between 1978 and 2000 resulted in over $30 billion in direct benefits to U.S. consumers and firms (even without including benefits such as public health).

However, China is emerging as a major challenger to the U.S. in energy technology innovation and production. Some attendees noted a troubling trend of Chinese companies buying out bankrupt U.S. energy companies, some of which received federal funding for technology development. This represents an inefficient loss of U.S. investment and innovation due to a lack of support for bringing technologies to market after the initial research and development (R&D). China now comprises 70% of the global renewable energy trade and sets clear and consistent goals that will result in the expansion of its energy sectors. Without further investment in renewable energy technology and consistent energy policy, the U.S. will continue to fall behind and miss the opportunity to create clean energy jobs.

An innovation system with a holistic approach is required to avoid these losses by promoting not only the development of new technology, but also the commercialization of technology. In the development of new technology, there are three phases: demonstration, early deployment, and full commercialization. While policies are in place to push the development of new technologies, analogous policies are not in place to pull the technology to market (or stimulate the commercial take up of these technologies).

To be successful, these policies must also be consistent. Under the current system, policies are fragmented across states. This policy uncertainty hurts jobs and labor because companies cannot count on the support of policy. To operate and invest effectively, businesses need predictability, durability, and simplicity of policy. The stop-and-start nature of R&D programs is debilitating to the private sector. Longer term and more sustained programs are needed to encourage efficient innovation and growth. In general, private sector R&D is declining in the energy sector, partly due to the need to provide returns on a quarterly basis. Research in the public sector is necessary to support projects that provide undervalued contributions to the public good or that otherwise do not produce returns in the near term, such as the high-risk/high-return projects funded under the Advanced Research Projects Agency for Energy (ARPA-E).

The U.S. needs to set clear goals and adopt a systemic approach to push and pull technology into fruition if it is to fully harness its well-trained workforce, world-class universities, and productive national laboratories and maintain its reputation as a leader of innovation. Conferees largely called for market-based policies to create financial incentives that would pull the new technologies into the commercial markets. These policies could be performance standards (such as clean energy standards pertaining to power generation, vehicle emissions, the built environment, and industry), a carbon tax, or cap and trade. In order to achieve these goals efficiently, scholars cautioned against picking winning technologies and advocated for technology neutral policies. Many also advocated for the removal of energy subsidies to level the playing field.

To achieve these goals, multiple conferees suggested that it is necessary to reframe the debate over energy policy. Innovative technology development that will benefit the public good and achieve environmental goals can be spurred by focusing on the development of a good economy and the creation of jobs in growth industries. Messages about energy-driven industrial policy may be more successful than those about energy policy. The debate surrounding the declining use of coal for energy production has highlighted the importance of communication and consultation of workers in this time of energy transition. While the advent of hydraulic fracturing and subsequent shale gas revolution are primarily responsible for the displacement of coal jobs, this displacement is frequently blamed on environmental regulations set by the Environmental Protection Agency (EPA). Labor needs to be involved in navigating these transitions to prevent the loss of jobs to American innovation and to promote the transition of workforces to provide craft labor required for new technologies (such as hydraulic fracturing). A shift in messaging would also aid in these efforts. For example, in western Pennsylvania, there are currently more jobs in the clean energy sector than in the coal sector, despite a long history of coal mining in the area. Similarly, enhanced messaging is needed to communicate counterinitiative ideas. For example, one expert posited that the only way to save coal is the creation of a carbon standard. If a certain percentage of fossil fuels is given a place in our future energy plans, companies will again have the certainty required to invest in coal in the long term.

The Future of the Auto Industry: Evolution or Revolution?

This session focused on major debates relevant to the auto industry: the electrification of vehicles, the implementation of enhanced vehicle emissions standards, and the need for R&D of cutting-edge technologies such as autonomous vehicles. Historically, the auto industry focused predominantly on the improvement of the conventional internal combustion engine, but the major improvements to be made in this technology are expected to be exhausted by 2025. As the auto industry, which employs hundreds of thousands of workers in the U.S., seeks to shift to cleaner and modernized fleets of vehicles, it faces challenges of bringing new technology to market and navigating changing U.S. policies.

The U.S. is currently the *de facto* standard setter for most of the world's motor vehicle emissions standards. Eighty-five percent of the worlds’ vehicles are sold in markets with standards. These standards start with aggressive technology-forcing regulations set in California, then flow to the rest of the U.S., Europe and the world. In the past, this resulted in the advent of the catalytic converter, which reduced smog.

However, with respect to fuel economy and climate change, the U.S. has lagged behind other countries such as China, which modified its fuel economy standard to include a sales mandate for new energy vehicles, and Europe, which proposed a 30% increase in stringency in carbon dioxide standards from 2021 to 2030. In 2012, the Obama-era EPA and Department of Transportation (DOT) took steps to address this by publishing regulations which would set greenhouse gas emissions (GHG) standards for passenger vehicles from 2017 to 2025 and fuel economy standards for passenger vehicles from 2017 to 2021. While the auto industry had sought to tweak the Obama-era proposal, thirteen automakers and the state of California signed statements supporting these standards after the EPA made a commitment to conduct a midterm evaluation of longer-term standards from 2022 to 2025. The payback period of the fuel standards for consumers was estimated to be three to five years.

The proposed rollback of fuel economy standards published on August 1, 2018 in the Safer, Affordable, Fuel-Efficient Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks (SAFE) would exacerbate the discrepancy between the U.S. standards and the leading global standards. Furthermore, the proposal has created regulatory uncertainty, which impedes efficient business operation. Several conferees suggested that the change of standards proposed in SAFE is highly disruptive to the auto industry. Previously, the auto industry wanted to change the Obama-era proposal by weakening the fuel economy standards by 20%, adding in a timeline with midterm evaluation, and adding in incentives, but SAFE overshot these demands by proposing an 80% reduction in the stringency of the standards. It was noted that the auto industry already invested to meet the fuel standards and a reversal represents a waste of that investment.

Similar to the conversations held in the previous section on energy technologies, the auto industry would prefer to see the implementation of a national program and be accountable for meeting one national standard. Currently, the Clean Air Act (CAA) gives California the right to make rules about tailpipe emissions. The SAFE proposal seeks to withdraw California's waiver under the CAA to set GHG emissions standards because those may be seen as *de facto* national fuel economy standards. According to one scholar, it is likely the GHG emission standards will not hold up in court. Currently, 35% of the U.S. vehicle market (twelve other U.S. states and the District of Columbia) follow California's standards. If California loses its ability to set independent emissions standards, this will also apply to the other states. Canada has also adopted GHG standards similar to those proposed by the Obama administration. In light of the SAFE proposal, Canada is expected to review and reconsider these standards, creating additional uncertainty for auto manufacturers.

According to one scholar, another central question in transportation policy is how quickly the transition from conventional vehicles to electric vehicles (EVs) can occur. Battery technology has greatly improved since the inception of electric vehicles and the costs are decreasing, which will enable this transition.

In order to promote the electrification of America's automobile fleet, both regulations and incentives are required. This conversion faces four major barriers including model availability, cost, convenience, and consumer awareness. Of the four, model availability is necessary to broaden the market and is directly impacted by emissions and zero emissions vehicle mandates, which drive EV investment. The SAFE proposal threatens the California zero emissions vehicle mandate and could thus delay EV conversion. One conferee noted that consumers may be reluctant to drive smaller vehicles like the currently available EVs and suggested that conversion would have to include larger vehicles such as pickup trucks. In the near term, the cost and performance of electric vehicles of this size would not be comparable to those powered by a combustion engine, but that this may be accomplished in 10-15 years. The necessity of pickup trucks is more pronounced in rural areas, where charging infrastructure would also present challenges. Until cost and performance parities and the infrastructure challenge could be addressed, plug-in hybrids may offer a solution for these types of vehicles.

Incentives can be used to address the other challenges to EV conversion. For example, convenience is often linked to availability of charging infrastructure, which is determined by the grid. Several companies are competing to build out charging infrastructure, but public support will be necessary in rural areas that would otherwise be underserved. Cost is also a determining factor in the success of EV sales. While some models such as the Tesla 3 can be as profitable for automakers as SUVs, most of the current EV sales are driven by consumer incentives such as federal subsidies. These incentives are necessary to lower the upfront EV costs while battery costs are still declining. However, one conferee posited that EVs do not sell at a premium, which stifles competition. Finally, education campaigns can be used to increase consumer awareness.

As with the previously discussed energy technology, research and innovation are still key in the transportation sector. The U.S. is behind with respect to storage capabilities and battery technology is currently led by South Korea, China, and Japan. Furthermore, the current technology relies on elements such as cobalt, 60% of which is extracted from the relatively volatile Democratic Republic of Congo. Currently, the U.S. and Europe are on par with Asia in EV production, but this could change in the future. China has a large market and a competitive advantage when it comes to reaching cost parity, because cost parity is achieved through increasing the volume of production. Finally, new technologies changing mobility such as autonomous vehicles and ride-hailing vehicles will change current transportation paradigms and play into the EV transition. Autonomous vehicles can offer a reduction in accidents and accidental deaths while ride-hailing vehicles could reduce the need for parking in cities. The U.S. is leading in both of these pioneering technologies. However, one scholar noted that current appropriations for R&D are not enough to generate large gains in innovation or for the U.S. to be competitive in some of these industries.

Multiple conferees pointed out that national laboratories are critical to research that industry will not fund, such as technology that is too far from commercialization. As an example, Argonne National Laboratory has been the source of multiple breakthroughs in battery technology. These labs need double or triple the current level of funding and changes need to be made to assist in translating their research to commercial markets.

National laboratories are most effective when working hand in hand with agencies creating regulations. In the previous administration, the DOE created Centers of Excellence that were spread across the country evenly and generated Quadrennial Energy Reviews that related policy to research. National labs performed the modeling and policy staff performed a review. These reviews are not currently active, but could be made into a required report, which would provide policy makers with valuable, research-based information. It is also critical for these organizations to accept risks and failures inherent in R&D. If failures are politicized, entities will begin to avoid taking the risks necessary to drive innovation.

Similarly, the culture at national laboratories varies based on the history of the lab. Labs that were founded to work on weapons are typically less open, but laboratories such as the National Renewable Energy Laboratory (NREL) in Golden, Colorado are more willing to collaborate openly with outside entities. Each year, NREL hosts a workshop for venture capitalists. Asking the directors of national laboratories how they contribute intellectual property and how the work performed there contributes to society and the economy can be used to promote cultural change at these institutions and to promote research that addresses the grand challenges faced by the nation.

Canada's Approach to Energy Challenges and Implications for the U.S.

Conferees discussed Canada's approach to addressing energy challenges including the implementation of carbon taxes, development of the oil sands, build out of pipeline infrastructure, and renewable incentives. The implications for the U.S. were addressed due to the nations' interdependence. As one scholar pointed out, the exchange of electricity often runs north and south across the border. For example, Ontario receives natural gas from Pennsylvania and the transmission lines used to convey power facilitate north-south exchange.

Canada is a relatively young country with vast amounts of land per capita and a government that is focused on social programs. Approaches to challenges are designed to prioritize the people of Canada. With that in mind, Canada has implemented the Pan-Canadian Framework on Clean Growth and Climate Change (PCF) and is working to meet their 2030 Paris Agreement commitments. To do this, the federal government is reliant on provincial governments. The PCF allowed provinces to come up with a framework for meeting government goals on carbon pricing to allow for regional variability. If the provinces did not come up with their own carbon pricing, a federal backstop would be applied. A lack of compliance would result in the withholding of funding while early adoption would earn provinces incentives.

Alberta serves as an interesting case study for climate change policy. With a population of four million people, Alberta holds the third largest proven oil reserves in the world and is the world's seventh largest oil producer, ninth largest gas producer, and the largest supplier of oil to the U.S. This province is traditionally very conservative yet recently elected a left of center party for the first time, with climate change as one of the five pillars touted by this party. By engaging representatives from industry, environmental organizations and indigenous communities, Alberta has focused around several common goals to create policies that mitigate risks and promote both a healthy economy and environment. In 2008, Alberta successfully instituted a carbon price of $10 per ton in the midst of the global recession (and well before the federal government). Today, the economy-wide price on GHG emissions is $30 per ton. The revenues generated by this price on carbon stay within Alberta to fund green infrastructure, technology, support coal communities, and to give the middle class refunds (based on tax returns, with 62 percent of the province's citizens receiving refunds from the carbon tax). Community by community consultations are being performed as communities shutter some coal plants and transition others to natural gas. In addition, industry performance standards have been implemented and companies are required to pay less if standards are met or exceeded. These financial incentives spur additional innovations for carbon reduction.

The early adoption of a carbon price and strong environmental regulations was a strategic move that allowed Alberta to get ahead of possible federal regulations, force economic diversification, and address concerns about the climate impacts of its fossil fuels as it sought to promote the build out of pipeline infrastructure. Energy is a global commodity and Canadian companies realize that they are competing on a global stage. Even with the U.S. pulling out of the Paris Agreement on climate change, the rest of the world is still set on the clean energy trajectory. Large extraction companies advocate for carbon pricing and climate change actions because they believe that these measures de-risk future investment. Divestment movements typically target coal and oil sands extraction due to public perceptions, but it was argued that the heavy oil from Canada is not as energy intensive as people commonly believe. Canada has rigorous environmental standards and engages indigenous communities, making it a preferable source for oil in some respects when the alternative is to import oil from countries such as Venezuela or Nigeria with worse environmental and human rights records.

In other provinces such as Ontario and Quebec, cap and trade systems were adopted to cap emissions below the anticipated growth and focus on driving down emissions. This system was used to modernize large oil refineries that were aging. By focusing on decarbonizing as both fuel and material switching and by modernizing aging industrial infrastructure, this transition can address the issues of the Rust Belt and promote economic development. As an example, the salvaging of aluminum can help to re-localize economies and reduce the need to mine bauxite in Jamaica.

Conferees from both Canada and the U.S. voiced concerns about the challenges facing the development of pipeline infrastructure, which is critical for the distribution of oil and gas resources. Market analyses have shown that the development of pipelines does not encourage fossil fuel development as claimed in the public sphere. Without pipeline infrastructure, the development will continue due to market forces, but transport mechanisms that are less favorable to public and environmental safety such as trains may be employed. In both countries, state or provincial governments have hindered pipeline development through the permitting process. One scholar noted that a permit for the Keystone XL pipeline was denied under the Obama

Administration due to symbolic reasons. In the future, cooperation between the countries to develop best practices for permitting could ease these issues.

The issue of rhetoric was raised as an obstacle that prevents productive conversations that move the country toward solutions. One conferee urged political leaders to take on the heavy lifting and to listen to each other and, more importantly, reconcile with each other. The debate surrounding coal was raised as an example of a situation where rhetoric impeded solutions. While the issue of coal is relatively minor, it is viewed as an issue where one side wins and the other loses. The U.S. labor force consists of 160 million people, 80,000 of which are coal miners. However, it should be noted that these miners are often located in isolated communities with few other options for employment. In order to reframe this debate and provide a just transition for these communities, solutions need to be found for the employment of these workers. A Civilian Conservation Corps model (adapted for today) was proposed as a means of retraining this workforce, providing jobs, and implementing the projects needed to address climate change.

In both the U.S. and Canada, the hope is to build a long-term political consensus to address climate change and provide certainty for the private sector. In order to promote the Pan Canada Framework successfully, discussions focused on critical infrastructure resilience and tangible effects of climate change such as wildfires and floods to communicate both the urgency and the importance of these issues. Scholars suggested that a renewed focus on the record fires causing smoke in the west, record rainfall causing severe damage from flooding, and record heat waves causing loss of life would bring a similar urgency to this issue in the U.S. Issues relevant to critical infrastructure and national security such as the need to rebuild flooded military bases and threats to food and water security also merit more attention.

One scholar noted that much of the discussion has focused on emissions reduction and mitigation of climate change, but that a larger conversation about adaptation and resilience is necessary. One necessary adaptation is increased funding for sustainable forest management, which can have an economic benefit and mitigate the risk of wildfires. Currently, the U.S. Forest Service budget for managing forests is consumed by fighting the increasingly prevalent forest fires. Additionally, when communities or regions experience damage, it provides an opportunity for rebuilding in a manner that strengthens that area and makes it more resilient to hazards. These opportunities are not being exploited due to limitations imposed on the Federal Emergency Management Agency by the Stafford Act. This act currently only allows restoration of infrastructure to the state that it was in prior to the natural disaster. This was recently exempted for Puerto Rico due to the inadequate state of the infrastructure prior to Hurricane Maria. If this limitation was changed on a broader scale, disaster response could be used to promote better building codes in vulnerable areas or to improve energy efficiency in areas that are rebuilt. Another limitation of the Stafford Act is it that it is not triggered by slow-moving disasters such as rising sea levels, leaving some communities without federal support for rebuilding in the wake of destruction caused by climate change.

The Northern Belt & the Arctic and Climate Change: Impacts and Their Relevance for the U.S.

Next, conferees discussed the impacts of climate change in the Arctic, the larger United States, and around the world as well as policies that could be used to adapt to and mitigate these impacts. The conversation opened with a discussion of the principal effects of fast warming in the north. Alaska is warming at two times the rate of the U.S. mainland. Irrespective of geographic location, scientists are predicting changes in climate around the globe that will result in widespread and varied impacts.

Scientific consensus has been reached on the matter of climate change and the contribution of anthropogenic GHG emissions to climate change. The Intergovernmental Panel on Climate Change (IPCC) conducts a thorough review of all literature and synthesizes a report, which is subject to both scientific peer review and public review. Any contradicting evidence is included and discussed and uncertain topics are not presented as consensus. While it is true that the climate system has experienced natural perturbations in the past due to variation in earth's orbit, volcanic eruptions, or other factors, the change of climate currently experienced on earth is five times that of previous natural cycling and greater change is projected. At this point, the consensus is that the earth is committed to hundreds of years of a warmer climate. It is not a question of the science, but a matter of using the science to inform action.

With changes in the climate, Alaska will experience a warmer climate, which will enable a longer growing season and a reduction in the amount of fuel needed to heat buildings in the winter. However, it will also result in a longer fire season. This warmth will reduce the amount of sea ice, which will have many indirect impacts. This would both speed warming and increase coastal erosion in areas previously protected during storms by the ice. As noted previously, communities dealing with gradual disasters such as the erosion of their coast are not eligible for federal assistance through the Stafford Act and may not have the finances to move.

The loss of sea ice could create greater economic opportunities with respect to shipping, but this also poses new security concerns. The U.S. never signed the Law of the Sea treaty, so it cannot effectively negotiate with respect to the development of the Arctic Circle. Thin ice on both the sea and rivers will increase the risks of travel in coastal communities and will affect those who rely on the ice to meet their subsistence food needs. This is part of a larger cultural concern because it will impact indigenous cultures who have been able to predict weather in the past, but may misread cues in the changed climate.

The thawing of permafrost will also have huge impacts on Alaskan infrastructure and broad environmental impacts. As the permafrost thaws, the soil will become unstable and damage existing infrastructure. This thawing will also allow water to percolate farther into the ground, resulting in drier fuels and more fires. This will, in turn, contribute to the levels of carbon dioxide in the atmosphere and exacerbate the climate change already occurring.

Both in the Arctic and beyond, increasing carbon dioxide levels in the atmosphere are expected to result in increasing levels of carbonic acid in marine ecosystems. This ocean acidification creates problems for crustaceans and small plankton that serve as the base of the food chain for many marine ecosystems. This could lead to the collapse of these food chains, negatively affecting fisheries. Salmon populations are currently declining throughout Alaska but the causes are unknown—this could be due to the change in river temperatures or food chain impacts.

The North Pacific fishing fleet is experiencing the impacts of a changing climate. As cold water fish move farther north, this strains the fleet and may pose a problem for U.S. exports. With the loss of sea ice, fishing could possibly begin in the Arctic Ocean, but there is currently a moratorium until the full impacts of fishing in this area are understood.

Other effects of climate change will be widespread and are expected to include heat waves, increased frequency of intense storms and hurricanes, droughts, and floods. All of these are expected to drive areas facing challenges to extremes. The melting of the polar ice caps and glaciers can result in sea level rise. In recent years, evidence has emerged suggesting that cold water sourced from the melting of sea ice in Greenland may interrupt the thermohaline ocean current running from the Caribbean to Europe. If this were to be interrupted, it could result in significant cooling of Europe, but the science on this phenomenon is more preliminary.

The effects detailed in these conversations provide compelling reasons to act on the issue of climate change. The policies, which can most effectively reduce carbon dioxide levels in the atmosphere and mitigate warming, focus on reducing carbon emissions or on enhancing carbon dioxide removal by natural carbon sinks. Geoengineering in the form of carbon capture and sequestration could be used to capture carbon dioxide—which would address the root cause of the problem. Other geoengineering approaches such as solar dimming (with sulfur dioxide in the atmosphere) are more likely to have secondary, unanticipated impacts and may not be worth the risk.

One scholar noted that the science is clear: any steps that are delayed in dealing with carbon dioxide in the atmosphere will be less effective in reducing the future impacts of climate change when compared to sooner actions. In order to hasten action, they urged policymakers to focus on tangible impacts such as changes in weather, increasing jobs in renewable energy, or other topics that will achieve the same solutions without becoming entrenched in battles that have blocked prior efforts.

When it comes to mitigating carbon emissions, Alaska has included targets for energy efficiency and 50% renewables by 2050 even in former Governor Sarah Palin’s energy strategy. The energy market in Alaska is fairly unique. There is no continuous electric grid. While there are some regional grids, most energy distribution is handled through microgrids. There are 100 utilities with an average of 2,500 customers each within this completely open market, with no regulation except on the largest ones. Most power generation relies on the import of diesel fuel, so many are seeking to find more local solutions for energy production. This environment, coupled with the high cost of fuel, creates an interesting living laboratory that can be used to hone technology that is less cost competitive elsewhere. There are minimal subsidies in this market, so it is not distorted. In these microgrids, resiliency is particularly critical. For both this context and larger grids, appropriate metrics need to be determined for valuing resiliency to enable appropriate incentives at the policy level.

On a national level, any policy aimed at reducing the cost and speeding the development of carbon neutral technology would be useful. Once cost competitive, the market will promote the implementation of cleaner energy technologies. Several scholars voiced concerns that the U.S. was not investing enough in R&D to maintain its technological leadership and that, by pulling out of the Paris Agreement, the U.S. had removed itself from international discussions on climate change mitigation and would fall farther behind its peers.

With respect to the removal of carbon dioxide using natural systems, this can be achieved using reforestation, wetland restoration, efforts to plant trees in cities and similar initiatives. Some cities are using tree planting programs to help reduce impacts of heat waves. In order to avoid the carbon emissions of increased forest fires, sustainable management of forests is necessary to reduce the risk of fire. A bipartisan initiative to incentivize private landowners to manage small plots responsibly or to assist municipalities in tree planting may be warranted. However, additional funding to the U.S. Forest Service would be necessary because, as mentioned before, the forest management budget is entirely consumed by fire suppression.

NAFTA's Impact on Energy Use in the Americas

In this session, conferees discussed the implication of the North American Free Trade Agreement (NAFTA) on energy use in the Americas. When considering the region, three factors have changed the energy landscape, making North America an "energy powerhouse." First, the unconventional revolution has boosted U.S. oil production from 6.8 million b/d in 2008 to 13.8 million b/d in 2018, which reduced the regions import dependence from 45% to less than 15%. This has also enabled the export of liquified natural gas (LNG), making the U.S. one of three large LNG exporters worldwide. Meanwhile, the exploitation of oil sands in Canada created the third largest oil reserves in the world. Finally, the comprehensive energy reform has sparked a complete revolution in the way energy functions in Mexico, resulting in 107 signed contracts to 79 companies to liberalize energy. NAFTA, one scholar asserted, can help all three of these changes continue over time.

Free trade of energy due to NAFTA has benefited all three countries. In the U.S., this trade has assisted in the pursuit of national security goals. For example, Canada and Mexico have supplied oil to U.S. refineries previously reliant on Venezuela. This is critical because it allows these refineries to avoid funding Venezuela's authoritarian regime and to mitigate risk associated with the possible collapse of Venezuelan exports. The U.S. and Mexico are also interdependent with respect to natural gas, with the U.S. exporting more natural gas to Mexico than the rest of the world combined (60%). Without Mexico buying this natural gas, the gas price would collapse and cut short the benefits of U.S. natural gas production.

Several political factors could affect cross-border energy commerce. The first is the challenges in permitting of pipelines that all three countries have faced. These hinder both imports and exports of resources, but development of best practices could work to address these constraints. Additionally, in the wake of the July 1, 2018 Mexican election, questions have been raised about the continued reform path of energy policy in Mexico. The election represented a large consolidation of power with 65% of the lower house, 60% of the upper house, and 19 states controlled by the coalition supporting the newly elected Mexican president, Andrés Manuel López Obrador. The contracts awarded as a result of the energy reforms are currently under review by the current administration. The administration also may be considering freezing gas and electric prices, which would threaten private investments in both industries. This would not affect NAFTA in its current state because Mexico was not able to initially sign onto Chapter 6 (the energy section of the NAFTA accords) because it relied on a state-owned oil company at the time.

In the face of renewed NAFTA negotiations, multiple conferees called for successful NAFTA re-negotiations that would maintain free cross-border energy trade and that would add Mexico as a signatory to Chapter 6. At a minimum, the hope was that the mutually beneficial energy relationships established would not be harmed by these re-negotiations. Aside from the previously discussed exchange of oil and gas, electricity lines have run between Canada and the U.S. for nearly 100 years, with over 30 U.S. states trading in electricity with Canada. Ideally, one scholar suggested, a North American energy strategy would be developed with the objective of transforming North America into the world's leading energy region.

Additional cooperation between the U.S., Mexico and Canada could deepen benefits for all countries. This could result in the development of best practices in infrastructure (pipeline) permitting and finance and hydraulic fracturing to allow these developments to progress in an acceptable manner and to prevent local concerns from trumping national priorities. Cross border cooperation is also needed for the exchange of wind energy from the U.S. and hydropower from Canada. The integration of the Canadian hydropower can provide baseload supply to areas with wind resources in the U.S. Similarly, cooperation is needed to protect the grid against cyber and physical attacks. This is a national security issue for all three countries and, with trade amongst the nations, there should be no weak links in the supply chain.

While one conferee pointed out the need for key political leaders to give a voice to the importance of NAFTA, others pointed out the political capital necessary to support trade agreements, which are not popular among constituents. While the trade system has allowed the world economy to grow, income gaps persist in the U.S. and the perception among citizens is that imports are bad for American workers. In particular, constituents believe that NAFTA is responsible for the decline of U.S. manufacturing and loss of American jobs. However, trade is only a small piece of the picture. Studies suggest that much of the job loss attributed to trade (87%) is not due to trade but, instead, automation. This trend will only continue in the future, but humans will continue to attribute the loss to trade, which is a more tangible cause. Transitioning the workforce so that those losing jobs can take advantage of the new jobs created by trade is key to addressing this perception.

NAFTA and the North American market it facilitates aid in the stability of three countries. It also enhances energy security. However, negotiations continue between the U.S. and Canada without resolution due to differences on five sticking points: the U.S. desire for a sunset clause after five years, supply management, dispute resolution mechanism, the rules of origin on autos, and government procurement.

Changing Contexts for Energy and Implications for U.S. Policy

In the final session, conferees discussed trends in energy technologies, the effects on existing markets, and the policies that would be needed to ensure the U.S. is a leader in energy that is affordable, reliable, clean, and safe. When examining the energy transitions taking place today, it is important to note that energy use is stagnant in the U.S., making shifts in electricity generation a zero sum game. This means that transitions to new energy technologies will replace older technologies.

For example, half of the coal plants in the U.S. are projected to shut down in the next twelve years because they are being outcompeted by natural gas. Many of these plants are old and the maintenance costs required to keep the plants in operation can be enough to prompt shut downs or transitions to natural gas. While environmental regulations (such as the new regulations on mercury that were instituted in 2015) are often cited as the reason for the decline of coal energy production, the shut down and conversion of coal plants is largely driven by market forces. At this time, there is twice the capacity for generation than is needed, so the market price is decreasing because of oversupply. Gas plants can more efficiently produce the same amount of electricity as coal, and the coal price would need to be lower than the gas price to be cost competitive. In the absence of a clear regulatory signal of what the carbon price will be in the next 30 years, new coal plants will not be built because financial feasibility cannot be determined.

Meanwhile, the rapid transition to wind and solar will likely require new strategies and technologies to maintain continuous balance between energy supply and demand. This balance can be managed using storage technology, the concept of which is not new. Pumped hydropower has been used for energy storage historically and is still the dominant source of storage today. However, it is inherently a large-scale technology limited to places with geologic and hydrologic favorability that are tied to a large grid. Batteries and other storage technologies can range in scale and can be sited not just on bulk systems, but also on personal property. This siting flexibility allows storage to provide new services, avoiding the need to upgrade the distribution system. Instead, storage can be stacked with assets on the distribution system, which can be used to increase the flexibility of the load and shift the paradigm to shape and adjust the peak load. Another solution could entail extending the grid to average out regional variation in generation, but difficulties exist in siting electronic transmission lines. This solution would be significantly impacted by both cost and policy considerations.

The next generation of storage is largely focused on lithium ion batteries, which have high energy density, high responsiveness, and medium duration. There is a huge push with respect to the private sector investment in this aspect of battery research because there is a big market in EVs and consumer electronics. However, the push for grid storage research is relatively small at this point. Longer duration-flow batteries (reactors where electricity is generated and stored in tanks of retroactive liquid) also are relevant in the long term, but this research is not being pushed in the private sector because it is too far from profitability.

When it comes to energy policy, the goals should be to make energy affordable, reliable, clean and safe. Regulations should be structured around these goals instead of capital expenditure to shift the discussion from a commodity issue to technology issue. Based on the prospects of creating new jobs, creating cheaper sources of energy, and lessening U.S. reliance on foreign resources, this issue can and should be a bipartisan issue. The cost of renewable energy technologies has decreased dramatically with solar and onshore wind down about 80% in price and offshore wind down 50% in price. This has allowed for broader deployment. It was noted that 2/3 of the installed wind and solar technology in the U.S. is located in traditionally "red" states.

To promote an energy transition that meets these goals, energy policy should not favor specific technologies but instead focus on attributes of the technologies themselves. One technology should not be championed over the others, and pressure should be kept on all technologies to continuously improve.

Policies utilizing performance standards, economic signals, and support for R&D all have their benefits and disadvantages. Performance standards can be used successfully (such as in food and building safety), but they can also send the opposite signal than what was intended. For example, fuel efficiency standards initially meant to decrease oil consumption and break Organization of the Petroleum Exporting Countries (OPEC) eventually backfired because gasoline became cheaper and consumers chose to drive more. Instead, policies should be technology and price finding. When performance standards are used, it is important that they create long-term regulatory certainty in order to improve R&D and reduce costs. With this in mind, one scholar noted, the current fuel efficiency standard should not be rolled back as proposed in SAFE because the auto industry has already invested in preparing for this standard. Performance standards should also focus on continuous improvement to avoid creating ceilings and plateaus in innovation by setting one number. The building code in California, which features continuous improvement based on cost, is an example of such a standard, which only had to be passed once in the 1970s and still spurs innovation today.

When using economic signals, if a price is fixed, it will usually be wrong. If a technology requires a subsidy, reverse auctioning can be used to make technologies that are on the horizon of being cost competitive reach the finish line. For example, if a utility seeks to give a subsidy for 1000 kilowatts of wind, companies would bid for the subsidy and the proposal with the lowest subsidy would secure the contract. This auctioning would be repeated for additional projects. When the subsidy is close to zero, it signals that the technology has become cost-competitive and the program can be discontinued. This avoids over or under-rewarding companies.

Policy is needed to address permitting concerns in the U.S. It costs twice as much to put solar panels on a roof in the U.S. than it does in Germany, largely due to differences in the permitting system. In Germany, the permitting process has been streamlined for renewable energy development, but it is still largely decentralized in the U.S. One way to overcome this would be to pre-zone renewable energy development. Some areas could be designated as red (not suitable for development), others as green (suitable for development and guaranteed 90 day approval if all standards are met, and everything else as yellow (a middle ground between the two). As permitting currently stands, the permitting process is lengthy and uncertain for these projects and can delay projects and drive up costs.

A wide swath of issues that need to be addressed with policy were revisited: increasing R&D funding to support the development of battery storage and other critical technologies, providing more consistent R&D support to create certainty for long term research projects, updating the grid to protect it from cyber and physical attacks, and setting a cap or standard on GHG emissions with flexibility states to implement systems that work best for their region. Additionally, a call was made to pass an energy plan and to require the DOE to produce the Quadrennial Energy Review.

As with other sessions, multiple conferees raised concerns about an issue that transcends energy: how to improve the adaptability and resiliency of our population. Specifically, the need for the U.S. to prepare workers for the changing nature of jobs in a world of increased automation and advanced technologies. This current system is incomplete, insufficient and needs to be revamped at the national level. With respect to changing energy technologies, it was deemed essential to have a plan to take care of American citizens and stimulate job growth. This could be funded through revenues obtained through carbon pricing.

U.S. Energy Diplomacy in an Age of Energy Abundance[1]

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For decades, fears of energy scarcity drove American energy diplomacy. The dependence of the global economy on oil, and America's need to secure ever-growing quantities of this commodity, underpinned complex networks of alliances and intensive diplomatic endeavours. An atmosphere of ever-increasing global competition for resources made these labours all the more urgent and high-stakes. Today, in an age of energy abundance, many anticipate that the new U.S. energy prowess will render such efforts obsolete and pave the way for American disengagement in the world. Yet a sober look at reality suggests that this should be far from the case. Although the U.S. no longer needs to import foreign energy at a huge scale, it continues to have many of the same energy diplomacy priorities that it has had in the past. What *is* different is that in a new environment of plentiful energy, the U.S. will have an easier time reaching these objectives. Nevertheless, the U.S. is not necessarily moving into a period of easy energy diplomacy. It might squander this advantageous moment by politicizing its own energy prowess instead of taking comfort in the fact that transformed energy markets are themselves delivering great benefits to America and her allies.

Objectives are constant, and easier to realize

A look at three objectives the U.S. has traditionally pursued through its energy diplomacy reveals how the new energy abundance does not annul their relevance, but simply enhances U.S. efforts to realize them.

1. **Ensuring that global energy markets—the global oil market in particular—are well supplied.** The pursuit of this objective has shaped complex relationships between the U.S. and many countries, with Saudi Arabia being the most prominent example. While the relationship between Washington and Riyadh has had many dimensions, America has often looked to the kingdom to take action to stabilize global energy markets. Whether this involved increasing Saudi production in advance of military action in Iraq or Libya, or continuing to invest in productive capacity in the face of burgeoning demand from emerging economies in the 2000s, Washington often sought Riyadh's help in calming global oil markets and minimizing the impact of increased energy competition on the global economy. Oil, for better or worse, was always a topic of earnest exchange between senior policymakers from both countries.

[1] This article first appeared as Sullivan, M. (2018) 'U.S. energy diplomacy in an age of energy abundance' in *Oxford Energy Forum 112: What's next for U.S. energy policy?, Oxford Institute for Energy Studies.*

Today, the U.S. remains connected to global markets, even as it has reached the status of the world's largest producer of oil and gas combined. It continues to have a keen interest in seeing that global energy markets are well supplied and that disruptions to the markets are minimized. Yet, while the objective remains the same, America has other avenues to advance this goal, including ensuring continued production of its own resources. Although the Saudis and other traditional producers remain important players in the global oil market, their spare capacity is less critical in managing global oil markets than it was in the past. While not nearly a perfect substitute, the productive capacity of America's own tight oil can help meet new demands for oil. In addition, given the widespread availability of unconventional resources worldwide, the U.S. has the option—which it has not yet fully taken advantage of—of working with other countries to bring such resources on line in the future. The U.S. will remain interested and invested in Saudi stability, as nothing could send a shock wave through the global oil market more than a collapse of the regime or the outbreak of violence in the kingdom. But America will have less of a need to engage the Saudis directly to urge them to increase (or in rare instances to decrease) their production levels; oil will no longer dominate the bilateral agenda between Washington and Riyadh.

2. **Encouraging allies to diversify their own sources of energy**. Nowhere have U.S. diplomats invested more energy to this end than in Europe. Only months after President Ronald Reagan moved into the Oval Office, he openly opposed Europe's plans to build extensive pipelines connecting the Soviet Union with Europe, fearing that such links would give the Soviets undue political influence. In the decades that followed, following the break-up of the Soviet Union, American officials sought to convince their European counterparts that the reliance of the continent on energy imports from Russia created dangerous political and security vulnerabilities. Such efforts went beyond diplomatic entreaties and included great exertions to midwife new pipelines to bring natural gas supplies from the Caspian region to Europe. Some—such as the ill-fated Nabucco pipeline—failed, while others—such as the more modest TANAP and TAP pipelines—successfully provided Europe with some element of diversification of supplies.

   Today, the U.S. still has keen interests in seeing that the energy supplies of its allies in Europe and elsewhere are diversified. Yet, it (and the allies in question) now have many more options for achieving that diversification. One of these options is the purchase of liquefied natural gas (LNG) directly from the U.S. But it is not simply the advent of America as an exporter of LNG that has transformed prospects for many U.S. allies. Even more consequential have been changes in natural gas markets which are beneficial to consumers more generally. Thanks to increases in production of unconventional gas, and reduced costs associated with the liquefaction and transport of natural gas, global markets are more flush with gas than they were five years ago and more integrated with one another. The number of countries exporting LNG more than doubled between 2000 and 2016, while the number importing LNG tripled. The dominance of oil-indexed pricing has begun to give way to gas-on-gas pricing in many parts of the world, also increasing efficiency. The net effect is that leverage has shifted from the producer to the consumer, changing the balance of power in key relationships. In the case of Europe, the energy security of the continent is much improved, not primarily because of new mega-pipelines or even the chance of importing American LNG, but because of changes in the structure of natural gas markets.

3. **Using its power as the largest global consumer of oil to penalize countries, or to compel them to change policies**. Generally, this somewhat different objective of U.S. energy diplomacy has involved the use of sanctions, often on oil and gas producing nations. Over the past decades, oil producers have been disproportionately represented on the list of countries sanctioned by the U.S. The desire and the need to use sanctions to advance foreign policy objectives has not diminished. If anything, in a world where military force is difficult to deploy and where America's ability to secure outcomes through persuasion alone is increasingly questioned, sanctions continue to play a critical role in the tool kit of U.S. foreign policy.

   Yet, while the desire to use sanctions remains, some might surmise that because the U.S. imports less oil and virtually no natural gas today, its ability to wield influence through sanctions is diminished in the new world of energy abundance. It is true that America's increased self-sufficiency means that its power to influence outcomes through unilateral sanctions alone is more limited to exceptional instances and sanctions that go beyond the export and import of oil and gas. However, in a globalized world where most countries have complex linkages to the world economy, unilateral sanctions are of limited value in any case. What matters much more to the U.S. ability to affect particular foreign policy outcomes is the country's capacity to secure the cooperation of other nations to impose *multilateral* sanctions; such sanctions have much better track records of delivering their desired results. Here the new energy abundance actually provides the U.S. with a distinctive advantage, at least when it comes to imposing sanctions on oil producing countries.

   As demonstrated by the recent case of sanctions against Iran, securing the support of other countries for sanctions against one of the world's largest oil producers is easier in a climate of well-supplied energy markets. Like the Bush Administration before it, the Obama Administration initially found both domestic and international resistance to ramping up sanctions intended to constrain Iranian exports of oil at a time when oil prices were consistently over $100 a barrel. Many actors feared such sanctions would spur oil prices to new levels, jeopardizing already-fragile economic growth. It was only through intensive diplomatic efforts that the U.S. was able to convince countries from India to China and beyond to curb their purchase of Iranian oil. In making the case to foreign counterparts, U.S. officials were able to point to burgeoning U.S. oil production; annual increases of more than one million barrels of oil each year helped persuade initially skeptical officials that greater pressure on Iran need not be synonymous with escalating oil prices and increased strain on the global economy.

Dangers of overreach

For decades, U.S. policymakers considered America's energy predicament a major strategic vulnerability. Now, they are beginning to appreciate that the improved energy environment brings new opportunities and strengths to the U.S.—among them, a greater ability to deliver age-old energy diplomacy objectives. Yet dangers exist as perceptions and actions related to American energy prowess come into line.

Policymakers may feel that such a dramatic change in energy fortunes should bring with it new, blunt tools better suited to directly shape foreign policy and national security outcomes. For example, senior members of the Trump Administration have reportedly urged European and Asian countries to buy U.S. oil and natural gas as a way to rebalance the trade deficit—or be prepared to face penalties. President Trump himself publicly said that U.S. exports of LNG would push Russian exports out of Europe and make that continent less vulnerable to political blackmail.

In reality, such exhortations will not help the U.S. meet its enduring energy diplomacy objectives, but will likely hamper its ability to do so. Many of the political benefits being enjoyed by the U.S. as a result of the new energy abundance are *not* because the new environment has presented new instruments of power, but because markets have changed in ways that alleviate past concerns or are more conducive to U.S. and allied interests.

As a result, rather than looking for ways in which they can use American energy prowess as a cudgel to address a particular problem, policymakers should prioritize the smooth functioning of global energy markets. Any effort, or even intimation, that America energy exports will be used for political purposes will ultimately work against U.S. interests— and the country's ability to achieve its traditional energy diplomacy objectives. Now that the U.S. is an exporter of oil and natural gas—and poised to be a major global player in the latter at least—it must be seen as a reliable supplier if it wants global markets to continue to evolve in ways which—as described above—are generally conducive to American interests.

The other danger present in today's American energy diplomacy is that the current administration perceives its energy interests too narrowly and fails to appreciate how its actions and rhetoric in other domains have major bearings on its ability to achieve energy diplomacy goals. The clearest example of this risk is the current question mark around America's willingness to maintain its historical role in ensuring freedom of navigation and safe passage of the seas. President Trump has publicly questioned whether the provision of such public goods is too costly for the U.S. to sustain; these musings alone could be damaging to the smooth functioning of energy markets.

Conclusion

Fears that America's new energy prowess will contribute to the retrenchment of the U.S. from abroad are overblown. Although the global energy environment has changed significantly in a few short years, these changes do not suggest that fundamental U.S. energy diplomacy priorities have undergone a similar revolution. If anything, the new energy abundance has simply made these priorities easier for the U.S. to attain. Nevertheless, the road ahead for American energy diplomacy is not necessarily a seamless one. Policymakers must resist the understandable impulse to wield energy as a weapon (as many other countries have done) and instead maintain America's traditional focus on the smooth functioning of global energy markets, which will require a better integration of energy policy with many other elements of national security and foreign policymaking than ever before.

The Importance of American Energy Innovation

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The United States led the world in public investments in energy research, development, and demonstration (RD&D) from the end of World War II to the turn of the century. Although we have little data on global private sector investments, it is likely that American firms also led the world in their investments during that period. Around the turn of the century, China began to challenge U.S. leadership in these investments, and it is estimated that Chinese public investments have now surged to be approximately twice as large as U.S. government investments.

Even in the heyday of the post-WWII period, the United States always struggled to take a systemic approach to energy innovation, where industries were supported through market creation and export assistance, because the innovation "push" was disconnected from innovation "pull" (push policies are those that spur the development of new technologies available to the marketplace and pull policies are those that stimulate the commercial take up of those technologies). Appropriations for RD&D budgets were not coordinated well with broad-based energy policies. As a result, U.S. industrial and manufacturing strength waned, and the United States lost its leadership position in a number of key energy technologies including nuclear, advanced coal, solar, and wind to France, Japan, Germany, Denmark, and China. Manufacturing in these technologies largely shifted to these countries. Nonetheless, tremendous opportunity exists to reinvigorate energy-technology innovation in the United States. If a strategy can be devised and implemented, manufacturing jobs and economic growth could be bolstered in this sector, and the United States would be well positioned to profit from the global shift to a low-carbon economy during this century.

Since taking office, the Trump Administration has consistently proposed a drastic 50-60% reduction in U.S. government investments in energy research, development, and demonstration at the Department of Energy. Such reductions, if enacted by Congress, would reduce the pace of U.S. energy-technology innovation, ultimately harming the U.S. economy, energy security, environmental quality, and the capacity of the world's second largest emitter of greenhouse gases (GHGs) to do its share in reducing the emissions driving global climate change. This abdication of leadership would adversely impact not just U.S. interests but global interests as well. So far, Congress has rejected the Trump Administration's requested budget cuts for energy innovation and largely maintained U.S. investments at constant levels.

Historical Perspective

Figure 1 depicts the Trump administration's proposed FY2019 budgets for fossil fuel, fission, fusion, renewables, and energy efficiency RD&D. Amid other striking proposed reductions, the

Advanced Research Projects Agency for Energy (ARPA-E), which supports high-risk/high-return research on particularly innovative energy-technology improvements,[1] is singled out for complete elimination. Moreover, the Trump budget would also eliminate DOE's loan guarantee program for early commercial use of advanced technologies, the advanced-technology vehicle-manufacturing program, the program for weatherization of low-income housing, and state energy grants.

Having tracked DOE RD&D investments at the program level since 1978[2], it is clear in that historical context that President Trump's proposed cuts to U.S. government energy RD&D would be unprecedented in many respects. President Trump's proposed cuts in aggregate are greater than the Reagan era cuts of 1982, which were the most drastic single-year cuts to U.S. energy RD&D budgets since 1978.

Rationales for Government Investment in Energy Innovation

The Reagan cuts were motivated by a combination of plummeting oil prices in the early 1980s, indications that the costs of synfuels technologies were larger than originally predicted, and the belief that the private sector would do most of the energy RD&D that was warranted. These motivations do not make sense today. Not only are oil prices now rising again, but the complementary roles of government and private-sector funding in energy-technology innovation are better understood now, and, perhaps most importantly, there is now an immensely powerful "public goods" argument for government investments to accelerate low-carbon innovation to address the challenge of climate change.

Consider the government-academia-industry symbiosis that is now understood to drive energy-technology innovation.[3] Industry funds about 70 percent of all R&D in the United States, and the Federal government funds less than 30 percent.[4] A similar split prevails in energy RD&D, although exact figures are elusive because of definitional and reporting issues. In terms of the research stage, government funds the lion's share of basic research and early-stage applied research, while industry funds most late-stage applied research and an even larger share of development and demonstration. Most of the government-funded research is performed in universities, where a huge side benefit is the role of that research in teaching and training the students and post-graduate researchers who will populate the next generation of scientists, inventors, entrepreneurs, and professors, in a virtuous cycle.

Public-private cooperation on energy innovation has been particularly effective in the United States.[5] Perhaps the most striking example is the shale gas revolution, which came about as the

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[1] NAS. An Assessment of ARPA-E. National Academies of Sciences. 2017 Report. The National Academies Press. Washington D.C.

[2] Gallagher, K.S. and Anadon, L.D. DOE Budget Authority for Energy Research, Development, and Demonstration Database. The Fletcher School, Tufts University; and Department of Politics and International Studies, University of Cambridge, Harvard Kennedy School. https://figshare.com/articles/DOE_Budget_Authority_for_Energy_Research_Development_and_Demonstration_Database_2017/5339497, DOI: 10.6084/m9.figshare.5339497.

[3] Gallagher, K.S, Grubler, A., Kuhl, L., Nemet, G. and C. Wilson 2012, *Annual Review of Environment and Resources*, 37:6.1-6.26, doi:10.1146/annurev-environ-060311-133915.

[4] National Science Board 2016, *Science and Engineering Indicators.* https://www.nsf.gov/statistics/2016/nsb20161/#/downloads/report

[5] Narayanamurti, V, Odumosu, T. 2016. 'Cycles of Invention and Discovery: Rethinking the Endless Frontier.' *Harvard University Press*, Cambridge MA, United States.)

result of early shale fracturing and directional drilling technologies developed by the Energy Research & Development Administration (later the DOE), the Bureau of Mines, and the Morgantown Energy Research Center, the Eastern Gas Shales Project (a public-private shale drilling demonstration program in the 1970s), public subsidization of demonstration projects including the first successful multifracture horizontal drilling play in West Virginia in 1986, and Mitchell Energy's first horizontal well in the Texas Barnett shale in 1991, among other collaborations.[6]

As serious studies involving energy-industry leaders as well as academic and government experts have long agreed, there is a crucial role for government support of energy innovation even beyond the early research stages—that is, in late-stage applied RD&D and early deployment—when there are strong public-goods reasons for the government to bring new technologies that address those public goods to the point where they can compete with entrenched incumbent technologies that do not address them. This was one of the most important conclusions of a study of R&D challenges for the 21st century conducted twenty years ago by the Council of Advisors on Science and Technology (PCAST), with strong industry participation.[7] That study found that many public-goods rationales exist for moving beyond the incumbent fossil-fuel-based technologies dominating U.S. and world energy supply including reducing the potential for conflict over access to oil and improving air quality and thus public health. But, the reason that is most demanding and thus most deserving of government engagement, in partnership with industry, is climate change. Practically every major study since the 1997 PCAST study, using newer information and different analytical tools, has agreed[8,9,10] and called for increases of 2- to 5- (or even greater) fold in government support for energy-technology RD&D and accelerated deployment.[11,12,13,14,15,16]

The Trump Administration's proposal to slash the federal government's energy RD&D investments appears to be based on three propositions: that the human role in whatever global

[6] Trembath, A., Jenkins, J., Nordhaus, T., and M. Schellenberger 2012 'Where the shale gas revolution came from', *Breakthrough Institute.*

[7] President's Council of Advisors on Science and Technology 1997, Federal Energy R&D for the Challenges of the 21st Century. Washington, DC: Executive Office of the President of the United States https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-nov2007.pdf

[8] Energy Future: Think Efficiency. How America Can Look Within to Achieve Energy Security and Reduce Global Warming, American Physical Society. Available at: http://www.aps.org/ energyefficiencyreport/ [2011, 09/20]

[9] A Business Plan for America's Energy Future. Washington, DC: American Energy Innovation Council. Accessible at http://www.americanenergyinnovation.org/full-report

[10] American Enterprise Institute, Brookings Institution & Breakthrough Institute (2010). Post Partisan Power: How a Limited Approach to Energy Innovation Can Deliver Cheap Energy, Economic Productivity, and National Prosperity. October. Washington, D.C., United States

[11] NCEP, (2004). "Ending the Energy Statemate. A Bipartisan Strategy to Meet America's Energy Challenges", The National Commission on Energy Policy, pp. 99.

[12] Kammen, D.F. & Nemet, G.F. (2005). "Supplement: Estimating energy R&D investments required for climate stabilization," Issues in Science and Technology, vol. 22, no. 1, pp. 84-88.

[13] President's Council of Advisors on Science and Technology 2010. *Accelerating the Pace of Change in Energy Technologies Through an Integrated Federal Energy Policy, Washington, DC: Executive Office of the President of the United States*

[14] See reference 10.

[15] Anadon, L. D., Chan, G. & Lee, A. in Transforming US Energy Innovation (eds Anadon, L. D., Bunn, M. & Narayanamurti, V.) Ch. 2, 36–75 (Cambridge Univ. Press, 2014).

[16] Chan, G. & Anadon, L. D. Improving decision making for public R&D investment in energy: utilizing expert elicitation in parametric models. Preprint at https://doi.org/10.17863/CAM.7842 (2016).

climate change is going on is uncertain; that being so (and the hazards to humans and ecosystems from fossil-fuel-driven air pollution, oil spills, ground-water contamination, and acid precipitation, among others, being likewise negligible), expansion of the incumbent fossil-fuel technologies should be the energy strategy of choice; and, to the extent that any advances over those technologies should be thought desirable, the private sector can be relied upon to pay for the needed innovation. On climate change, the strongest statement came from Trump's Office of Management and Budget Director Mick Mulvaney, who announced that, "We're not spending money on [climate change] any more. We consider that to be a waste of your money."[17]

None of these propositions finds significant support in the extensive, international, peer-reviewed literature addressing these topics.[18,19] The multi-trillion dollar externalities of the incumbent fossil-fuel technologies are extremely well documented.[20,21] Furthermore, the economic literature shows that the private sector will never invest as much in basic and early-stage-applied research as the interests of society require (because of high uncertainty about directly realizing any economic returns and the long lead time for any that do materialize), and even less so where significant public goods are involved that are not reflected in the marketplace.[22]

History tells us that it is exceedingly unlikely that the private sector will come to the rescue. After growing steadily during the late 1970s, private energy R&D peaked around 1985 and declined steadily after that (concurrent with the declines in federal investments), eventually dropping to less than half of the 1985 peak.[23] Today, the R&D intensity (the percentage of sales invested in R&D) in the energy industry is only 1%, far lower than the 10-15% in the pharmaceutical and information technology industries.[24] But even if, optimistically, the private sector continues investing in energy RD&D at current levels, the proposed cuts would still cause total U.S. energy RD&D investments to be much lower and, crucially, less adventurous. In other words, the high-risk high-return investments exemplified by the types of research funded by ARPA-E will go missing.

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[17] Greenfieldboyce, N. Trump's Budget Slashes Climate Change Funding. *The Two-Way* 16 March 2017. http://www.npr.org/sections/thetwo-way/2017/03/16/520399205/trumps-budget-slashes-climate-change-funding

[18] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland. U.S. National Academy of Sciences and The Royal Society, "Climate Change Evidence and Causes" (2014) http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf

[19] Holdren, J.P. *The science supporting the Climate Action Plan*, Testimony before the Committee on Science, Space, and Technology, U.S. House of Representatives, 17 September 2014, 23 pp. https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/house_testimony_sst_sept_17_2014.pdf

[20] IRENA (2016) "The True Costs of Fossil Fuels", available at: http://www.irena.org/DocumentDownloads/Publications/IRENA_REmap_externality_brief_2016.pdf

[21] Coady, D. et al. (2015) "How Large Are Global Energy Subsidies?" International Monetary Fund WP/15/105. https://www.imf.org/en/Publications/WP/Issues/2016/12/31/How-Large-Are-Global-Energy-Subsidies-42940

[22] Nordhaus, William (2004), "Schumpeterian profits in the American economy: Theory and measurement," National Bureau of Economic Research Paper No. 10433, available at: http://www.nber.org

[23] Nemet, G. and D. Kammen. *Energy Policy* **35**, 746-755 (2006).

[24] Jaruzelski, B, Dehoff, K. The Customer Connection: The Global Innovation 1000. (Booz Allen Hamilton, October 2007). Available at:

Why U.S. Energy Innovation is Good for America

Numerous future benefits accrue to U.S. residential, commercial, and industrial consumers from investments in innovation in the form of increased competitiveness of U.S. energy technologies in global markets; cost savings from improved energy-end-use efficiency; increased start-up creation and job generation in energy industries; the reduction of the public-health and environmental burdens resulting from fossil-fuel-derived conventional pollution; and, of course, attaining the deep reductions in U.S. GHG emissions required for the United States to do its share in addressing global climate change.

Increases in U.S. oil and gas production as a result of the shale revolution and the rise of more affordable renewable electricity generation have moved the United States closer to energy independence than it has been since before the Arab-OPEC oil embargo of 1973 (although it must be added that energy security, and not energy independence, should be the policy goal in this realm); U.S. net energy-import dependence in 2016 was under 12%, and only 8% of the U.S. negative trade balance was due to the energy sector. Similarly, the $7 billion (in 1999) invested by DOE in energy efficiency and fossil fuels between 1978 and 2000 resulted in a benefit to consumers and firms of $30 billion by 2000 (not including from reductions in damages from conventional pollutants or climate mitigation).[25] The overall benefits largely accrued from the development and use of energy-efficient technologies that avoided expenditures on fuels, including on imports from foreign countries. At ARPA-E, one-third of the grants between 2009 and 2016 went to small U.S. companies and start-ups; 56 new companies were established and $1.8 billion in follow-on funding was attracted as of February 2017.[26] Also, although it is too soon to fully understand the impact of the Obama Administration's public-private energy-innovation hubs, early assessments are positive.[27]

A slowdown in the pace of energy-technology innovation in the United States could be catastrophic to the competitiveness of U.S. energy technologies in global markets, where other countries are speeding up their efforts. Using many energy technologies originally developed in the United States and Europe, China is now the largest global manufacturer of solar panels and wind turbines, and it is positioning itself to capture newer markets, such as electric vehicles.[28]

Concerning energy RD&D explicitly focused on reducing GHG emissions, 22 countries including the United States established the Mission Innovation consortium in Paris in December 2015 with the aim of doubling their public funding of clean-energy R&D over the space of five years. If the United States does not honor its pledge (which accounted for 43% of the baseline), other countries will have less incentive to honor theirs. The global public good of stabilizing the climate simply compels cooperation and cost-sharing.

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[28] Gallagher, KS 2014, *The Globalization of Clean Energy Technology: Lessons from China*. Cambridge, MA: MIT Press

How to Improve Energy Innovation

There are many opportunities for improving the energy innovation system in the United States. The last 10 years have seen significant institutional innovation in the U.S. energy RD&D space, the emergence of new analyses on the effectiveness of different energy RD&D programs, and the application of novel decision- support methods for energy RD&D investments. Research has found, for example, that the productivity of DOE investments in energy innovation can be improved through more effective utilization of DOE's national labs and increased use of partnerships. In particular, increasing lab-directed research funds at the margin, facilitating the interaction of lab researchers with the private sector, and providing new contracting mechanisms by the labs may improve their already important inputs.[29]

The ARPA-E model has produced very promising outputs in its eight years of operation[30]. As innovation necessitates timescales exceeding that duration[31], it should be given at least another 5-10 years to demonstrate that a portfolio of high-risk investments can, in fact, produce substantial rewards.

As for DOE-wide improvements, the Administration should renew the appointment of a joint Undersecretary for Science and Technology to reduce siloing of investments across all programs and to dissolve the divisions between basic and applied research.[32] Finally, new analytical approaches to energy innovation policy could lead to better decisions regarding the allocation of energy RD&D investments across technology areas, leading to a more coherent and strategic portfolio approach.[33,34]

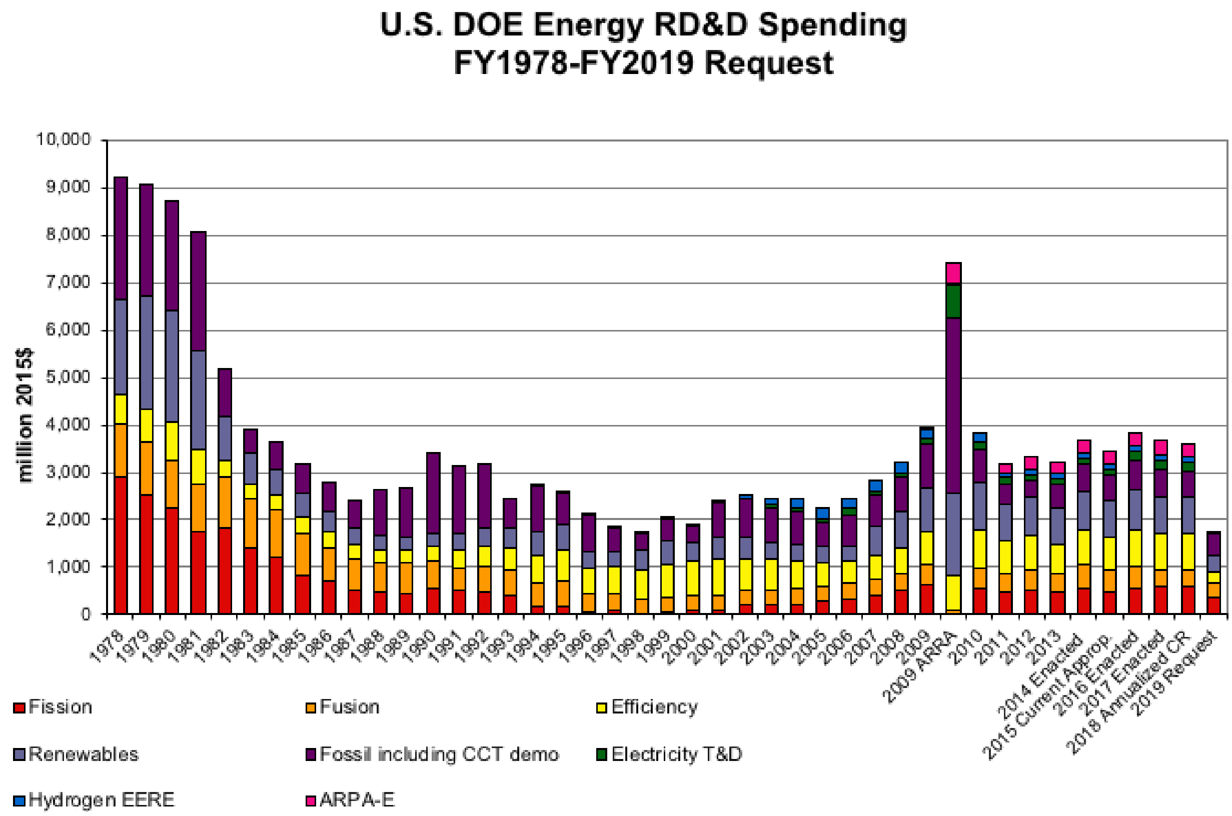
More generally, a public-private strategy for enhancing the American energy innovation system in the 21st century is badly needed. The United States must be able to compete in the global marketplace for energy technologies or else it will continue to lose the manufacturing jobs and economic benefits that are associated with these industries. As the rest of the world continues to implement the Paris Agreement, low-carbon energy technologies will be increasingly needed, and the United States should be positioned to be the leading supplier of them.

This essay is adapted and updated from Anadon, L.D., Gallagher, K.S., and J.P. Holdren 2017, "Rescue U.S. Energy Innovation," Nature Energy, Vol. 2: 760-763.

[29] Anadon, LD, Chan, G, Bin-Nun, A, Narayanamurti, V. *Nature Energy*. 1, 16117 (2016)
[30] National Academies of Sciences, Engineering, and Medicine. *An Assessment of ARPA-E*. Washington, DC: The National Academies Press. (2017).
[31] Grubler, A. et al. 2012. Policies for the Energy Technology Innovation System. Chapter 24 of the *Global Energy Assessment*, Cambridge University Press: Cambridge, UK.
[32] Narayanamurti, V. & Odumosu, T. Cycles of Invention and Discovery: Rethinking the Endless Frontier (Harvard Univ. Press, 2016).
[33] **Anadon, LD**, Baker, ED, Bosetti, V. *Nature Energy* 2, 17071 (2017).
[34] Chan, G, Anadon, LD. (016. 'Improving Decision Making for Public R&D Investment in Energy: Utilizing Expert Elicitation in Parametric Models. University of Cambridge, Energy Policy research Group Working Paper 1631 and Cambridge Working Paper in Economics 1682. Available at: http://www.eprg.group.cam.ac.uk/wp-content/uploads/2017/01/1631-Text.pdf .

FIGURES

Figure 1: Past and proposed energy RD&D investments at the U.S. Department of Energy.



Gallagher, K.S. and L.D. Anadon, "DOE Budget Authority for Energy Research, Development, and Demonstration Database," The Fletcher School, Tufts University; Department of Land Economy, University of Cambridge; and Belfer Center for Science and International Affairs, Harvard Kennedy School; March 21,

Modernizing the Department of Energy to Meet the Nation's 21st Century Clean Energy, Environmental Stewardship, and National Security Objectives

James L. Connaughton

President and CEO Nautilus Data Technologies; Member of the Advisory Board and Senior Policy Advisor to the ClearPath Foundation; former Chairman of Council on Environmental Quality under President George W. Bush

Richard J. Powell, Executive Director, ClearPath Foundation

Jeremy B. Harrell, Managing Director of Policy, ClearPath Foundation

Background

Global energy systems extend through every part of our economy: electricity, transportation, manufacturing, agriculture and everything in between. International energy systems are facing dramatic growth, along with policy and technology evolutions to address growing populations and environmental objectives. Total energy demand is expected to increase by 48% by 2040, requiring $67 trillion in investment. The increased emphasis on cleaner, more reliable, and more affordable energy technologies presents a tremendous opportunity for American businesses and entrepreneurs to expand, export, and develop new markets both at home and abroad.

Despite this immense opportunity, energy R&D in America is slowing down. US private sector energy research remains below 1% of sales, lower than all other sectors, and ranking the U.S. 12th globally for energy R&D investment per capita. Other global players, particularly China, continue to expand their research and development (R&D) capabilities with a focus on clean energy technologies. China recently overtook the U.S. in applied R&D investment and is rapidly surpassing the U.S. in global commercialization of nuclear energy, solar energy and lithium, all technologies invented in America.

Bolstering and modernizing the American energy innovation engine is imperative to increasing the domestic supply of clean, reliable, and resilient electricity, while strengthening American geopolitical standing, maintaining economic prosperity, and assuring our national security. The economic and national security benefits of innovation are vast and sweeping: trillions in economic potential, billions in consumer savings, substantial geopolitical leverage over nuclear proliferation, the weakening of both OPEC and Russian gas exports, and the checking of Chinese economic expansion.

To seize this opportunity, America needs more than just an increase in dollars and cents. The world renowned Department of Energy innovation engine must be refocused around breakthrough-technology goals. These goals should be aimed at bridging the gap to commercialization, driving down the costs, and ultimately increasing global deployment of clean energy technologies necessary to meet global electricity demand and emission reduction imperatives.

Staying Ahead of the Curve

Modernizing key research, development, and demonstration (RD&D) programs is essential to securing our nation's role as a global technology innovation leader while facilitating a cleaner, more reliable, and affordable domestic electricity supply for the American public. Secretary Perry told the House Energy and Commerce Committee last October: "America is at the beginning of an energy renaissance." Domestic oil, natural gas and solar energy production are at record highs, while improvements in efficiency allow us to do more with less energy. As a result, North American energy prices are historically low and may stay that way for the foreseeable future.

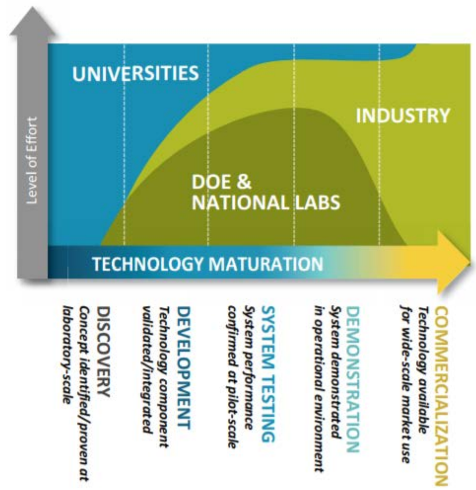
This era of abundance must not make us complacent. Staying ahead of the curve and reinventing energy systems is slower than turning a supertanker, requiring a decade or more of lead time for cutting-edge technologies to mature. Hydraulic fracturing, as well as today's solar and wind technologies, took several decades and significant investment from both private and public sources before widespread commercial deployment. It is essential that our nation capitalize on this era of abundance and invest in the technologies needed to meet the electricity needs of tomorrow.

Global energy demand is expected to grow 28% by 2040. This market in India alone is valued at $2.7 trillion by 2040. A homegrown U.S. advanced energy economy can shape and even lead such a market, furthering our energy security, geopolitical influence and economic opportunities abroad. China is seizing this opportunity and outflanking us. China is attracting advanced nuclear talent, bringing two high temperature gas reactors online early this year, at least half a decade before even our most ambitious plans. China is already the global leader in solar manufacturing, a technology American entrepreneurs invented in partnership with the Department of Energy. China is deploying the most efficient coal plants in the world. And the future bounty under development and early deployment in China is of even greater significance, including ultra-cheap large scale batteries and cutting edge nuclear reactors.

DOE's Critical Role in America's Innovation Engine

The Department of Energy and its 17 national laboratories, combined with the nation's premiere research universities and facilities, constitute the most comprehensive energy research and development network in the world. As the largest funder of physical sciences research in the U.S., DOE has spurred many technological advances of the modern energy era – in engineering, materials science, computing, physics, health sciences and more. DOE and its predecessor agencies pioneered civilian nuclear energy, funded many of the core technologies used in fracking, and produced the first solar cell. The Department is a critical link between university research and commercial products. The private sector alone is often unwilling to assume the risk of pioneering new and capital-intensive technologies, especially in the heavily regulated and risk-averse power sector. Many power companies are regulated and most are structurally discouraged from developing , let alone buying first-of-a-kind technologies.

Figure 2-2: DOE National Laboratories' Relationship to Universities and Industry in the Energy Innovation System



Source: Annual Report on the Status of the National Labs

ClearPath believes that DOE must modernize if our nation is to export technologies of the future to meet the world's rapidly growing energy appetite. America's specialty is in cutting-edge technology development and manufacturing, not in mass-production of commodity goods.

To that end, the best way for the United States to play a role in meeting future energy demand is to develop increasingly advanced technologies that can outcompete rival nations. We may not be able to beat China with cranes and concrete, but we can in building printable solar panels, modular nuclear plants, carbon capturing fuel cells and other energy tools of tomorrow.

Therefore, a strong commitment to energy innovation and a modern DOE is essential for: (1) improving the nation's geopolitical position as foreign competitors, such as China and Russia, invest in advanced energy research, development and demonstration (RD&D) concepts; (2) enhancing American energy independence with more clean, reliable and affordable generation technologies; and (3) seizing a multi-trillion dollar economic development opportunity that will revitalize domestic manufacturing and create thousands of high-paying jobs.

We can and should aim for clean, reliable and affordable U.S. energy dominance.

But simply spending more taxpayer dollars with a "business as usual" approach will not achieve these goals. While funding is a critical component, collaboration with the private sector must be improved to make innovations more readily transferable to industry and able to thrive in international markets.

The last major overhaul to our national energy strategy was the Energy Policy Act of 2005 and many aspects of power generation have greatly evolved since then. Modern market realities such as low-cost natural gas, the declining cost of wind and solar technology and, greater competition in clean energy technology from global competitors should prompt a reconsideration of federal R&D priorities.

In addition to adapting to the current market environment, DOE can maintain our domestic competitive advantages with long-term research priorities rooted in nonpolitical market and technology projections. Science and research should be nonpartisan enterprises, operating on longer terms than year-to-year appropriation bills or four-year election cycles.

The Need for DOE "MoonShot" Energy Technology Goals

Too often, DOE's role is thought of in terms of capabilities, or dollars spent on priority topics. The question is rarely asked what outcomes DOE is actually working towards. President Kennedy's original MoonShot concept, proven more than half a century ago, has withstood the test of time. DOE has found success at times emulating the MoonShot model, with clearly articulated goals aligning all the management and funding of the Department from the Secretary's desk to the scientists bench. Unfortunately, the concept has only been sparingly used. The Obama administration provided a noteworthy, but narrowly implemented blueprint with its 2011 SunShot Initiative. It aligned secretary-level, interdisciplinary resources on reducing the cost of solar power by 75% within 10 years. Last year, the Department reached its goal years ahead of schedule. More federal energy innovation goals are needed to maximize the commercial impact of DOE's vast capabilities and resources.

Clearly articulated, long-term research priorities would insulate critical RD&D efforts from changing political whims. Ambitious technology development goals provide a way for the Department to avoid micromanaging the day-to-day operations of national labs and universities while preserving clear guidance. Important parts of the DOE research portfolio, including nuclear energy and energy storage, lack systematized goals with high level buy in and adequate resources. Establishing more technology-inclusive goals would leverage limited federal dollars and resources to drive down cost and bring breakthrough technologies to the marketplace. These goals must be accompanied by deep private sector engagement to ensure alignment, proper funding, sufficient flexibility, and regular review to ensure research accountability.

Secretary Perry recently called for an increased emphasis on the development of advanced reactor technologies, including small modular reactors, stating they should play an important role in the American clean energy portfolio while presenting unique export opportunities. This is just one area that a MoonShot approach could be applied. A public-private advanced nuclear energy research initiative focused on tackling key performance challenges could demonstrate breakthrough reactors and have significant market opportunities.

Co-develop the Goals with Industry

Where applicable, the DOE should work closely with the private sector to meet mutual goals. This includes ensuring no undue regulatory burden on energy technology companies, utilizing funding opportunities for the private sector where appropriate, and partnering with private entities to develop technologies under larger MoonShot goals.

Adopt Private-Sector Management Practices

Relevant funding and management decisions should also be recalibrated around these MoonShot goals. Major "MoonShots" and corresponding subgoals should be used as a yardstick to evaluate the progress within research portfolios. Emulating the private sector, if specific technologies do not realize expected milestones or show progress, support should be reduced or cut and directed to more promising areas. This stands in contrast with the common practice of short-term research initiatives for "flavor of the month" technologies pushed by political appointees, as well as continuing research projects that are not bearing fruit. Additionally, the Department should be empowered to make the necessary human resource decisions for success, such as the ability to offer more competitive wages and terminate employees that do not meet expectations.

Maximize Private-sector Coordination

The DOE should look to prove business models with the private sector. One pragmatic solution is the Innovative Pathways funding program, which optimizes new private-sector financing mechanisms for energy innovation and commercialization. In some cases such as in finance, the private-sector is far better equipped to deliver on the goals of the Department than universities or national labs.

Finally, it is also crucial that the DOE works closely with the private sector to realize the completion of its technology MoonShots. Prematurely ending government support raises the risk that our rivals will commercialize them instead. For example, China has become the global leader in solar and lithium-ion manufacturing, and it is rapidly cementing its leadership role in nuclear plant construction. They have no philosophical objection to funding applied research, and are happy to take the fruits of American basic research and add applied dollars to demonstrate and commercialize them, thus reaping the benefits. A soup-to-nuts approach to energy research is needed - especially for capital intensive projects such as advanced nuclear and carbon capture projects. These sentiments have been echoed by diverse industry stakeholders, including the National Coal Council, the Carbon Utilization Research Council and NuScale Power. Striking a balance of appropriately supporting successful technology demonstration while avoiding market interference is a delicate one, but is necessary to maintain international competitiveness.

Conclusion

The Department needs to be more flexible in operation, without sacrificing accountability. The national laboratories have been prone to 'research drift' without an explicit national energy policy. Goals allow flexibility at the labs while ensuring accountability.

America has an opportunity to lead the global market for clean, safe, affordable and reliable electricity generation. Without a more focused and nimble government partner, American entrepreneurs are likely to lose the clean energy race to other geopolitical powers such as China, squandering an immense economic opportunity. An innovation-centric energy strategy would allow America to cut its own emissions far more cheaply than regulatory hammers, while creating rather than strangling American entrepreneurs and export opportunities.

MARKET-DRIVEN, PERMISSIONLESS INNOVATON IN THE US ELECTRICITY SYSTEM

JAMES L. CONNAUGHTON
JULY 2018

THE U.S. ELECTRICITY SYSTEM

3300+ ELECTRICITY COMPANIES

- Investor-Owned, Muni/Coop, Federal and State PMAs
- Mostly Price-Controlled, Guaranteed Monopoly and Profits

RELIABILITY AND RESILIENCY

- Evolving to Inflexible, Mandatory Standards
- Threatened by Distributed Energy and New Pricing Models

ENVIRONMENTAL REGULATION

- Major Shift to Ad Hoc, Permission-Based System
- Excessive Cost and Risk Premiums Born by Customers

CYBERSECURITY

- Meaningful Engagement and Investment Lagging
- Misplaced Focus in Current Portfolio of Activities

IMPEDIMENTS OF INCUMBENCY

- Business and Regulatory Model; Spend More, Make More
- Risk Averse Culture of Both Companies and Regulators

POLITICAL ECONOMY OF POWER

- Federal, State, Local
- Regulators Unable to and Will Never Lead

Non-Competitive, Inefficient, Inflexible, Regressive, Captive to Government

2

UNLEASH THE POWER OF MARKETS TO TRANSFORM U.S. ENERGY SYSTEM

MAKE ELECTRICITY MARKETS COMPETITIVE

- Unleash Investment in Innovation
- Constitutional Lawsuit or Federal/State Legislation

SIMPLIFY POWER GENERATION MANDATES

- Tech Neutral, Performance-Based, Cost Cap, Pre-Emption
- Enable Natural Gas, Clean Coal, Nuclear, Hydro, Renewable

SIMPLIFY TRANSPORTATION MANDATES

- Tech Neutral, Performance-Based for Vehicles
- Tech Neutral for Fuels, Performance-Based for Fuels--National Security, Energy Density, Emissions Profile

DEPLOY ANALYTICS FOR POWER, VEHICLES, MFTG

- About 25% Power System Efficiency Gain; 8% in Grid Alone
- Federal Policy, PUC Policy—Data as New Utility Asset

TRADE ENERGY SUBSIDIES FOR MUCH MORE R&D

- Portion to Public and Private R&D; Portion to Pay Down Debt
- Tax Reform, Federal and State Budgets

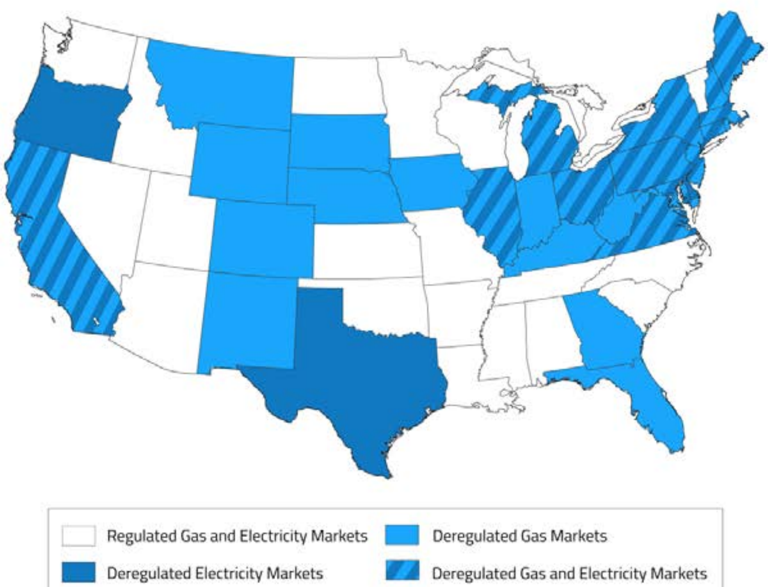
ADDRESS IMPEDIMENTS TO CLEAN BASELOAD

- Existing, Gen3 Plus, Gen 4, and Small Modular Nuclear
- Carbon, Capture, Use and Storage for Coal and Gas

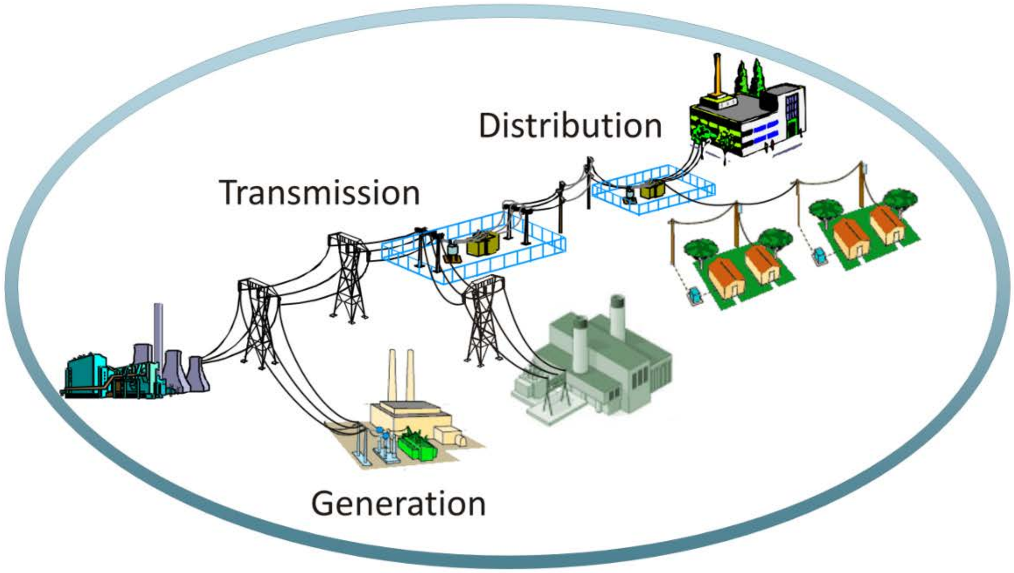
Tax Policy: Repatriation, Corporate, Expensing

Must Inspire/Scare China to Reform & End US Job/Emission "Leakage"

2017 ELECTRICITY MARKET MAP

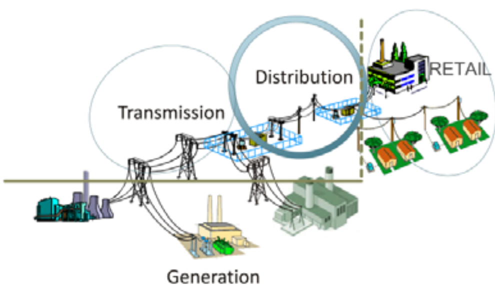


35 STATES: INCUMBENT VERTICAL MARKET POWER & REGULATION

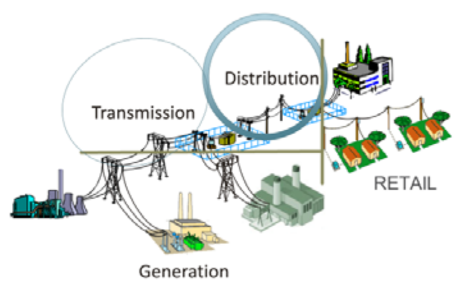


14 STATES + DC: MOSTLY RESTRUCTURED
TEXAS: NEARLY FULLY COMPETITIVE

MOSTLY RESTRUCTURED



NEARLY FULLY COMPETITIVE



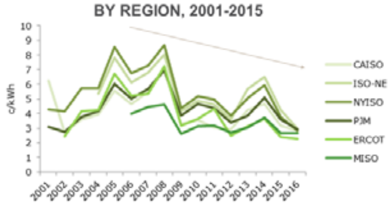
WITH COMPETITION: WHOLESALE PRICES ARE LOWER, CONSUMERS BEAR LESS INVESTMENT RISK, AND CLEAN ENERGY IS MORE PREVALENT

TOTAL RETAIL ELECTRIC BILLS INCREASE WHILE WHOLESALE PRICES FALL TO RECORD LOWS

"UNFAVORABLE INCREASES IN ELECTRIC BILLS ARE ALMOST ENTIRELY DUE TO INCREASING T&D COSTS"

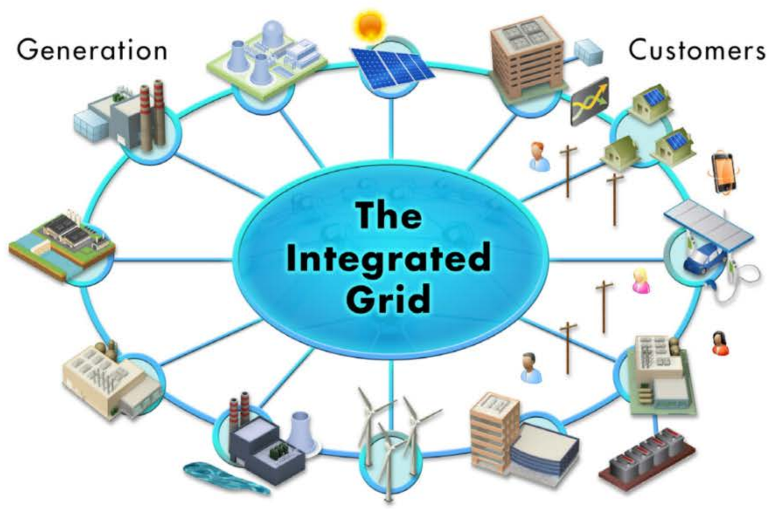
- Total electric bill for the typical US consumer is increasing, despite wholesale electricity prices collapsing to record lows.
- Radical decrease in wholesale electricity prices is buffering escalation of consumer electric bills as regulated utility spending on transmission and distribution infrastructure continues to skyrocket.
- Consumer bills are set to dramatically increase as the power industry steps up investments to meet government mandates, T&D costs continue to rise, and commodity price trajectories revert to more normal levels.

AVERAGE WHOLESALE MARKET PRICES BY REGION, 2001-2015



- A University of Chicago study found that competitive wholesale markets save consumers $3 billion annually relative to non-competitive power markets.
- A NYISO study found that the introduction of competitive wholesale markets in New York has saved consumers $6.4 billion in fuel costs and $540 million in investments on system reliability.
- A PJM study identified up to $2.5-$3 billion of annual value to consumers from wholesale competition across its region.

A FULLY INTEGRATED GRID IS NOW FEASIBLE DESIRABLE, AND COMPETITIVELY ADVANTAGEOUS



SOURCE: EPRI (2014)

FINISH THE JOB OF ELECTRICITY MARKET RESTRUCTURING

INTERSTATE COMMERCE CLAUSE CHALLENGE

- Electricity Historically Intrastate
- Electricity Now Fully Interstate (except Hawaii and Alaska)
- No Constitutional Waiver in Federal Power Act

QUARANTINE THE MONOPOLY

- Fully Decouple Medium Voltage Distribution System
- Competition in Generation, Transmission, and Retail Services

POTENTIAL PLAINTIFFS

- U.S. Government – strong, successful precedent
- Manufacturing, Transportation, Infrastructure, Tech, NGOs

FOUR JUDICIALLY NOTICEABLE FACT PATTERNS

- "Monopoly Hypocrisy"—Monopoly In-State, Competitive Elsewhere
- "Monopoly Island"—Monopoly Inside or Beside Competitive Market
- "Half-Pregnant"–Mostly Monopoly, But Partially Competitive
- "Goretex"—Sells Surplus Power Out, But Blocks Power Coming In

RETAIN STATES' ROLE UNDER FEDERAL POWER ACT

- "Exclusive Authority Over Retail Sales"—Parens Patriae
- Focus on Regulating and Enforcing Fair Competition

RECALIBRATE THE POLITICAL ECONOMY OF POWER: MARKETS, INNOVATION, LEGISLATION, REGULATION

Once In a Generation Opportunity on Par With Historically Transformative Analogs in Aviation, Rail, Telecom, Bulk and Retail Shipping, Etc.

9

BENEFITS OF ELECTRICITY MARKET RESTRUCTURING

COMPETITION AND CUSTOMER CHOICE

- Commercial/Industrial Demonstrably Robust
- Consumer Retail Opportunities Emerging
- Innovative Service Offerings, Community Aggregation, Other Trends

EFFICIENCY AND COST CONTROL

- Plant Operations: Capacity Factors, Refueling Time, Fuel Efficiency
- Trading and Dispatch: Significantly Improved, Highly Adaptable
- End Users: Energy Efficiency, Demand Response, Conservation

CAPITAL PLANNING

- Introduction of Cleaner, More Reliable, and More Flexible Resources
- Prospect of More Effective Transmission Planning and Investment

CONSOLIDATION OF CORE ENTERPRISES

- Generation Companies: Scale and Balance Sheet to Support Investment
- Distribution Utility Companies: Broad Synergies, Enables New Tech
- Transmission Companies: Heft to Handle Multi-State Challenges

INTEGRATION OF NON-CORE INNOVATION BY OTHERS

- Greater Incentive and Freedom to Introduce Innovation
- Decisions at Market Speed, with Market Discipline
- Scalably Accelerate Cross Sectoral Interoperability—e.g. IoT

RISK MANAGEMENT

- Shareholders vs. Ratepayers
- Incentives and Accountability Properly Aligned

Market Restructuring Will Produce Rapid and Massive Gains for Consumers, Infrastructure, Workers & the Economy

10

APPENDIX

CURRENT U.S. EMISSIONS POLICY IMPACTING ELECTRICITY SYSTEM
A MAZE OF OVERLAPPING AND CONFLICTING MANDATES AND INCENTIVES

Over 100 Federal and State Mandates	Over $150B Incentives
Renewable Power* (37 States)	Tax Credits (on and off again)
Greenhouse Gases* (10 States)	Clean Energy Payments
Power Plant Air Pollution*	None
Vehicle Fuel Efficiency*	Tax Credits, Subsidies
Renewable Fuel*	Tax Credit (Expired), Subsidies
Lighting Efficiency*	Tax Credits, Subsidies, Rebates
Appliance Efficiency	Subsidies, Rebates
Ozone Depleting Substances	None
Building Efficiency Codes (50 States)	Tax Credits, Subsidies
Clean Power Plan (On Hold)	Clean Energy Incentives (On Hold)

* USES MARKET-BASED SYSTEM IN WHOLE OR PART

12

Just Around the Curve Ahead, the Future of Transportation[1]

Robert Bienenfeld

Assistant Vice President, American Honda Motor Co., Inc.

The future of transportation is obvious. Nothing is as convenient as the automobile, except in the most crowded urban centers. In the future you will be whisked from place to place in automated, connected, shared, on-demand electric vehicles (EVs). Faster, cheaper, accident- and pollution-free transportation. For everyone.

If that's not enticing enough, consider all the concomitant benefits! Because vehicles won't crash, they can shed weight, requiring fewer resources to build and less energy to move. On-demand vehicles will drive seven or eight times more miles than personally owned vehicles. More miles per vehicle means fewer vehicles (up to one-eighth as many) which will require much less parking. Enormous resources will be freed. Parking lots, parking structures, on-street parking, residential driveways and garages can all be repurposed. Fourteen percent of the land in Los Angeles is dedicated to parking[2]. Billions of dollars can be re-imagined and re-created.

This vision—let's call it the 2050 Vision—is the easy part. Countless news stories articulate elements of this vision, as has popular entertainment. Some visionaries justly lay claim to seeing more of this future earlier—Amory Lovins, Robin Chase, Dan Sperling to name a few. Beyond the visionaries there are thousands—engineers, marketers, even policymakers—who have been working toward this vision in great and small ways over the last three decades.

Here's the hard part: it is very difficult to see how long all of this will take, in what order events will occur, what prerequisites will enable which dramatic leaps, and what laws and regulations will be needed to help bring it forth. Between now and then, there is a long, messy interim where new 2050 Vision elements must coexist with the old, frustrating realities of today. Cars that inform one another about braking, accelerating and turning events will share the streets with cars that can't. Valuable curbside real estate needed for picking up and dropping off riders will compete with personally-owned, idle, parked vehicles. And lots of seriously retrograde citizens (like me?) will still want to occasionally enjoy the singular pleasure of taking the wheel and driving themselves wherever and whenever they want to go (without each turn recorded on servers who knows where).

Standing between the reality of today and the dream of tomorrow are millions of interim steps, made by millions of people. There is technology to be invented, entirely new businesses to be imagined, fortunes to be made (and lost), and significant disruption to occur. Research and

[1] This essay reflects the thoughts and opinions of the author, only, and do not necessarily reflect official company positions of American Honda Motor Co., Inc.
[2] https://la.curbed.com/2015/11/30/9895842/how-much-parking-los-angeles

engineering are underway for autonomous vehicles. Vehicle electrification has a healthy start. New business models associated with sharing and on-demand "mobility as a service" (paying for transportation by the mile) are well beyond the exploration phase. Billions of dollars and countless careers are at stake.

Is this a revolution? For most consumers, no. Transportation will evolve to be cheaper, faster, safer and more convenient. Some households will opt to not buy that second car; a few will not need the first. Eventually calling up an autonomous, shared car to commute to work will be more convenient, less expensive and safer than driving your personal car. For those who work in this space, however, the answer will be more personal. If your job survives it is "evolutionary;" if your job disappears it's a revolution.

Today, major automakers are investing in on-demand vehicle systems, vehicle electrification (hybrids, plug-in hybrids, battery electrics and fuel cell electric vehicles), and autonomous vehicles. They are committing teams of researchers, developers, business staff and marketing people. In addition, there are hundreds of start-ups dotting the landscape—partnering, merging, and competing head-on with the old guard. Traditional suppliers like Delphi, Denso and Bosch provide key components from both home-grown technology and technology licensed or acquired from start-ups that didn't exist just a few years ago. In the on-demand space, new entrants (such as Uber, Lyft and others) are being challenged by automaker-funded "start-ups" like Maven (GM), Car2Go (MB), and DriveNow (BMW) to name a few.

Yet, how this transformation unfolds depends not just on engineering achievements and business ventures. It also depends—significantly—on the actions of legislators, regulators, and other policymakers who are responsible for setting the rules. So what is the role for policymakers in creating the 2050 Vision? Will the 2050 Vision emerge from Adam Smith's "invisible hand" of the market without the prompting and guidance of social constraints? Or must this future be "designed?" It is worth noting that flourishing markets benefit from transparent, well-defined rules. From a public policy standpoint, it is even better when those rules are well-aligned with social goals. Moreover, social goals are most likely to be achieved if they are clearly articulated and broadly supported. In other words, clear rules, thoughtfully applied, and supported by the public can play a critical role in helping reach the 2050 Vision.

In our current transportation systems, pollution and congestion are "externalities"—that is to say, the costs of pollution and congestion are not accounted for in the cost of a new car, or the expense of driving an extra mile. As new markets are framed-up there is an opportunity to reinvent these systems and more properly account for pollution, congestion and other externalities. However, we must be careful to not burden new markets with costs that are not born by existing markets.

This admission may seem strange coming from an automaker representative, as these days it seems nearly everything about automobiles is regulated. From traffic rules to safety standards, from advertising to sales, from cybersecurity to environmental requirements, the automobile industry is highly regulated and constrained. Automakers employ teams to scour hundreds of government websites, paranoid that a missed regulation in some far-flung agency at the federal, state or local level will result in fines, recalls, reputational damage or lost sales.

Most regulations are backward-facing (some might say "fighting the last war"). Today, we are required to test unbelted dummies despite seatbelt usage exceeding 90%. Side mirrors are required, causing excess fuel consumption due to poor aerodynamics, despite the ubiquity and reliability of cameras and screens. We are required to test emissions at high altitude even though sensors automatically correct for air density. The list goes on and on.

These are real regulatory burdens on automakers, consumers and society. Backward-facing rules need to be updated, or eliminated if found wanting. And while nobody likes to be regulated and told what to do, there is wide recognition that regulations play an essential role. My company was invited to help calculate the "total cost of regulations" in a new car. A colleague quipped, "Oh, I see, you'd like to compare a new car to the cost of a dirty, unsafe new car?" That ended the discussion; clearly there is a role for regulation.

I'd suggest that the environment has a higher claim to government regulation than safety because consumers can choose safety; they can vote with their wallets. In every vehicle category and in every price range there are vehicles that are highly rated for crash-safety by the National Highway Transportation Administration (NHTSA) and the Insurance Institute for Highway Safety (IIHS). One customer's desire for safety might exceed another's, but until now, the two choices do not affect one another. The environment, however, is a shared responsibility. One individual can clean up only so much of it, and the negative externalities range from subtle to gross. It is hard to directly connect my driving in Santa Monica to someone else's asthma in San Bernardino—but we know the effects are there. We know that copper in brake pads ends up as dust on the roads, washes into streams and confuses the internal compass of fish in rivers[3]. And we certainly know that our driving puts enormous amounts of CO_2 into the atmosphere. The *Tragedy of the Commons*[4] is simply that market incentives for individuals do not align with the social goals with respect to the environment (or any other negative externality).

Some policymakers are eager to start shaping the future to accelerate and ease the transition from this messy interim to the 2050 Vision. We need to be careful that we don't stifle the very innovation we seek to encourage. Forward looking rules—statutes, regulations, laws in all forms—are funny things. The consent of the governed is necessary. Make a rule that is too far forward, too disconnected from today's problems, and you're out of office. Or you're accused of picking winners and losers. There are noisy claims of rent-seeking and crony capitalism. Or you upset business incumbents with thousands of today's jobs and today's customers at risk. Ignore the 2050 Vision, maintain the status quo too long, and new opportunities are missed, squandered, or delayed.

Reducing greenhouse gas emissions from automobiles is essential; there is little disagreement on this. Most of the discussion is not about if, but rather when and how much. There is unanimity among automakers and external experts that future vehicles must be electrified in order to achieve the greatest reductions. Conventional internal combustion engines can continue to marginally improve, but by 2025 the major improvements are likely to be tapped out. However, the truly transformative benefits happen with grid-based electrification. Importantly, a clean electric grid is essential for ultra-low carbon transportation. The rapid reduction of greenhouse gas emissions from automobiles cannot occur without vehicle electrification and a clean grid. Policies that decarbonize the grid and encourage vehicle electrification are essential (and not rent-seeking[5]).

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[3] https://www.epa.gov/npdes/copper-free-brake-initiative

[4] http://pages.mtu.edu/~asmayer/rural_sustain/governance/Hardin%201968.pdf, Garrett Hardin, 1968

[5] Unlike traditional "rent-seeking," in which a small group seeks benefits at the expense of others (e.g. windfall profits for the few occur from small, incremental taxes on the many), here the benefits to society (reductions in

We have examples of how different regulators approach this challenge. The greenhouse gas fleet regulations, implemented by the Obama Environmental Protection Agency (spurred forward by California) deserve a lot of credit. They set fleet standards that steadily, ineluctably become more stringent every year. For the first ten years, the rules include generous incentives for vehicle electrification to help automakers jump-start these necessary technologies. We are now in the midst of negotiations for the final four years of the rules, trying to extend incentives for a few more years, at least.

In contrast, California (and nine other states) has promulgated a very aggressive and prescriptive Zero Emission Vehicle (ZEV) regulation. The ZEV Mandate is lauded for being "technology forcing." Society can invest in technology pathways, companies can strengthen their research and development efforts, but it is absurd to say technology can be "forced" (otherwise we would have "cold fusion" and numerous other, wondrous things). The ZEV regulation has been on the books since 1990, and has evolved more to match technology than the other way around. Originally envisioned as a means to reduce smog, ZEV was put on the back burner when the technology didn't cooperate—it was neither cost effective nor marketable—and conventional vehicles became so clean that California grudgingly labeled them "partial zero emissions."

Today, the ZEV mandate dictates not only how many vehicles are required to comply but what kind of technology approaches are allowed. In 2018, 55.6% of an automaker's ZEV credits can come from plug-in hybrids, but in 2025, that declines to 37.5% of credits. This precision is worthy of Nostradamus. On the other hand, to California's great credit, this onerous rule is supported in many positive ways, including cash incentives to consumers, subsidies for infrastructure, access to car pool lanes, direct consumer advocacy efforts, and more. Sadly, this same support lags by years in the other states that adopted the ZEV mandate, with commensurately low sales results and high automaker burdens.

Although industry has great confidence in the need for EVs, plans for charging them are much less clear. Ten years ago it was a settled fact that charging at home, overnight, was the best approach to EV charging. Electricity is cheapest at night, and peak demand is during the day—especially between noon and 6pm. Today, the situation in California has completely reversed. California's incentives for solar now result in a surfeit of kilowatts during peak daylight hours. It is now obvious that we need systems to signal when to start and stop charging in order to both take advantage of renewables on the grid and to help stabilize the grid.

For decades, electric utilities were staid monopolies regulated by slow-moving public utilities commissions. In this new world of EVs charging and communicating with the grid, we have more than a thousand utilities, each governed by different rules, trying to work with more than a dozen automakers and tens of thousands of automobile dealers, as well as other new market entrants. New systems that benefit customers, stabilize the grid and lower CO_2 need rapid support and development, but we need careful, flexible policies.

While the conventional wisdom for EV charging at home has been turned on its head, industry, utility and EV advocates are now rushing headlong to demand government support for EV charging away from home. Today there is just as much certainty that public charging is

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greenhouse gasses) are derived from fleet standards which are burdens on a limited few (i.e. automakers). The incentives afforded to automakers for vehicle electrification merely offset these burdens *assigned to them* by policymakers; these burdens could just as easily be assigned to consumers.

critical, and that fast charging is essential in order to market and sell electrified vehicles. But we really don't know where those stations should be or, for that matter, how many we need. Today, it is commonly thought that exclusive EV parking is helpful—for theaters, restaurants, grocery stores—but the critical locations are probably at work. Similarly, it is believed that so-called "fast charging," which replaces 80% of the battery charge in 30 minutes, is needed along highways to give consumers confidence to take longer trips.

By contrast, airlines did not install phone charging on planes and in airport lounges to encourage the sale of smartphones. Consumers purchased smartphones because of their intrinsic value, and demanded convenient charging to get the most out of their phones. Are we confusing causality with correlation? And what if the future does consist primarily of electrified, on-demand, shared, connected and automated vehicles? The providers of these on-demand, electric vehicles will develop their own charging infrastructure, making current infrastructure investments stranded.

So what is the attentive policymaker to do? Maybe this is a trivial example, but there is an apocryphal story of Dwight Eisenhower when he was President of Columbia University. A new section of campus was under construction and there was fierce disagreement about where the walkways should go. Legend has it that Eisenhower told them to complete the buildings without the walkways—to wait and see where students cut paths in the grass. That's where the infrastructure should go; emergent order.

Patient encouragement of new, risky endeavors that benefit society is an essential role of government. Transitions from the status quo to new, socially beneficial modes are expensive and difficult. It is the government's role and responsibility to creatively lower barriers to these transitions, not necessarily to pave the way, or obligate the private sector to take these risks, but to make the transition easier.

Today, we are busier than ever, trying to help shape rules for the future. What is the least disruptive way to reduce greenhouse gas emissions from cars? What is the best way for automobiles to talk to the grid or, more importantly, for the grid to talk to automobiles? When a new credit market is created—for example, to monetize externalities—who gets the credits? Policymakers need to consider the best use of policy tools such as minimum standards, incentives, and new credits which arise from created markets (for example, credits to reduce CO2), default electric rate choices, etc.

In Genesis, we are told the story of Abraham (then Abram) and Lot. Their two tribes were dwelling together, but there was conflict and overgrazing (see the *Tragedy of the Commons*). "Please let there be no quarrel between me and between you and between my herdsmen and between your herdsmen, for we are brethren. Is not all the land before you? Please part from me; if you go left, I will go right, and if you go right, I will go left."

For hundreds of years, this described the United States; it's a big country. We don't need conflict, so let's part. If you go to the right, I'll go to the left. With two oceans for protection and a sparsely populated continent, our cultural mind-set included self-reliance, optimism, and a healthy distrust of power, authority and experts[6]. The American ethos has a strong libertarian

[6] In Jonah Goldberg's "Suicide of the West," page 156, the author shares the Seymour Martin Lipset story about the Metric system: in the mid 1970s, both Canada and the United States passed very similar laws to adopt the metric system. Within a few years, Canada had converted completely, while the US abandoned the effort. "Canadians, with their deeply ingrained deference to political authority, obliged almost instantly…Not so in America."

quality to it (whether real or imagined): fewer rules, distrust of government, and boot-strapped independence.

But things started changing about fifty years ago. Astronauts went up, and a new world view came down. Our beautiful, blue planet, floating in the heavens appeared smaller, and more vulnerable than we ever dreamed. It was an epiphany. We have been more or less rapidly cleaning up pollution in the water and the air ever since. Reducing greenhouse gas emissions, however, represents a significantly greater challenge to society. Lowering tailpipe criteria pollutants involved a lot of engineering that did not affect the customer experience. Lowering greenhouse gas emissions will be much more expensive and challenging.

The societal benefits of automobiles and mobility have been only slightly constrained by the conflict engendered by their use. Along with the innumerable benefits of mobility, are the dis-benefits: traffic accidents, pollution, congestion, extra land costs, and more. More than 37,000 deaths associated with automobiles in the U.S. last year—despite the safest cars ever on the roads. An estimated seven billion hours are wasted annually in traffic. And while our tailpipe emissions are one one-thousandth as dirty as fifty years ago, the average car still emits more than a pound of CO_2 for every mile traveled. With nearly 250 million registered light duty vehicles and nearly three billion vehicle miles traveled each year, the consequences add up.

Much of the looming revolution will take place at the local level: local utilities, local grids, local zoning and parking restrictions, local adoption of ride hailing apps and vehicle ownership models, locally-determined needs for EV charging and local support for autonomous vehicle services. Federally, mandates for cleaner electric grids, mandates for cleaner vehicles, and support (encouragement) for the transition to electrified vehicles are probably necessary.

In 1988, late in his career, the great Nobel-prize winning economist, F.A. Hayek, wrote: "The curious task of economics is to demonstrate to men how little they really know about what they imagine they can design." While a great deal of the future needs to be guided and defined by policymakers to accommodate and protect the social good, the vast majority of it will emerge in clumsy, chaotic ways. As bad as that may seem, it would appear to be the best path forward. The challenge for policymakers is to lower barriers, account for externalities, and overall use a light touch to ensure innovators can continue to pursue revolutionary new technologies that will transform the future of transportation.

The Future of the Auto Industry: Evolution or Revolution?

Drew Kodjak

Executive Director, International Council on Clean Transportation

The central question among transportation policy makers and the auto industry is how quickly the transition from conventional to electric vehicles (EVs) can occur. The International Council on Clean Transportation, along with several investment houses and other experts, including from Deutsche Bank, UBS, Morgan Stanley and Merrill Lynch, have projected cost parity in the 2020-2030 timeframe with variations in timing depending on the fuel prices, vehicle segments, and electric driving range. Reinforcing these reports, General Motors announced EVs could be profitable by 2021, and Volkswagen estimates EV parity with their diesel cars by 2023-2025. After reaching cost parity, Morgan Stanley forecasts 80% EVs in 2050 with annual sales of 130 million vehicles globally.

What will it take to reach cost parity and launch the transition to electric? While global sales of EVs have risen quickly from a couple hundred in 2010 to over a million in 2017, this is still 1% of world vehicle sales. The transition to electric depends on a number of factors—primarily the need to increase EV and battery sales which will increase economies-of-scale for manufacturers and associated cost reductions. One risk is that EV sales stall out before economies-of-scale drive down battery costs. This could result from premature phase-out of consumer subsidies, roll back of efficiency standards (e.g., in the U.S. and markets that follow it), or failure to enforce existing standards (e.g., Europe). Some automakers have committed to electrify, but most include hybrids in their long-term electrification plans, and even the most enthusiastic ones still seek profits from larger conventional vehicles. Short-term volatility swings on battery materials, such as cobalt and lithium, could slow cost reductions. Consistent and steady pro-EV national and local policies across major markets can largely offset these risks.

Even once cost parity is reached, an equally important question is whether mainstream consumers will find EVs as attractive as conventional vehicles. Basic forecasts assume consumers will switch quickly, but given the more diverse barriers to going electric, this is not assured. Moving beyond early adopters to the mainstream market means attracting consumers with different driving needs and preferences. For example, expectations are tied not only to upfront cost, but also range (over 300 miles for typical vehicles) and charging time (less than 5 minutes). Early EV buyers typically have home charging and are less dependent on a public charging ecosystem. Car buyers do not typically know what EV models are available or consider fuel savings in their purchase decision, so consumer education will be key. As a result, even after the necessary policy to drive up investments to achieve EV cost parity, ensuring mainstream consumers make the transition to EVs will require continued long-term support.

Electric Vehicle Growth and Manufacturer Developments

Global sales of electric vehicles have increased dramatically since the first Nissan Leaf and Chevrolet Volt models were introduced in 2011. Annual electric vehicle sales have increased at an average rate of over 60% per year from 2012 (100,000 sales) to 2017 (1.2 million sales), an unparalleled rise for any alternative fuel. Through 2017, cumulative electric vehicles around the world surpassed 3.2 million. Nearly all of these sales are in markets that have done the most to pave the way for the early market launch. Over 90% of all EV sales have been in China, Europe, and the U.S., where the most comprehensive local and national policies are in place to drive the fleet toward electric for air quality and climate change mitigation goals.

The gravity of the early EV growth is more readily seen from an industry perspective. Most major automakers are now in the EV market. Twenty automakers are each now producing more than 20,000 EVs annually. Ten companies—BAIC, BMW, BYD, Geely, GM, Hyundai-Kia, SAIC, Tesla, Toyota, Volkswagen—each had more than 50,000 in annual sales in 2017, up from five such companies in 2016. Battery suppliers are serving multiple automakers and achieving higher production scale more quickly. Six battery manufacturing companies—Panasonic, CATL, LG, Samsung SDI, BYD, and Wanxiang—each produced batteries for more than 100,000 EVs per year in 2017.

The overall scale in EVs and the number of companies manufacturing the vehicles show that this not simply the *fuel du jour* or mere pilot demonstrations. This many companies do not make this many vehicles simply to score marketing points to sell conventional vehicles (a common view among insiders regarding hybrid vehicles). They do so with the intention of being leaders in a market they expect will be profitable one day. Moreover, this shows there is a global competition underway among automakers to develop EVs and among battery suppliers to drive down the battery costs. This global competition is in part driven by sales mandates in California on other U.S. states, and more recently in China and Europe, which are forcing car makers to develop EVs and anything they can do to increase their individual market share of EVs will reduce their losses from meeting the mandates. As we point out in our recent paper, the implications of this transition to electric also plays into the industrial competitiveness for the major auto manufacturing regions around the world.[1] The risk of losing auto manufacturing, or that the powertrain shifts to electric battery production elsewhere, make governments more apt to adopt pro-EV policies beyond meeting their air quality and climate change mitigation goals.

Understanding what these EV developments mean for 2025 and beyond can be looked at from two perspectives: Automaker announcements and government goals. Many automakers have announced goals to go electric, in many cases to surpass 1 million EVs per year or over 20% of their new vehicle sales by 2025. These announcements now sum to over $160 billion and over 13 million EV sales per year by 2025 (see Table 1).[2] At the same time, governments have set their own electrification goals. Combined government policy goals from around the world amounts to annual EV sales of at least 8 million by 2025 and 20 million by 2030.[3] The

[1] Nic Lutsey, Mikhail Grant, Sandra Wappelhorst, and Huan Zhou, "Power play: How governments are spurring the electric vehicle industry," (ICCT, May 15, 2018). https://www.theicct.org/publications/global-electric-vehicle-industry

[2] Ibid.

[3] Nic Lutsey, "Global climate change mitigation potential from a transition to electric vehicles." (ICCT: December 2, 2015), https://www.theicct.org/publications/global-climate-change-mitigation-potential-transition-electric-vehicles

governments of France, Germany, the Netherlands, Norway, the United Kingdom, two Canadian provinces (Quebec, British Columbia), and eight U.S. states (California, Connecticut, Maryland, Massachusetts, New York, Oregon, Rhode Island, Vermont) have stated their intention to move to 100% EV sales in the 2025-2050 timeframe. Although automakers lobby to weaken near-term standards, their production announcements exceed 2025 policy goals, showing how industry is readying itself for the transition.

Policy Landscape for Electric Cars

The EV market as it exists today is the product of sustained policy interventions in the market. As mentioned above, three regions of China, Europe, and the U.S. represent over 90% of global EV sales. This is due to these regions each having much more comprehensive systems of regulatory, consumer incentive, and charging infrastructure policies to overcome barriers for the new technology.

In basic terms, the growth of EVs is impeded by four primary consumer barriers: Model availability, cost, convenience, and consumer awareness. Having enough EV models across different brands, vehicle types, and price points is necessary to broaden the market and sell more EVs. When automakers make more models available, they invest in marketing the benefits of EVs. Regulations, including strong efficiency regulations and especially direct ZEV (Zero Emission Vehicle) mandates, compel EV investment and deployment and thus are a prerequisite to greater model availability. As discussed above, vehicle cost is a critical attribute to sell any car, and therefore EV consumer incentives are key to temporarily lowering the upfront EV cost while battery costs are declining. Consumer questions about the convenience of EVs can be addressed by developing a robust charging ecosystem of home, workplace, and public charging. Finally, understanding about EV availability, fuel savings, and charging options can effectively be addressed through consumer awareness and education campaigns.

The top EV markets around the world have taken these consumer barriers head-on to grow the market. The U.S. provides an especially rich natural policy laboratory, with varied local policies to support markets.[4] Figure 1 illustrates how the U.S. EV market has developed with much greater concentration in a number of regions. The share of new vehicle registrations that are plug-in electric across U.S. cities varies from the highest in San Jose at 13%; to other top markets across California, Colorado, Oregon, New Hampshire, and Washington at 3% to 5%; and many others at less than 0.5%. The analysis finds that higher EV shares correlate with state consumer incentives, local promotion policies, charging infrastructure, model availability, and very likely aided by ZEV mandates. In our global analysis, we see much of the same. The "world EV capitals" including Amsterdam and Oslo in Europe, and Beijing and Shanghai in China demonstrate that similar policies to break down consumer EV barriers, tailored to the local context, are growing EV markets.[5]

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4 Preliminary results from unpublished paper. For last year's, see: Peter Slowik, Nic Lutsey, Expanding the electric vehicle market in U.S. cities (ICCT, 2017); www.theicct.org/publications/expanding-electric-vehicle-market-us-cities

5 Dale Hall, Hongyang Cui, Nic Lutsey, Electric vehicle capitals of the world: What markets are leading the transition to electric? (ICCT, 2017); www.theicct.org/publications/EV-capitals-of-the-world-2017

How Does New Mobility Tie into the EV Transition?

New mobility companies—especially ride-hailing companies such as Lyft and Uber—introduce an interesting wrinkle to these EV developments. Considering ride-hailing vehicles' use patterns and their more rapid proliferation in some cities than EVs, these vehicles offer an opportunity to accelerate the electric transition. Ride-hailing companies offer some great synergies with EVs. In some cases, ride-hailing fleets are a commercial investment, so the companies more highly value fuel savings than private drivers. Lyft and Uber drivers typically drive much more, 50,000-70,000 miles per year or 3-5 times more than private drivers. This greatly increases the annual fuel and maintenance savings, and decreases the payback period, for buying EVs. Of course, electrifying ride-hailing cars amplifies their contribution to broader city air quality and climate goals, including reduced car ownership and urban parking, and getting more people in shared rides. Considering the other burdens of these ride-hailing fleets (adding to congestion, substituting transit commuters), cities are especially keen to accelerate their shift to electric.

Increasingly, fleets around the world are beginning to sort out the purchasing, ownership, charging infrastructure, and logistics involved in the shift to electric ride-hailing. Projects in Amsterdam, Beijing, Lisbon, London, Paris, Portland, San Francisco, Shanghai, and Singapore are helping to sort out the difficulties. Key charging questions are about how and where to optimally place charging infrastructure, how much at what charging speeds is needed, and what local authority (e.g., allowing curbside and right-of-way charging, EV-ready building codes, parking, zoning) can be used. In addition, new pricing schemes are emerging, such as fees for ride-hailing vehicles that are selectively applied to combustion vehicles, that could be adapted to accelerate the shift to electric. Going much further, new mobility technologies, including sharing *and* autonomous vehicles have additional complexity and more opportunities for micro-transit and heavy-duty freight. They also have greater risk of increasing travel activity and the associated emissions due to vastly lowering the cost of transport, and, as a result, make it even more imperative to find policies to steer these vehicles toward electrification.

How Long Will Conventional Passenger Cars Continue to Dominate?

With all these EV developments, it might be tempting to think the focus should only be on EVs. However, this would be to the detriment of global climate change mitigation efforts. All the projections for all the major auto markets could move the three prime EV markets (China, Europe, U.S.) to roughly 10-20% electric share by 2025, 50% by 2035, and 100% by 2050. *Achieving this will require steadfast and herculean efforts across these regions, and remaining markets are likely to be slower yet*. This means the global vehicle fleet will continue to add roughly 90 million combusting vehicles per year through 2030. In other words, a billion *new* 2018-2030 vehicles that combust fossil fuels are a given. So, for these billion-plus new combusting vehicles, efficiency standards are a necessity to capture the potential fuel savings and CO_2 reductions from the most cost-effective technologies available.

Conventional vehicle policies can provide the most near-term reductions, while the transition to EVs provides deep long-term reductions. There appears to be no other option for governments around the world interested in reaching both mid-term (i.e., before 2035) and long-term climate goals other than to simultaneously implement the strongest possible efficiency standards while also accelerating the shift to electric. The policy lever that most effectively does "double-duty" is efficiency standards, which require the maximum incremental improvements, while also requiring that automakers make EV investments and early deployments to initiate their shift to electric.

What We Know About Other Transport Segments

While electric cars around the world are at 3 million and counting, the rest of the transport sector, except for buses, is largely just sorting out its zero-emission technology options. As indicated above, there appears to be an emerging path toward decarbonizing passenger vehicles. Although they represent a smaller fraction of global climate emissions, the electrification of bus fleets appears underway as the economics of the transition are proving to be sound and the local air quality motivation is strong.[6] However, a transition to a fully climate-friendly transport sector means decarbonizing all modes. As a result, trucks, maritime, and aviation, which each emit substantial growing carbon emissions,[7] also need to be addressed.

The next largest CO_2-emitting transport segment, freight trucks, is furthest along in developing zero-emission options. Freight trucks include commercial vans, medium duty trucks, and heavy-duty tractor-trailers. Smaller trucks and vans have the most commonality with light-duty and will greatly benefit from the same technology and policies described above. In fact, there are many incumbent manufacturers and start-ups already in this space (e.g., Nissan, Streetscooter). Heavy tractor-trailers are a greater challenge, as well as opportunity. From our recent analysis with the ZEV Alliance,[8] several intriguing technical solutions are in play. As shown in the Figure 2, similar to cars, efficiency options are available to bring mid-term reductions, and electric-drive solutions enable deep-long-term carbon cuts. To greatly simplify, there are plug-in options (as explored by Tesla, Mercedes, Cummins, BYD), a catenary overhead electric option (championed by Siemens), and a hydrogen fuel cell option (as promoted by Nikola and Toyota). The great news is that there are cost-effective solutions with per-mile cost savings for these options by 2030. But the more complex story is that the regulations are insufficient to drive this sort of result, and there will need to be massive infrastructure plans to complement each vehicle technology.

Meanwhile, deep carbonization options for the maritime and aviation applications remain more elusive. Promising technology approaches are emerging, and many of them have demonstrations, in pilot projects mostly in Europe. The ICCT's work in this is just at its early stages, as we have been commissioned by the ZEV Alliance to help scope out the state of technology based on the emerging projects. Our early findings indicate that although zero-emission options for smaller planes are proving feasible, electrification of larger commercial aircraft is still remote, requiring significant airframe modifications, improvements in electric motors and fuel cells, or transformative advances in battery technology. In the maritime sector, smaller zero-emission vessels (such as battery electric ferries) are already cost effective in certain applications, and demonstrations are underway in short-sea shipping. For longer-range applications, zero-emission pathways are less clear, but interest in hydrogen, electric, and other

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[6] Bloomberg New Energy Finance. Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO_2. https://c40-production-images.s3.amazonaws.com/other_uploads/images/1726_BNEF_C40_Electric_buses_in_cities_FINAL_APPROVED_%282%29.original.pdf?1523363881

[7] International Energy Agency, Energy technology perspectives 2017 (June 2017); www.iea.org/etp/. LDV, MDV, and HDV denote light-, medium-, and heavy-duty road vehicles, respectively.

[8] Marissa Moultak, Nic Lutsey, Dale Hall. (ICCT, July 2018). https://www.theicct.org/publications/transitioning-zero-emission-heavy-duty-freight-vehicles

novel solutions remains strong. In both the maritime and aviation cases “mid-term” solutions (including advanced liquid fuels) warrant deeper analysis and policy options to supplement incremental efficiency solutions with deep carbon reductions.

Canada's Climate Policies in a Decarbonizing World

Glen Murray

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While Canada has made significant strides in recent years with the creation and ongoing implementation of the Pan-Canadian Framework on Clean Growth and Climate Change (PCF), there is still a way to go. To close the gap in meeting our 2030 Paris Agreement commitments, all currently announced climate policies need to be rigorously implemented.

Canada, like all signatories of the Paris Agreement, has committed to lowering emissions and carbon pricing is a keystone policy as part of a comprehensive climate policy package. An anchoring piece of the PCF is the federal commitment to put a price on carbon across all Canadian jurisdictions. At the same time as Canada is committing to and taking climate action, there is a growing understanding that Canada's economy needs to diversify, and to embrace the opportunities that come with a growing clean energy sector.

Carbon pricing is an economically efficient policy tool to address rising levels of accurately measurable sources of carbon pollution. According to the High-Level Commission on Carbon Prices a well-designed carbon price is an indispensable part of a strategy for reducing emissions in an efficient way. While the U.S. federal government is not moving forwards with a price on carbon, this tool is quickly becoming the norm around the world; 65 jurisdictions are applying a price on carbon, including a growing number of U.S. states. For example, California launched its cap-and-trade program in 2013 as one of a suite of major policies to lower greenhouse gas emissions in the world's 5th largest economy. The system successfully reduced greenhouse gas emissions, and contributed to California meeting its 2020 target ahead of schedule, and is expected to reduce emissions an additional 40% by 2030. The Regional Greenhouse Gas Initiative established a cap-and-trade program in 2005 to reduce emissions from the power sector in nine participating states, which account for more than one-eighth of the U.S. population and more than one-seventh of the U.S. gross domestic product. Since 2009, the RGGI states have received $2.8 billion in proceeds from allowance auctions and disbursed them back into the economy to further promote innovation and climate mitigation. Those benefits come in addition to a more than 50% cut in emissions of carbon. With China having launched its national carbon market in December 2017, the share of global annual greenhouse gas emissions covered by a carbon price is close to 25%.

This fiscal policy approach has also emerged as a keystone element of climate policy at the provincial level in Canada. Carbon pricing has a long track record in British Columbia where it has been successful at reducing emissions while growing a strong economy and in recent years has been adopted by Quebec, Ontario and Alberta. However, the newly-elected Ontario government is moving ahead with their campaign promise to dismantle the province's cap-and-trade system.

The federal government has ensured that all Canadian provinces and territories will have a price on carbon, through the national commitment to introduce a benchmark. Announced in fall 2016, Canada is designing a national approach to carbon pricing whereby all provinces and territories must have a price on carbon by January 1, 2019. In June 2018, the senate passed the budget bill C-74 which enacts the Greenhouse Gas Pricing Pollution Act, effectively creating a permanent national carbon pricing benchmark. Jurisdictions (i.e. provinces and territories) can comply with the benchmark by designing and implementing regionally-tailored policies as long as they meet a set of minimum requirements or applying the federal backstop. More specifically, the federal requirements can be met by 1) establishing a carbon tax that meets or exceeds the federal schedule; 2) establishing a hybrid system with a carbon levy on fossil fuels and an output-based pricing system; or 3) implementing a cap-and-trade system where the cap decline rate equals 30% below the 2005 level by 2030 (i.e. equivalent to Canada's nationally determined contribution via the Paris Agreement). The Government of Canada will implement the backstop in part or in whole in any jurisdiction that does not have a system that meets the benchmark. Jurisdictions that apply their own system, and therefore manage the collection and redistribution of revenues, will have full discretion over how to best use those revenues. If a jurisdiction chooses to apply the backstop, the federal government will return the carbon pricing revenues directly to the government of the jurisdiction. This revenue can be used in a variety of ways at the discretion of the region—a key tenant of the federal framework. Should the federal government need to apply the backstop in a jurisdiction (i.e. a provincial or territorial government decides to neither implement their own system, or the federal backstop), the federal government will have the option to bypass the subnational government and return the revenues directly to households and industries.

This measure, in combination with other important climate policy measures contained within the PCF, positions Canada to be a beacon of climate progress to the world, and will help establish Canadian industries as competitors in a low-carbon global economy.

A successful national approach to carbon pricing will support Canada's economic and climate goals—and it will also likely have an impact beyond our borders, as other countries work to implement climate plans to comply with the Paris Agreement and look to peer jurisdictions for policy guidance.

As we move to a low carbon future, a price on carbon can enable jurisdictions to be more competitive in two ways: more directly by offering low carbon solutions in a global marketplace that increasingly demands these products and services, as well as indirectly, as the policy approach drives innovation which can often result in solutions that lower carbon but also lower costs through reduced energy use, more efficient processes, etc. Revenues raised through a price on carbon can replace other taxes such as income tax, or provide a source of funding for programs to reduce emissions.

The Canadian government is being very aggressive in addressing competitiveness and leakage concerns. Carbon leakage refers to a situation where a firm makes a decision to move its production out of a jurisdiction with more stringent climate policy to one with less stringent climate policy because production cost may be lower in the new jurisdiction. This results in no net emissions reductions and a loss of economic productivity in the jurisdiction that has applied more stringent climate policy. The risk of carbon leakage may be higher in certain energy-intensive industries, but specific examples of leakage have yet to be demonstrated in Canada. As an increasing number of jurisdictions apply carbon pricing, the risk of leakage is reduced. Another measure to address leakage is also to apply a border adjustment carbon price on imports.

The federal carbon pricing system, similarly to the Alberta system, is composed of an upstream charge on fossil fuels and an output-based pricing system (OBPS) meant to maintain a signal to lower emissions while protecting the small portion of Canadian industries that may be exposed to competitiveness pressures resulting from higher carbon prices at home than in competing countries. Effectively, the OBPS minimizes the risk of leakage by providing a subsidy to production, incentivizing EITE (Emissions-Intensive and Trade Exposed) firms to maintain production even as input costs go up.

The OBPS should therefore target only those sectors that can demonstrate material competitiveness pressures through both emissions intensity and trade exposure. For all the attention given to these concerns, it is important to note that the risk of leakage as a result of competitiveness pressures is often overstated. The establishment of a fair and transparent process and informed by evidence is key to the successful assessment of this risk and therefore to the overall development of the policy. Importantly, the competitiveness pressure analysis must isolate for the difference between the Canadian carbon price and the price in foreign jurisdictions and exclude the pressures caused by the array of other economic and policy factors that influence firm performance.

The Canadian government is further supporting industries in this transition through the Low Carbon Economy Challenge. Funded projects will leverage Canadian ingenuity across the country to reduce emissions and generate clean growth in support of the Pan-Canadian Framework on Clean Growth and Climate Change. To be eligible for funding, projects must deliver material, low-cost domestic greenhouse gas reductions while also encouraging other benefits that contribute to clean growth by reducing emissions, saving energy, and creating jobs.

Canada’s experience shows a price on carbon can work to lower carbon pollution, while being compatible with economic growth. In 2017, the four best performing provinces in real Gross Domestic Product growth were Alberta, British Columbia, Ontario and Quebec. These provinces also had a carbon pricing system in place that same year. Finally, in 2017 Canada led the G7 in economic growth. It was the country’s best year for job gains since 2002, with unemployment at a four-decade low .

In addition to carbon pricing, a growing renewable energy sector is critical for Canada to meet its Paris Agreement targets. Unlike the approach in the U.S., Canada has not offered nationwide incentives for renewable energy. With a set of provincial electricity grids that vary quite widely in their carbon footprint, the policies to increase renewable energy are very much at the provincial level. Canada has a number of provinces with significant renewable energy penetration. For example British Columbia, Manitoba, Quebec, Newfoundland and Labrador, Prince Edward Island, and the Yukon all have over 90% of their electricity from renewable sources (up to 100% in the case of Quebec).

Provinces that have lower amounts of renewable penetration such as Alberta, Saskatchewan, and Ontario are moving to increase renewable energy generation using the mix of tools that fits the nature of the local electricity market. For example, Alberta implemented a legislated renewable energy target, similar in some ways to the renewable portfolio standard (RPS) used in many U.S. states, and recently completed a successful first round of renewable energy procurement through a reverse auction with a “contract for difference” structure that lowers the cost of capital to deliver renewables at competitive prices while protecting consumers against windfall profits for developers.

There is a more direct effort in Canada to phase out coal-fired pollution with the implementation of a 2030 phase-out of coal-fired power. While there are a significant number of coal plants closing due to market forces in the U.S., the regulatory certainty is allowing Canada to plan for the coal-less future. Both countries have much to gain from working together on ensuring that the transition is a “just transition” by applying best practices and continuing to develop new policies and programs to support impacted workers.

In Canada as well as across the U.S., system operators are increasingly finding that renewable energy represents the lowest cost options, allowing grids to transition to lower carbon while remaining competitive .

In Canada, the other side of the equation of growing the renewable energy sector is diversifying the economy to not be as reliant on fossil fuels. In Alberta, where the vast majority of oil and gas production takes place, there is a general acknowledgement that diversification of the province’s economy to not be heavily reliant on fossil fuels is a positive thing, as it provides greater stability to the provincial economy, government revenues, and reduces the negative impacts of boom and bust economies. Across Canada, there is a lack of serious discussion among policy makers about how and if continued growth of the oil and gas industry can be consistent with Canadian progress to meet its national climate goals.

Despite the positives of diversification, the public rhetoric within Alberta (and broadly in Canada) continues to focus on the need to support the fossil fuel industry to remain “cost competitive” due to the perceived importance of the industry for Alberta’s economy, prosperity, and the general supply of jobs for workers in Alberta. This takes the form of cross party support for considerable concessions, subsidies and other allowances that further entrench the industry in the provincial economy.

However, this perspective faces international pressures, climate action and reduced fossil fuel demand that will threaten Alberta’s economic stability if the province continues to prioritize and entrench fossil fuel production and expansion as a major factor of Alberta’s economic success. Although future demand is impossible to accurately predict, an overestimation of demand may have significant implications for Alberta’s economy. The significant pressures that are challenging Alberta’s oil and gas industry include: other more competitive sources of oil and gas; shifts to alternative energy; disruptive technologies that reduce fossil fuel demand; increasing support for businesses (i.e. pensions, technology companies) to align global energy demand policies with international climate change goals (i.e. the Paris Agreement) and national obligations to align global energy demand policies with international climate change goals (i.e. the Paris Agreement).

If future international demand significantly decreases and creates an oversupply due to these pressures, Alberta’s oil and gas resources are likely to be an increasingly less attractive supply to fulfill future fossil fuel demand. This is due to Alberta oil’s high cost, low grade qualities (especially in the case of the oil sands), market constraints that significantly discounts the product, and increased competition from the U.S. markets that dampen oil prices and lower profitability. Further, as national and international climate policies are adopted and enforced, Alberta’s carbon intensive upstream products as they are currently produced will increasingly be less profitable and attractive to investors and consumers.

Canada has made important strides in recent years with the creation of the PCF. What is critical in the coming months is setting strong regulations in place for implementation—including the federal backstop on carbon pricing. To reach the Paris Agreement commitments, and to plan towards a decarbonized mid-century, Canada will need to do two things: strengthen existing policies over time, and better communicate the opportunities that come with climate action, both environmentally and economically.

Carbon Pricing in an Oil Economy: The Right (and Wrong) "Ands"

Gitane De Silva

Alberta's Senior Representative to the U.S.

The province of Alberta has the world's third largest oil reserves, comprised of the oil sands and significant traditional oil formations. Alberta also has an economy-wide $30/ton price on greenhouse gas (GHG) emissions.

Among major oil producers, Alberta and Norway are the jurisdictions with the most ambitious set of climate change policies. In Norway, Equinor (formerly Statoil), the country's largest oil producer, is predominantly state-controlled. Like the United States, private sector companies develop Alberta's oil resources. Among its global peers, Alberta stands out as an example of a large, growing, private sector-driven energy producer with an implemented price on carbon.

Implementing a price on carbon within a GHG intensive economy requires careful policy development. Governments must address impacts on short and long-term industry competitiveness, employment, and innovation while delivering emissions reductions. Achieving this balance requires finding the right set of "ands," complementary policies that mitigate risks and create a foundation for a healthy environment and economy. The Government of Alberta implemented a suite of these "ands" to strengthen Alberta's response to climate change and maintain a commitment to environmental health.

The following outlines Alberta's three major initiatives related to carbon pricing and why they may be relevant to other fossil energy-producing jurisdictions. This paper also touches on blocking energy pipelines and divestment, two policies under discussion in other jurisdictions that, in Alberta's experience, hinder the implementation of ambitious climate policy. These "ands" polarize the energy/climate debate, making progress more difficult and decreasing investment in the innovation required to reduce emissions and deliver the oil the world will need for decades to come.

The "Ands"

<u>Implementing a Competitive Carbon Price</u>

The global nature of the oil industry means that jurisdictions must remain competitive to retain and attract investment. Similar to other industrial pricing systems, Alberta's approach to carbon pricing for large industrial emitters accounts for this risk in two ways. First, the system is based on a measure of emissions intensity, or GHGs produced per unit of output. Regulating based on emissions intensity allows regulated companies to increase production while focusing on reducing emissions per unit of output, rather than constraining production by placing an emissions limit on individual facilities.

The second (and likely more important) policy is the use of an output-based allocation system through the Carbon Competitiveness Incentive Regulation. Under this system, all regulated entities receive free emission allocations up to a high performance or best-in-class benchmark emission-intensity for their sector. For example, if the benchmark emission-intensity is 50 metric kilograms (kg) of CO2 per barrel, a company emitting 25 kg per barrel would receive credits, which can be banked or sold, while a producer emitting 75 kg per barrel would have to pay the carbon price for emissions above the 50 kg benchmark[1]. As the benchmarks are generally provided on a sector-wide basis, all regulated entities have incentives to reduce emissions intensity to gain additional free credits, or catch up to the industry standard. In general, approximately 80 per cent of emissions from large industrial emitters are granted for free, while the carbon price is paid on the remaining 20 per cent. Granting free allocations ensures that industry can remain competitive with jurisdictions that do not have carbon pricing, while providing an incentive to reduce emissions. Free allocations are not unique to Alberta – the cap and trade systems in California and the European Union also grant free credit allocation to trade-exposed sectors.

Delivering Market Access

Alberta's ongoing oil production growth creates the need for access to new transportation capacity to move production to market. The controversy associated with the Keystone XL Pipeline project in the United States and the TransMountain Pipeline in Canada highlighted the fact that integrating energy with climate policies is critical to gaining regulatory approvals for new pipelines.

The most important "and" within Alberta's approach to climate policy is strong and active support for new pipelines to deliver responsibly-produced energy to market. If Alberta's companies and workers take on the costs and technical challenges associated with reducing emissions, they require the infrastructure to compete in the global market. Similarly, if other jurisdictions are concerned about the climate impacts of building oil transportation infrastructure, Alberta's robust and ambitious climate policy provides assurance. One of the suite of climate policies Alberta implemented was a hard cap on oil sands GHG emissions, giving regulators certainty that approving new pipelines would not lead to un-restrained increases in sector emissions. This new model, pairing infrastructure and climate policy, delivered federal regulatory approval for new pipeline projects to the United States and Canada's west coast.

Some critics contend that linking climate policy to new pipeline approvals is the wrong approach. They argue that stopping pipeline infrastructure is the right "and" accompanying carbon pricing because pipelines will lock-in the use of oil over the long term. Stopping pipelines is part of a broader view that oil producers, especially in wealthy, democratic jurisdictions, should stop oil production and provide a "just transition" to workers.

Historically, there is simply no precedent for governments successfully using regulation to end the activities of an industry producing a product that meets growing global demand, for which there are no available substitutes that can fully meet that demand. In Alberta's case, ending oil production would leave hundreds of thousands of workers unemployed and they would watch as other oil producers increased production to meet global demand. The

[1] The carbon levy is paid to the Government of Alberta. All of the revenue generated remains in the province and is used to fund rebates; renewable energy and electricity transition supports; energy efficiency programs; carbon reduction technologies; Indigenous climate initiatives; and green infrastructure projects.

government's ability to provide transitional support would be constrained by the loss of a major part of the Alberta economy and the scale of the assistance required. The injustice of such a policy, sacrificing workers to an uncertain future while they watch competitors step up to produce more oil, cannot be overstated.

Carbon pricing is critical to providing a framework for a truly "just transition." There are many historical examples of government advancing the public good through new regulation and financial frameworks that allow industry and workers to innovate to achieve the desired outcomes. Alberta's carbon pricing policies are premised on the belief that workers should compete, innovate and deliver new solutions as we transition to a lower-carbon economy. Allowing workers to see themselves as part of the potential solution is critical to building a social consensus around climate policies.

Those arguing for oil producing jurisdictions to "leave it in the ground" undermine the ability of governments in energy-producing jurisdictions to make the case for more ambitious climate policy. If implementing effective climate policy that allows workers to compete and innovate does not matter from a market-access perspective, then jurisdictions have a strong incentive to avoid the cost of GHG reduction and oppose climate policies.

Investing in Innovation

The other important "and" in Alberta's climate policy is a significant commitment to innovation investment. The two core ambitions within Alberta's innovation system include implementing technology at existing facilities to reduce emissions from current oil production, and creating next-generation technologies that will deliver major reductions at future facilities. Alberta supports these goals by using carbon revenue to partner with industry on technology projects and research and development. The province funds Emissions Reduction Alberta, an agency that offers support for emissions-reducing projects across multiple sectors. Alberta's research and development agency, Alberta Innovates, supports applied research focused on building next-generation technologies. Alberta has allocated $1.4 billion in technology support over seven years to ensure that Alberta's industries stay competitive in a low-carbon future.

Alberta's oil sands industry also operates the Canadian Oil Sands Innovation Alliance (COSIA), a partnership of oil sands companies that enables companies to share intellectual property related to environmental solutions. COSIA partners have shared hundreds of technologies worth more than $1 billion, and now coordinate environmental research investments to ensure progress in priority areas. All of this is done within a legal framework in compliance with Canada's anti-competitive behavior rules.

While Alberta invests in new oil technologies, some organizations advocate for divestment from oil companies as a climate policy "and." They maintain that oil will play a rapidly declining role in the global energy mix, making new oil investment unnecessary and unprofitable.

The International Energy Agency and the Energy Information Administration both project that global oil consumption will remain substantial for decades to come and, even in scenarios adopting stringent climate policy, oil will remain an industrial feedstock and energy source. Within this energy context, divesting from oil companies working to reduce the GHG emissions associated with oil production makes little sense. It is akin to divesting from Ford because it produces vehicles with internal combustion engines that generate GHG emissions. Ford has a substantial research and development budget and popular products. Over the coming years, Ford will likely reduce overall emissions by building more efficient internal combustion engines even as it develops and markets zero emission vehicles. The same is true in the energy space. Oil companies can reduce emissions through incremental improvements in production technologies even as renewable energy sources gain market share. Denying critical infrastructure or capital to oil companies capable of incremental emissions reductions within the context of today's oil-reliant energy system, even as we invest in energy transition, misses a significant opportunity for economic and energy transition, and for environmental progress.

The Alberta Experience

The space for pragmatic climate policy discussions related to fossil fuels has narrowed considerably in recent years. The "leave it in the ground" movement advocates for policies designed to reduce supply and associated consumption of fossil fuels via command and control regulations, like blocking pipelines or denying leases to energy companies. Some groups continue questioning the science of climate change, and whether western countries should adopt ambitious climate policies while Asian economies rapidly increase their emissions.

Alberta's policies represent a middle path with the following features:

- Acknowledging that fossil fuels will remain a significant energy source for decades to come.
- Driving improved environmental performance through predictable carbon pricing.
- Protecting the competitiveness of Alberta's industries.
- Supporting market access for Alberta's products.
- Investing carbon pricing revenue into emission reduction technology.

Achieving robust climate policy solutions with the support of industry and workers will require taking a middle path on questions of energy transition, competitiveness and the structure of carbon pricing. Alberta offers an example of a major energy producer that has implemented policy solutions addressing each of these issues. By 2030, Alberta expects its climate policies to achieve a reduction of 50 megatons of greenhouse gas emissions.

Alberta's policies represent an ambitious climate policy with "ands" encouraging competitiveness and innovation, all premised on a belief that Alberta industry and workers want to compete and deliver cleaner oil. "Ands" like blocking pipelines and divestment offer a dead-end for workers who are not interested in a "just transition" while they watch other countries meet global oil demand. Placing fossil energy workers at the center of climate policy rather than the periphery is critical to increasing the pace of environmental progress and crafting durable solutions.

The Northern Belt & The Arctic and Climate Change: Impacts on Agriculture, Forestry, and Commerce and Its Policy Relevance for the U.S.

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Climate Change in the U.S. and Alaska

U.S. average air temperature has risen by about 1.8ºF since 1900 (about half of this since 1970), similar to the global average warming. This is the warmest period in the history of modern civilization. Human emission of greenhouse gases (especially carbon dioxide, or CO_2) is the only mechanism that has been proposed that can explain this pattern of recent warming. Further increases of 3-12ºF are expected by the end of the century, the warming rate depending largely on future emissions of CO_2. Alaska has warmed about twice as fast as the global average and will continue to warm more rapidly than lower latitudes. Consequences of warmer temperatures in Alaska include:

- Longer growing season and longer fire season. The longer growing season improves opportunities for gardening, agriculture, and forestry, where soil moisture is adequate. However, summer drought and distance from markets make large-scale agriculture challenging.
- Greater productivity and changes in species composition of moist tundra, including more shrub growth. These vegetation changes allow expansion of moose, beaver, and other boreal animals into tundra. Forested areas are generally becoming less productive because of increasing drought stress, especially in interior Alaska, where the climate is drier.
- Winter ice roads have a shorter season of use.
- Less fuel is needed for winter heating of buildings.
- More frequent winter rains and icing events create travel hazards and make lichens less available to caribou in winter.

Policy implications. The most effective way to reduce or reverse the future rate of warming would be to reduce the concentrations of greenhouse gases in the atmosphere. The most important greenhouse gas to address is CO_2, which is responsible for the greatest amount of warming. Carbon dioxide is also the most long-lived greenhouse gas and will therefore have the most long-lasting effect on future climate. The most effective policy options for reducing CO_2 concentration are to (1) reduce rates of emissions and (2) enhance CO_2 removal by ecosystems (especially by forests and wetlands, which have a high capacity to store carbon in soils and trees). Removal of CO_2 by ecosystems can be accomplished by wetland protection, reductions in deforestation, and planting of trees (especially in cities, where the trees also reduce urban heat island effects). Technological processes for removing CO_2 from the atmosphere, such as scrubbing CO_2 from powerplant stacks and injecting it into deep geological reservoirs are being tested, but their long-term effectiveness and economic viability are uncertain. Other geoengineering approaches to climate manipulation, such as injection of sulfate aerosols into the stratosphere, are likely to create more problems than they solve. In contrast, CO_2 removal from the atmosphere directly addresses the major root cause of climate change.

Consequences of Climate Change in Alaska

Less sea ice. Because Alaska and the rest of the arctic are cold and temperature-sensitive, climate warming has large effects on arctic and boreal environments and ecosystems. The extent of late-summer sea ice has declined by 11-16% per decade and is expected to virtually disappear within 15-30 years. Decline in sea ice has several important effects:

- More rapid arctic and global warming because dark ocean waters absorb and release to the atmosphere more heat than does reflective sea ice.
- Greater coastal erosion, because of reduced coastal protection by sea ice during fall storms. This endangers life and property in many coastal communities.
- Greater opportunities for northern shipping. Greater shipping access to arctic seas reduces transport time and travel costs between Asia and Europe. It also raises safety and international security concerns. There are no deep-water ports in northern Alaska to serve as commercial ports or to harbor rescue vessels, and the U.S. has limited ice-breaker capacity to operate in arctic waters. New oil and gas exploration or mining opportunities are unlikely off of Alaska, because areas that will become ice-free are beyond the Alaskan continental shelf. Thus, Alaska experiences new risks from expanded shipping but few benefits. The Bering Strait, through which all arctic-bound shipping from the Pacific must pass, will assume greater strategic and security importance.
- More rapid warming of northern oceans with potential declines in cold-water fish (e.g., arctic cod and salmon) and northward movement of warm-water fish.
- More rapid acidification of the ocean as CO_2 enters more readily from the atmosphere. This negatively affects crabs, clams, and carbonate-dependent plankton that form the base of food webs in Alaskan waters. Arctic waters are acidifying more rapidly than non-arctic waters.
- Less habitat for ice-dependent marine mammals (e.g., polar bears, walrus, and seals) on which many coastal communities depend for food. Less access to whales. This will likely reduce the abundance of polar bears, walrus and seals and cause remaining polar bears and walrus to move onto land during summer and fall, which changes their ecology and interactions with people.
- The thinner sea ice and river ice make winter travel less safe. This makes it more difficult for rural indigenous communities to meet their subsistence needs.

Policy implications of sea ice loss. (1) Sea ice loss amplifies the rate at which global climate warms in response to human CO_2 emissions. This makes current control of CO_2 emissions more effective in minimizing climate impacts than delaying this action into the future.

(2) The coastal erosion that threatens arctic coastal communities is not one of the threats recognized by the Stafford Act as a disaster that triggers federal assistance. Consequently, communities cannot access federal funding to move to safer ground. They also cannot access funding to repair infrastructure that is damaged by repeated coastal storms because this infrastructure remains vulnerable to future flooding and erosion. In short, communities cannot move nor can they stay. The federal government has a trust responsibility to tribes that are the primary inhabitants of these coastal communities. This might imply greater federal responsibility for solving problems in Alaskan rural communities.

(3) Increasing vessel traffic in the Bering Strait and the Arctic Ocean creates new risks of pollution and ship collisions with marine mammals, for which the U.S. is currently unprepared in terms of port facilities or ice-worthy vessels. Also, since the U.S. has never signed the Law of the Sea, it cannot readily participate in treaty negotiations about economic opportunities to use the seabed of the Arctic Ocean.

(4) Changing fish distribution in the North Pacific will require adjustments in fisheries management, requiring consideration of the rights of indigenous peoples, Alaska vs. non-Alaska fishers, and U.S. vs. foreign fishers and processors. There is currently a moratorium on fishing in the formerly ice-covered Arctic Ocean, in recognition of its rapidly changing ecology. Fishing in this region and in the North Pacific doughnut hole which is not within the territorial limits of any nation (and therefore vulnerable to over-exploitation) should receive particular attention as north-Pacific and arctic fisheries change.

(5) Rising acidity of arctic waters can only be addressed by reducing CO_2 emissions, because CO_2 is the cause of the increased acidity and loss of sea ice (resulting from current warming) is the major reason that acidity is rising so quickly in the arctic.

(6) Declining populations of ice-dependent mammals creates conservation risks that will vary from place to place. Adaptation to these new conditions will require more flexible management that incorporates local knowledge. The only long-term solution is to reduce CO_2 emissions, which, through climate warming, is the cause of sea ice loss.

(7) Increased travel danger over thin sea and river ice increases risks of injuries, especially in coastal communities that are distant from major health facilities. Increasing travel risks over ice also challenge the ability of these communities to meet their subsistence food needs.

Thawing permafrost, glacier melt, and more wildfire on land. About half of Alaska is underlain by permafrost (permanently frozen ground), which strongly influences groundwater movement and therefore soil moisture and stream flow. Permafrost also influences the physical stability of soils and therefore its resistance to erosion and the stability of the ground surface to support infrastructure. These terrestrial changes have many important consequences:

- Soil instability as ice-rich permafrost thaws. This damages infrastructure such as roads and buildings, greatly increasing the cost of maintenance and repair.
- More extensive and more deeply burning wildfires, because of drier fuels (drier soils, more evaporation, and greater plant drought stress) and more lightning. This means that years with extensive wildfires will occur more frequently and extend over a longer fire season, leading to greater overlap in fire season between Alaska and the contiguous 48 states.
- Complex changes in arctic carbon cycles. Upland well-drained soils become drier and lowland boggy soils become wetter; both become warmer. Warmer soils support greater

nutrient release from decomposition of dead organic matter, supporting greater productivity where soil moisture is adequate. Generally, carbon capture by plants is greater than carbon release by decomposition, so ecosystems are storing more carbon. However, as permafrost thaws, previously frozen soils begin to decompose, releasing ancient carbon. Wildfires also release carbon as the forests burn. If the Arctic continues to warm, it seems likely that arctic and boreal ecosystems will become a source of carbon to the atmosphere.

- Thawing permafrost makes soils more vulnerable to erosion, causing an increase in river and coastal erosion, which threatens rural communities. River discharge increases in winter and decreases in summer, so rivers are shallower in summer, making summer travel more difficult.

Policy implications of permafrost loss and wildfire increase:

(1) Increased costs for infrastructure repair and maintenance will be sustained by private individuals, businesses and state and federal government. These costs will likely continue to increase as permafrost thaw accelerates.

(2) More frequent and extensive wildfires and greater overlap with the fire season in the contiguous 48 states will substantially increase costs of U.S. wildfire management. These costs are already greater than the U.S. Forest Service can support (generally half or more of its budget). Currently most of the wildfire suppression costs are associated with protection of structures rather than managing the changing ecology of fire. A radical re-evaluation of U.S. fire policy seems important. This might entail a shift of responsibility for wildfire disaster relief from the federal government to private owners (wildfire insurance requirements), changes in zoning to encourage development in fire-safe areas and discourage building in fire-vulnerable areas, and changes in fire management to reduce fire risk near communities, allowing more remote parcels to burn rather than attempting to suppress all fires.

(3) The only way to prevent arctic and boreal ecosystems from amplifying current warming trends (through increased CO_2 loss) is to reduce CO_2 emissions, so that climate will not warm so quickly. This is also the most cost-effective way to reduce vulnerability of permafrost soils to erosion. The sooner emission reductions are implemented, the more effective they will be in mitigating these risks.

Climate change is generally detrimental to human health. These effects occur for many reasons and are most pronounced in rural communities. Some health challenges directly related to environmental change include reduced air quality from wildfire smoke, food spoilage from thawing of ice cellars in permafrost, and increased injuries from more dangerous travel over sea ice and river ice. Other changes reflect damage to infrastructure from flooding and thawing permafrost, which often makes housing unhealthy and roads, rivers, and airstrips less accessible for emergency response. Finally, rapid and unfamiliar changes in a warmer climate cause psychological and cultural stress.

Policy implications of changes in human health. Many of the policy implications of changes in human health are addressed in previous sections (see discussion of infrastructure damage, wildfire smoke, increasingly hazardous travel and erosional threats to communities). In addition, there are psychological and cultural implications that are particularly pronounced in the arctic, where the changes are most rapid and where cultural and livelihood ties to the land are stronger than in many parts of the U.S.

Impacts of Arctic Change on the United States

The greatest impact of arctic change on the U.S. as a whole is the amplification of global warming by changes occurring in the arctic, as a result of sea ice melting and greater CO_2 release from terrestrial ecosystems. Consequently, the sooner and more strongly CO_2 emission reductions are implemented throughout the planet, the more effective they will be in reducing arctic amplification and the overall rate of climate change.

There has been considerable speculation that changes in arctic climate have modified detailed weather patterns in the contiguous 48 states—for example, changes in circulation patterns, frequency of storms and other extreme events. However, evidence for arctic-driven changes in fine-scale weather patterns is currently weak and should be considered speculative.

Beyond the Edge of the Grid Front: Alaska and Technological Transitions in a Niche Energy Market

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Alaska is a pioneer in the integration of high-contribution renewable energy from variable renewable resources such as wind or solar energy, as well as an early adopter of microgrid-enabling technologies. Today, Alaska has over 70 communities served by locally developed community-scale renewable energy systems, and over 250 microgrids[1] including remote, nested, and interconnected systems. This niche market has been driven by unique features of Alaska's energy paradigm—including both institutional/policy and technical/logistical characteristics—that have required novel solutions. The know-how derived from Alaska's experience is relevant to other parts of North America and the world, since increasing adoption of variable renewable energy sources as part of our primary energy supply will be key to decarbonizing global energy supply. Enabling technologies, such as microgrids, represent an important strategy for maintaining grid reliability and resiliency as we transform the way we produce, transmit, and use electric power.

Renewable Energy Development in the Arctic Region

The Arctic region as a whole leads in renewable energy technology development, with 50–60% of electric power derived from renewable resources (see Figure 1), compared with the global average of 22.8%.[2] While individual nations within the Arctic region, such as Norway[3] and Iceland,[4] have received global recognition for approaching 100% renewable energy utilization for power and heat, the Arctic region as a whole has been overlooked. This is because (1) the respective countries in the Arctic are generally considered part of North America (Alaska, Canadian Territories) or Europe (Iceland, Greenland, Norway, Sweden, Finland, and Russia) rather than a global region in and of itself; and (2) the low population density of Arctic nations

[1] The U.S. Department of Energy defines a microgrid as "a group of interconnected loads and distributed energy sources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid".
[2] REN21 Renewables Global Status Report, 2018
[3] Electricity generation in Norway is almost entirely sourced from hydropower, and significant portions of heating and transportation markets include electric heating and electric vehicles. Source: International Energy Agency Country Statistics (www.iea.org).
[4] Virtually 100% of primary energy for electricity and heating is sourced from geothermal and hydropower. Source: Iceland's National Energy Agency website (www.nea.is).

results in modest values for total installed renewable energy capacity and production compared with more populous regions.

When considering energy provisions, there is another natural division in the Arctic, demarcated by the northern edge of the continental electric grids on both continents (see Figure 2). In the European Arctic and parts of western Russia, an integrated electrical grid extends north all the way to the Arctic Ocean, but there are vast expanses of Alaska, northern Canada, Greenland, and north Central and Eastern Russia where a high proportion of remote communities are not connected to any form of central energy infrastructure (e.g., natural gas pipeline or regional electricity grid)[5]. These countries and Alaska have unique challenges related to economies of scale and the technical complexity of incorporating high-contribution levels of renewables in remote areas that have resulted in a much lower adoption rate of renewables when compared to the European Arctic. Nonetheless, there have been significant developments in the adoption of high-contribution renewable energy systems in remote communities in the Arctic, with some communities achieving instantaneous penetration levels exceeding 100% on a regular basis. These advances have centered on local microgrids, because vast distances, small population, and challenging terrain make the development of an interconnected grid practically and economically infeasible. As a result, the Arctic region has one of the highest concentrations of renewably powered microgrids in the world, with Alaska serving as one of the leaders in the field operating an estimated 10% of the total number of renewably-sourced microgrids in the world[6].

Technology Transitions and Niche Markets–Overcoming the Challenge of Remoteness

It is widely accepted that in order to meet international targets for CO_2 emission reductions, renewable energy development must become a considerable component of a sustainable global energy portfolio. However, the best renewable resources are often not co-located with population centers and, depending on the resource, are often variable and unpredictable in nature. This will require new transmission infrastructure and enhanced energy management and communications strategies on a macro scale. On a more localized scale, improved technologies and reduced cost for distributed energy systems have democratized energy production—no longer is the generation and provision of power solely the purview of utility companies, it is now hypothetically possible for any homeowner or business to install rooftop solar and become an electricity producer. In both cases, in order to transform our energy system from one that is largely reliant on baseload fossil fuel-based central power stations with a one-directional flow of power to passive consumers, to an energy system that has a high proportion of intermittent renewable energy, such as wind and solar, that are inherently unpredictable in nature and thus more challenging to integrate into the grid, a technology transition is required.

Technology transitions are defined as major, long-term technological changes in the way societal functions are fulfilled. As described above, we are currently in the midst of such a

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[5] According to the International Energy Agency, a remote community is defined as a community not connected to central energy infrastructure (*e.g.* natural gas pipeline or statewide electricity grid), which frequently results in a reliance on liquid fuels, lower quality energy supply, and higher energy costs.
[6] Based on data from the *Microgrid Deployment Tracker* published by Navigant Research. Note this estimate is based on the total number of installed systems and not installed capacity which is typically low in Alaska, reflecting the small population size of most rural communities and the state as a whole (739,800 in 2017).

transition related to the electric power industry. To facilitate this evolution, technologies and strategies that allow higher contribution of variable renewable energy generation, while improving or maintaining grid resilience and reliability, are key enablers. Microgrids, coupled with distributed generation and energy storage, are an example of the kind of enabling technologies needed to increase adoption of renewable energy.

Major technology transitions do not take place all at once—they often occur in fits and starts, and adoption rates across a population are not homogenous. Often, they are incubated in niche markets where incentives are highest due to a unique set of circumstances or needs requiring novel solutions. This is the case when it comes to renewable energy development in remote parts of Alaska. The incentive to shift to renewable sources of energy has not largely been driven by policy, but instead by market economics and the reality that the cost for importing fuel for heat and power to remote locations via complex and costly logistics results in some of the highest costs in the world for delivered power[7]. Policy instruments, such as Alaska's Renewable Energy Grant Fund[8], have been developed, but largely as a response to market demand rather than creating it. Market-driving policies, such as a state Renewable Portfolio Standard (RPS), have largely been absent. But, there are three significant institutional reasons why Alaska has become a niche market for renewably-sourced microgrid development:

1. Alaska has relatively low state and local subsidies for imported fossil fuels compared to other regions of the Arctic with a high proportion of remote communities. This has reduced market distortion and allowed renewables to be cost competitive with the status quo, which is typically diesel-based generation. When coupled with factors such as low household per capita income, high delivered energy costs[7], and high energy demand given the cold climate and seasonal darkness, there are significant incentives for shifting to locally sourced power.
2. A decentralized, private energy market dominated by not-for-profit utilities including municipally and cooperative (member-owned) utilities means decisions are often made at the local level and community members are directly engaged in decisions that impact their energy provision. In addition, because these electric utilities are deeply embedded in the fabric of the communities they serve, they often view themselves as "energy utilities" and undertake programs and policies to reduce heating costs in addition to electricity costs. This holistic approach has been critical to achieving high contribution rates of variable renewable generation since dispatchable thermal loads are a key supporting strategy.
3. Energy data on Alaska communities over the past 30 years is readily available[9] and easily accessible, including consumer price, fuel and non-fuel costs, and production

[7] The average cost of electric power for commercial users in rural Alaska is approximately $0.50/kWh, ranging from $0.09-$1.50/kWh. The highest costs are associated with communities where fuel is flown in; in most communities, barge transport is the most common delivery mechanism. Very few remote communities in Alaska are road-accessible.

[8] According to the Alaska Energy Authority Renewable Energy Fund Status Report (January 2018), the REF program has invested $257M in renewable energy projects since 2008, displacing approximately 30 million gallons of diesel fuel last year alone at an annual savings of over $60M.

[9] The most commonly used source of data is the Alaska Energy Data Gateway, managed by the University of Alaska (see www.akenergygateway.alaska.edu)

figures. This is due to reporting requirements for the Power Cost Equalization (PCE) program[10]. This data allows consumers to view information relevant not only to their own community or utility but also any other community in the state, thus creating some natural peer pressure to reduce costs.

As a result of these underlying conditions, Alaskans tend to view local energy projects favorably and with a sense of pride because locally developed projects inherently benefit the local community and usually the local community alone. There is also significant incentive to keep equipment maintained and operating, and many projects have been in service for over a decade with incremental improvements often enhancing system performance over time.

Alaska's Experience in Renewable Energy Development

Alaska is the only state in the U.S. with land in the Arctic region. Alaska has two regional electric grids: (1) the Railbelt, which serves the most populated areas of the state from Fairbanks to south of Anchorage with power generation derived from natural gas (~72%), hydropower (~20%), and coal (~8%); and (2) a smaller 100% hydropower-based grid in southeast Alaska. The rest of Alaska does not have an interconnected grid. Instead, it relies on local power stations typically using imported[11] diesel fuel to provide baseload power using diesel-electric generators. No portion of Alaska's grid infrastructure is connected to the North American electric grid that spans provincial Canada or the continental U.S. There are over 100 independent utilities in Alaska, including municipally, tribally, cooperatively, and privately owned utilities. The Power Cost Equalization Program (PCE), with an endowment of $1 billion, subsidizes the high cost of electricity for rural residential customers and public facilities, which account for an average of one-third of the electricity consumed in rural communities. Commercial and government consumers, which combined make up two-thirds of the electricity demand, do not receive any direct subsidy[10].

In addition to hydropower, Alaska has invested significantly in other renewable energy technologies and projects, many of which have benefited from the establishment of the Alaska Renewable Energy Fund in 2008[8]. Because this fund has prioritized high energy cost areas of the state, many of these renewable energy projects are small community-based systems that contribute little to Alaska's overall energy portfolio, but make a substantial difference at the local level. Alaska has more than 60 megawatts of installed wind capacity, which includes two large wind farms that supply the Railbelt grid, and approximately 40 smaller systems, the majority of which are installed in coastal areas of the western and southwestern portions of the state. Solar energy is increasing rapidly in the western and interior Alaska, and biomass fuels are commonly used for heating, with an estimated 100,000 cords of wood burned every year for residential space heating. Alaska also has a number of technology projects, including low-temperature geothermal, seawater and ground-source heat pumps, biomass combined heat-and-power, river hydrokinetics, landfill-derived natural gas, and fish oil used for boiler fuel.[12] In

[10] The PCE subsidy for rural residents based on average residential rates in urban Alaska (Anchorage, Fairbanks, Juneau) and applied to the first 500 kWhs of a rural resident's monthly electric bill. It is funded through the proceeds generated by a $1 billion endowment. The fund was originally capitalized using state revenue generated through proceeds from the oil and gas industry.
[11] While Alaska does have refineries, it is not economic to ship fuel from these refineries to most rural communities, which are mostly accessed via fuel barge during a short summer season. The majority of this fuel is sourced from western Canada.
[12] Based on data from the Alaska Energy Authority, Renewable Energy Atlas of Alaska (2013)

total, over 70 of the approximately 175 communities in Alaska have developed community-scale renewable energy projects (see Figure 3).

The primary goal for adopting renewable energy systems in rural Alaska communities is the displacement of imported fossil fuels—for both heat and power—in order to reduce local energy costs within the constraints of an operational microgrid. From this perspective, potential solutions must be economically viable and replicable. Generally speaking, Alaskans are not interested in pilot or demonstration projects although incorporating innovative system components is a common practice. Instead, these systems are expected to operate as the status quo, and thus must be self-supporting financially and robust enough to operate reliably in a remote area with minimal on-site technical expertise. This is somewhat unusual for a microgrid environment—in most cases, when a microgrid islands itself, or disconnects from the larger grid, this is in response to some sort of external disruption in service and higher costs are acceptable to maintain service within the boundaries of the microgrid. Alaska's microgrids need to perform as efficiently and economically as possible at all times, because islanded mode is the norm, not the exception. In addition, because Alaska's rural microgrids are permanently islanded, there is no option for sending excess renewables to users in other locations. Thus, from a technology standpoint, the challenge Alaskans have had to solve relates to integrating variable renewable energy on very small grids with very little inertia while maintaining grid reliability, which is inherently more challenging than such integration on a larger interconnected grid. With a central grid, as long as the percentage of intermittent resources on a grid is relatively low, the system can absorb fluctuations. Achieving this balance becomes more difficult as systems become smaller. In small grids, all typical loads are much greater relative to generation capacity and/or total demand level than in large grids. Starting a 1 kW appliance (e.g., en electric stove) in a 100 kW system is an immediate 1% load change, which requires ramping of the load-following generation. In contrast, the same 1 kW load is lost in the noise on a 100 MW grid. The same is true with generation. If a wind farm experiences a sudden gust or drop-off in wind speed, the potential impact will be much more dramatic on a small grid.

Strategies, Project Examples, and Policy Implications

Alaska utilities have adopted several general strategies to achieve their goal of reducing costs by incorporating variable renewable resources, including centralized and distributed dispatchable thermal loads, strategic use of energy storage including flywheels and battery systems, and employing innovative grid-forming strategies. Specific examples include:

1. *Dispatchable thermal loads—centralized.* Using a dispatchable load to increase the instantaneous load on a local grid has become a go-to strategy for Alaska utilities, employed in over 20 systems to date. Often, this dispatchable load is located in the powerhouse and connected to an existing space heating loop that utilizes rejected heat from the diesel generator to heat nearby community buildings such as a school, tribal hall, or washeteria. In other cases, the dispatchable load is located away from the powerhouse and provides heat to critical infrastructure. For example, in Kotzebue, the dispatchable load is an electric boiler installed in the communities' hospital resulting in the displacement of a significant amount of the facilities' heating oil requirements. In either case, the dispatchable load accommodates the temporary overproduction of wind power—up to 100% of the community load—by shunting

excess power to these dispatchable loads and avoids a requirement to curtail the resource. Note that in most other markets, dispatchable loads or interruptible loads have been used to decrease system load, whereas in Alaska it is being used to add load to the grid. This is required to maintain grid stability in these relatively low power capacity systems with intermittent renewable generation.

2. *Dispatchable thermal loads—distributed.* Some communities have installed dispatchable thermal loads in individual residences[13]. This requires a more complex control paradigm with a combination of distributed passive and/or network controls managed by the powerhouse via radio frequency connections. Thermal electric heaters, using ceramic bricks to store heat in the unit itself, are metered separately from electric power used for appliances and their power sold at a reduced rate that is cost-competitive with heating fuel oil. Thus, the benefit to individual community members is greater. Anecdotally, community members have reported up to a 2/3 reduction in heating oil consumption[14].

3. *Energy Storage.* Alaska communities have experimented with varying technologies and strategies for integrating energy storage. One of the largest battery systems in the world[15] is installed to support the Golden Valley Electric Association grid in interior Alaska. However, energy storage in rural communities, where applied, has generally been relatively modest in size and designed to replace spinning reserve[16] rather than time-shifting of energy production. Kodiak Electric Association has installed both a 3 MW Li-ion battery system to help manage variability on their 9 MW wind farm, as well as two small flywheels placed "in front of" the battery to manage inrush currents from a large electric crane in the harbor and to protect the battery from excessive charge/discharge cycles that can reduce its lifetime[17]. Combined with a storage hydro asset, these systems have allowed Kodiak Electric Association to achieve close to 100% of annual generation from renewable resources.

4. *Innovative grid-forming strategies*. One of the services provided by diesel generators is actually forming the electric grid. 'Grid-forming' means a system is able to control frequency and voltage to support operation of an islanded grid. In order to achieve very high contribution levels of renewable energy and turn off the diesel engines, an alternative grid-forming device must be incorporated into the system to provide this service in the place of the diesel generator. In most cases in Alaska where this is required, this service is provided via an inverter-based solution. However, the

[13] This strategy has primarily been pioneered by communities in the Chaninik Wind Group (Kongiganak, Kwigillingok, Tuntutuliak, and Kipnuk), in collaboration with the Alaska-based developer Intelligent Energy Systems (www.iesconnect.net).
[14] Based on interviews with residents of Kongiganak conducted by the Alaska Center for Energy and Power. A video documenting the project from the community perspective is available at: https://www.youtube.com/watch?v=90n9ga3SOQQ.
[15] The GVEA BESS is a 27MW Saft Ni-Cad system installed in 2003. At the time of its installation, it was considered to be the largest battery system installed in the world.
[16] Spinning reserve is the on-line reserve capacity that is needed to accommodate unforeseen load swings, or a rapid reduction in output from variable renewable generation. By using energy storage to replace spinning reserve in the system, utilities can operate their smallest diesel generator capable of meeting system demand, or (theoretically) turn the diesel engines off entirely when the wind resource is adequate to meet the demand.
[17] The Kodiak project has generated significant interest. An example of a story on the project can be viewed at: https://www.eenews.net/stories/1060038577

community of Saint Paul Island has operated at 100% wind power when the local resource is available for 15 years using a mechanical system, called a synchronous condenser, to form the grid and avoid using a battery and inverter to achieve diesel-off operation. While this method is reliable, it comes with a much higher loss of power to drive the synchronous condenser which is much less efficient than potential grid-forming inverter-based solutions. Nonetheless, it is an example of one of the creative solutions employed by Alaskans to reduce diesel fuel consumption.

Alaska is a niche energy market within the U.S., with a number of unique features related to the vast size of the state, low population density, and lack of an interconnected electric grid. For this reason, Alaska has had to innovate in order to integrate meaningful amounts of renewable energy in rural, remote communities where market economics present an opportunity to do so. Many of the strategies adopted by Alaska utilities and communities are applicable to other remote areas of the world, including territorial Canada. They are also equally applicable to more urban areas that are incorporating high levels of distributed renewable energy and investing in microgrids to improve system reliability. In addition to the technology solutions outlined in the previous section, there are some policy-related implications of the Alaska "model" that could be applied in other markets, including:

- *Open access to data:* Alaska has mandated that communities receiving energy subsidies report energy data on cost and electricity production and sales, and this data is made publically available on an annual basis. This creates an environment that naturally encourages operational efficiency and transition from the status quo (fossil fuels). Open access to data is particularly useful in identifying individual project opportunities as well as understanding how successful already developed systems are in displacing fossil fuels.
- *Cooperative utility model*: Alaska utilities are unusual in their small size and heavy reliance on cooperative models of government while managing both generation and distribution/transmission functions within their service area. While this sometimes reduces opportunities for economies of scale, it enables a nimbleness that is evident in their ability to act quickly and willingness to take pragmatic risks that are unusual for the typically conservative utility industry.
- *Advocacy and Outreach*: For small and/or niche markets, supportive policy and programs, including tailored funding sources, are critical. In Alaska, these policies and programs were developed largely through grass-roots efforts by stakeholders organized through an advocacy group called the Renewable Energy Alaska Project (REAP)[18]. Together with other stakeholders, REAP also led the development and implementation of energy literacy curricula across the state, reaching thousands of students since 2010[19].
- *Applied Research*: Simultaneous to an uptick in project development in Alaska a decade ago, the Alaska Center for Energy and Power (ACEP) at the University of Alaska Fairbanks developed a research program in power systems integration supporting high contribution renewable energy systems, including development of a testing laboratory that replicates a medium sized rural community at full power levels.[20] This program permits novel

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[18] REAP's website is www.alaskarenewableenergy.org.

[19] Alaska Energy Smart Curriculum – see www.akenergysmart.org

[20] For more information on ACEP's Power System Integration Program visit: http://acep.uaf.edu/programs/power-systems-integration.aspx

technologies and strategies to undergo testing prior to field deployment, and has created a strong synergy between ACEP and the utility industry including frequent research collaborations and the regular exchange of data and information.

In conclusion, the know-how and lessons learned from Alaska could help inform policies and strategies for transforming the continental electric grid and decarbonizing the global energy supply.

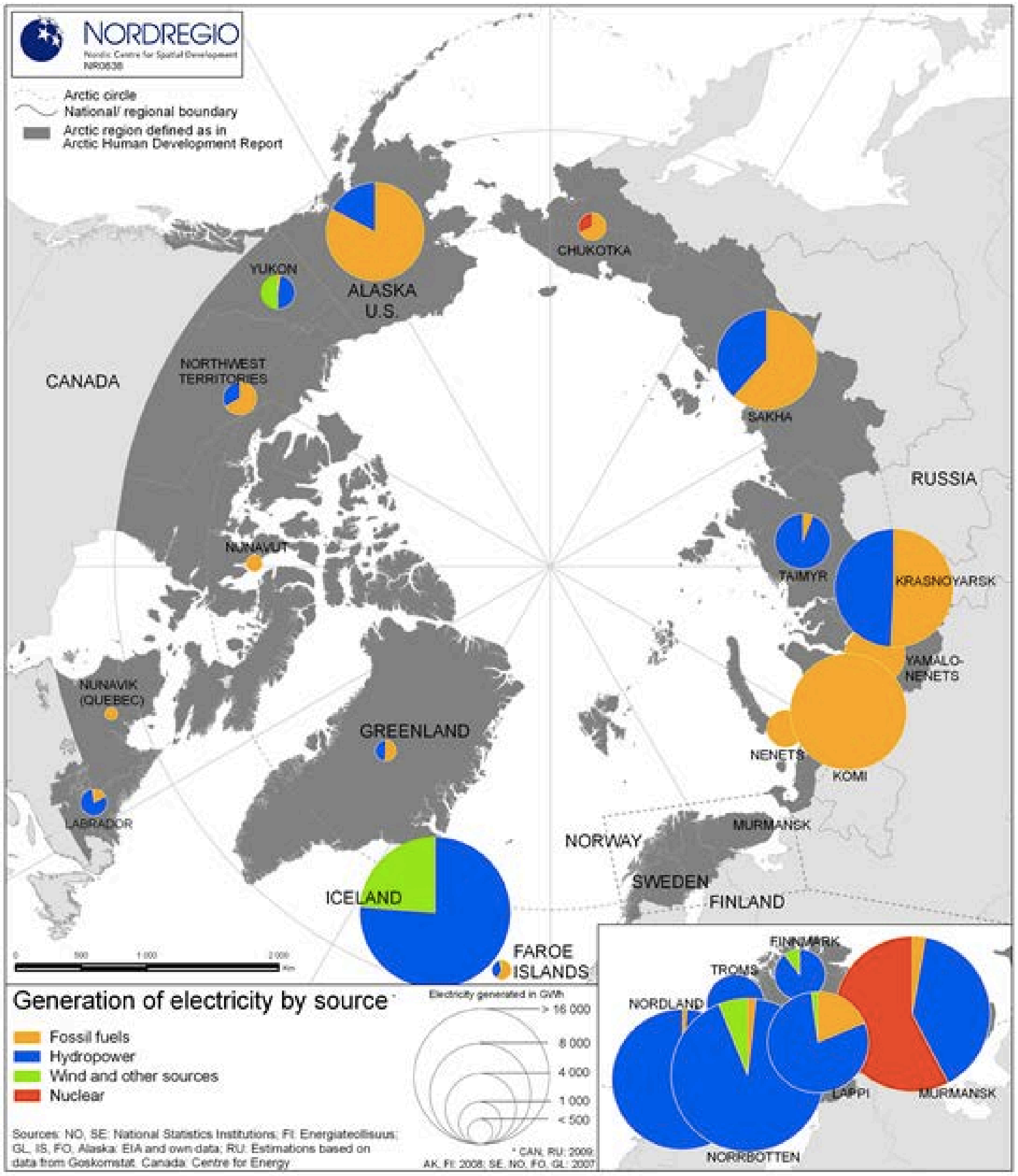

Figure 1. Map depicting generation of electricity by source for the 22 sub-national regions comprising of the Arctic. *Source: Nordic Center for Spatial Development (NORDREGIO).*

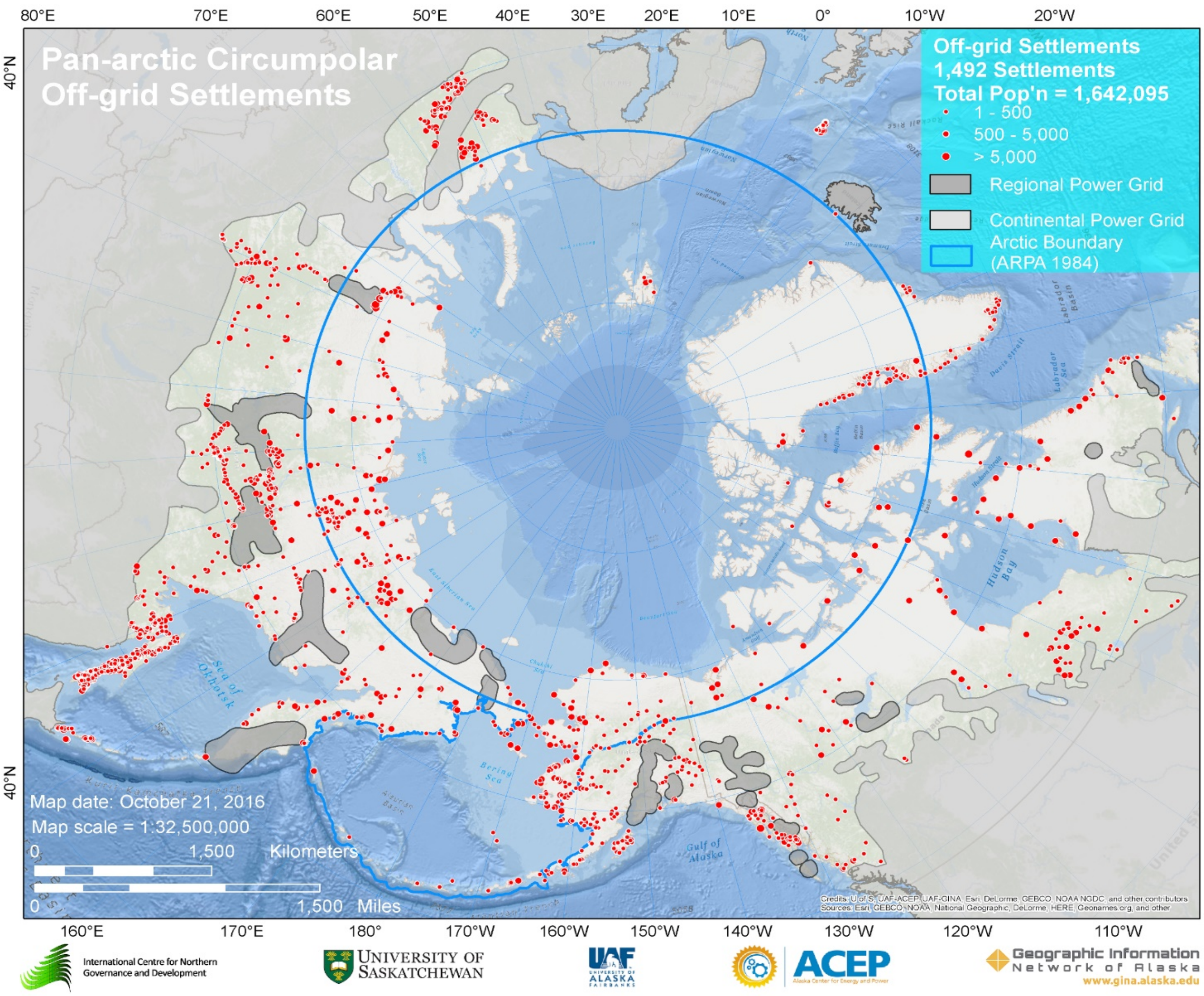

Figure 2. Map depicting regional grids and off-grid communities in the circumpolar Arctic region. *Source: Alaska Center for Energy and Power, University of Alaska Fairbanks.*

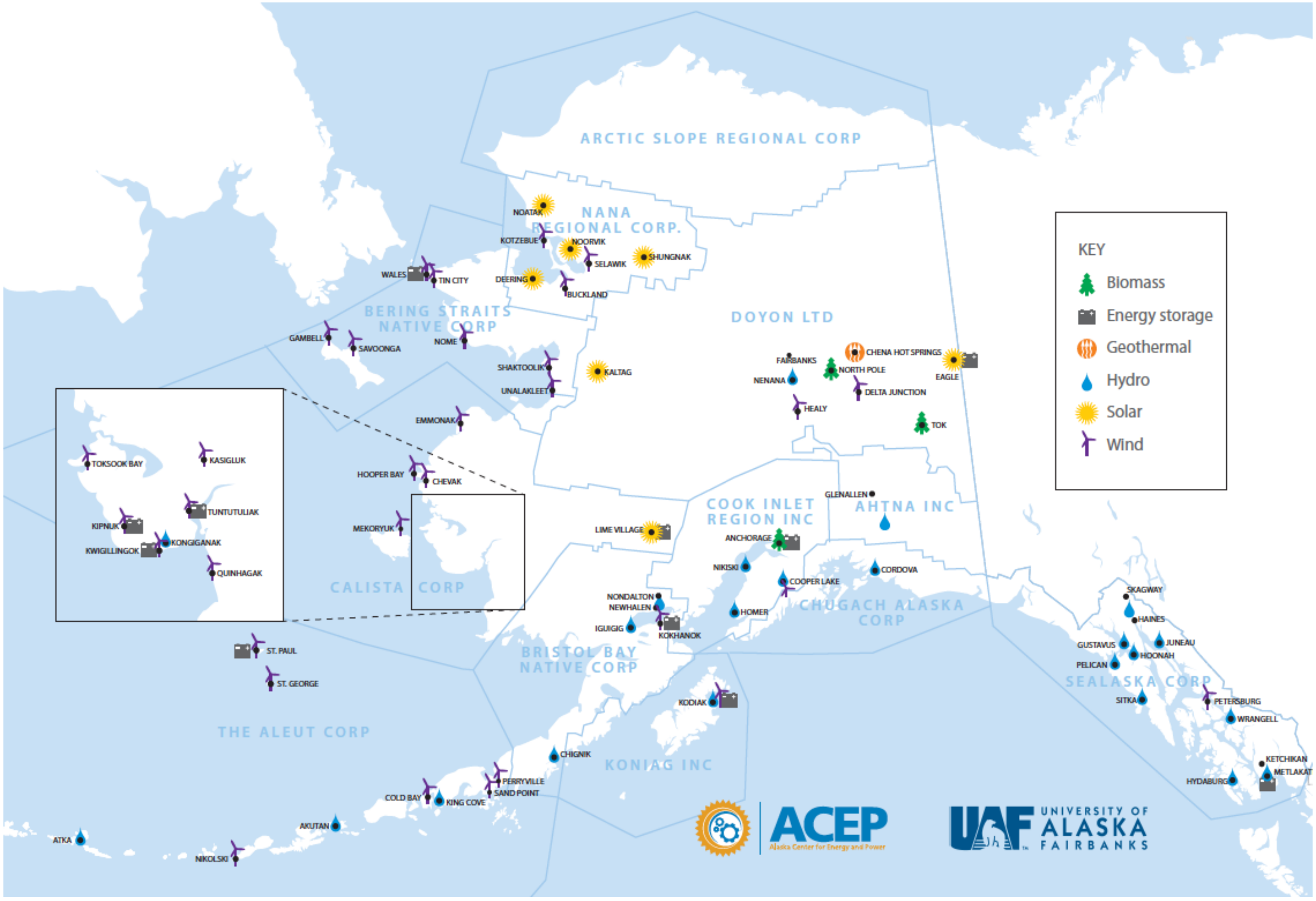

Figure 3. Map depicting renewable energy projects developed in Alaska based on technology. *Source: Alaska Center for Energy and Power, University of Alaska Fairbanks.*

Protecting and Promoting our Energy Partnership

Sergio Marchi

President and CEO, Canadian Electricity Association

It's great to have you in Canada and making the time to address issues relating to our continental energy strategy. A hugely important file.

Let me briefly touch on three matters;

First, in addressing the NAFTA talks, a little bit of bilateral context.

History has shown that the Canada-U.S. relationship has been one of the world's strongest, closest, and stable of partnerships. It has stood the test of time. But we all know that it has come under considerable stress of late;

- NAFTA negotiations have been precarious.
- Tariffs on Canadian steel and aluminum
- Measures against the Canadian aerospace sector
- Talk of hitting the Canadian dairy community
- Threats of tariffs on the Canadian auto sector.
- Misalignment on climate policy
- A differing approach to migration and human rights
- Tough criticism from your President of our Prime Minister at the recent G-7 meeting in Canada

The list is long, and its items are all substantive.

Moreover, the relationship between our Prime Minister and your President is not emblematic of the rich friendship that has characterized our relationship. And that is cause for concern.

While there will always be differences between countries and their governments, at this point, our overall collective task is to address and discuss these differences — openly, honestly, and respectfully, in an effort to shorten this list considerably. And be sure, our success or failure in this enterprise will inevitably impact the tone and chemistry of the NAFTA talks.

Second, when it comes to energy policy, the bilateral partnership has been exemplary.

Over the many years, Canada has been a trusted and reliable partner. Exporting our oil, gas, and electricity, over the many years, which has contributed mightily to your country's national energy security. Canada signed onto the security of energy supply to the U.S., which was your number one energy concern when NAFTA was established back in the early '90's. Looking specifically at electricity:

- We are joint custodians of an integrated and reliable electrical grid
- Some 30 US States trade electricity with Canada.
- Our first cross border transmission line was built in 1909. Now, 35 transmission lines travel north-south across the Canada and U.S. border. And seven more are in various stages of development, creating jobs while renewing infrastructure.
- We have developed institutions such as the North American Electric Reliability Corporation, to keep our shared grid reliable and secure from ever evolving cyber and physical threats.
- And, we help each other in times of need, providing mutual assistance in the aftermath of major storms and hurricanes.

Nothing wrong with this picture, is there?

In fact, when our Canadian Electricity Association Board visited Washington last year, as we do annually, it was four months into the Trump Administration. And in one meeting with senior officials from your National Security Council, they told us that while President Trump received a huge mandate for change, they felt an “obligation” to briefhim on the bilateral files that work well and that don’t require any wholesale change. And for them, at the top of the list, was our energy cooperation.

Thus, when it comes to dealing with energy in the NAFTA negotiations, our bilateral cooperation and experience should only be of positive influence and leverage.

Finally, when it comes to energy negotiations under NAFTA, the CEA has several priorities;

First up, do no harm.

Of course, one could and should modernize our agreements and protocols, but essentially, the energy status quo is working well. So, let us not look to fix something that is essentially not broken. CEA submitted an electricity policy brief to our negotiators before the talks began, outlining the main issues, both offensive and defensive. I then approached my U.S. counterpart, (there’s no current Mexican counterpart) the President and CEO of the Edison Electric Institute, Tom Kuhn, with the proposal of drafting and signing a joint letter to our respective negotiators, outlining our shared principals and concerns. And I am happy to say that we did that, and did so without any difficulty. The core message is that there is much that unites us, and protecting that progress, should be the first order of business

Second, Chapter 6 of the NAFTA arrangement has worked well, so let’s make sure we retain it.

We can build upon this platform further, whether it’s enhancing investor protections, skilled labor mobility, and other issues. We should also have Mexico sign as a full Party. They are ready now, given their significant energy reforms at home, and willing. Initially, the U.S. seemed determined to remove the Chapter, but they have since come around.

Third, we need to develop a North American Energy Strategy, with or without NAFTA. A continental strategy that would:

- promote energy security and affordability,

- reduce regulatory red tape,
- increase shared research & development,
- and transform North America into the world's leading and most competitive energy region, which would give our businesses a leg up on the global competition.

Fourth, we must cooperate even more closely in protecting the grid against ever increasing cyber threats.

Among the three Amigos (the leaders of the U.S., Canada, and Mexico), there can be no weak link in our chain. Secure, reliable electricity is essential for our way of life. This therefore means that protecting the system's integrity must be a top priority.

Finally, we must support infrastructure renewal through regulatory cooperation.

Powering North America's next phase of economic growth will require massive investments in grid infrastructure. The CEA would therefore welcome a joint study to identify any regulatory, resilience or security misalignment that could be ironed out through joint action

In summary, a vision for a stronger and more prosperous North America would be one where we can go beyond merely being a North American 'Free Trade Area', and instead build a North American 'Community'; a community of shared values and shared aspirations that will benefit all of our peoples.

The Changing Context for Energy: Implications for Energy Policies

Howard Gruenspecht

Senior Energy Economist, MIT Energy Initiative

The U.S. energy system is constantly evolving. Coal supplanted wood as the leading source of energy in the 19th century and was in turn supplanted by oil in the 20th century. In the latter half of the 20th century, natural gas and nuclear power became significant energy sources. Alongside these changes in the primary energy mix, electricity's share of final energy use grew steadily throughout the 20th century, replacing other fuels in buildings and industry and providing new products and services.

Both market forces and policies jointly shaped these past energy transitions and are currently driving new ones. Notably, U.S. oil and natural gas production has risen dramatically over the past decade as the combined application of horizontal drilling and hydraulic fracturing technologies enabled a 1000-fold or better increase in the contact between a well bore and hydrocarbons located in shale resources and other tight formations. A second ongoing transition involves growing reliance on wind and solar energy for electricity generation. The transportation sector, where a high proportion of travel over the past 50 years has been provided by personally owned and driven oil-fueled vehicles, is also in the early stages of transition with the emergence of ride-sharing systems, autonomous vehicle technologies, and electrification.

While the latest energy transitions can be viewed as part of a continuing process, there are some notable distinctions from earlier ones. First, while energy transitions in the 19th and 20th centuries occurred in the context of growth in overall energy use and even faster growth in electricity use, both primary energy use and electricity use in the United States have been stagnant for over a decade. The plateau in energy use reflects both the pace and direction of U.S. economic growth, widespread saturation of services that were key drivers of past growth in energy use, and also the effectiveness of both markets and policies in advancing energy efficiency. The absence of growth in overall energy use means that reductions in a given fuel's market share are now directly reflected as an absolute decline in its use.

Second, while environmental concerns have been key motivators for both past and current energy transitions, earlier issues such as soot and particulate emissions from industrial sources, urban ozone pollution (smog), and acid rain could often be addressed by adding pollution control equipment or changing fuel specifications rather than through a more fundamental shift in technologies and fuels. Mitigation of carbon dioxide emissions from fossil fuel combustion, a major driver for current energy transitions, is different. While it is technically possible to capture and sequester carbon dioxide emissions, a strategy of greatly reduced dependence on fossil fuels, which currently account for roughly 80 percent of total U.S. and global energy use is often less costly and more effective.

Third, shifts in the U.S. electricity generation mix throughout the 20th century generally involved switches among technologies and fuels capable of being dispatched by system operators to match electricity demand. The current rapid transition towards wind and solar resources, which together provided more than 8% of U.S. generation in 2017 (up from less than 1 percent in 2007), with an even more rapid increase in some states and regions, has many actual and potential advantages in terms of both environmental performance and the average cost of generation, but continuation of this trend will likely require new strategies and technologies to maintain continuous balance between electricity supply and demand. Options to supplement dispatchable technologies include electricity storage technologies, technologies or market incentives that enable electricity loads to flexibly respond to variation in generation, and greater interconnection of electricity systems to help smooth localized changes in wind speed and insolation.

Traditional electricity pricing systems recover system costs from residential customers primarily based on how much electricity is consumed over a billing period without regard to the time pattern of consumption and its relationship to generation. The same basic approach is used for non-residential customers, who often also pay a demand change based on their peak consumption. As the use of zero-fuel-cost variable renewable generation grows, this approach increasingly misaligns system cost recovery with the actual costs of providing service and also fails to encourage load to respond flexibly to variation in these non-dispatchable sources. Smart meter technology that has already been widely deployed throughout the country can facilitate the adoption of time-of-use pricing systems, which are currently being phased-in as the default for residential customers in California, or other dynamic pricing schemes that more directly reflect the balance between load and generation.

While technological options for decarbonizing electricity systems are clear, successful pursuit of the Paris Agreement goals for limiting global warming, which are still espoused by many states and localities notwithstanding the Trump Administration's intention to withdraw from that pact, would also require additional significant reductions in emissions from direct use of fossil fuel uses in transportation, buildings, and industry. The current transition in the transportation sector is still in a very early stage. One important dimension of the transition involves the electrification of light-duty vehicles and buses. While battery-powered vehicles still account for less than 1% of U.S. light duty vehicle sales as of 2017, advances in batteries and rapid cost reductions offer a path to significant electrification if widespread consumer acceptance of vehicles can be achieved. The development of extensive public recharging infrastructure is one important strategy, but how this should be done and who should pay is still unresolved.

Transportation is also changing through the increased penetration of ride sharing and autonomous vehicle technology. Ride sharing can lower overall transportation costs for many customers by cutting the fixed cost of vehicle ownership even as it raises the marginal cost of individual trips, which tends to discourage low-value trips. Autonomous driving technology can reduce accidents, enable more efficient vehicle operation, increase road capacity, and offer increased mobility to young, old, or disabled people who are incapable of driving. Autonomous vehicle technology is particularly valuable for both ride sharing and delivery applications, as it addresses challenges surrounding the cost and availability of human drivers.

A further synergy among autonomy, ride-sharing, and electrification may result from the expected high capacity factor (hours of use per day) of autonomous vehicles used in ride-sharing or delivery applications, which would accelerate the recovery of the up-front costs of electric vehicles through fuel savings. Driverless operation of ride-shared electric vehicle fleets can also enable centralized recharging on schedules that reflect aggregate ridership patterns, enabling individual travelers to make unplanned trips that might not be available from a personally-owned electric vehicle in the process of being recharged.

Transitions in transportation and the electricity system interact beyond the prospect of higher electricity sales for vehicle charging. Even with low sales penetration of electric vehicles to date, transport electrification has been the primary driver of the rapid growth in scale of battery production and a fivefold decline in the cost of lithium-ion batteries over the last seven years. Lower battery costs, in turn, are driving significant increases in recent and planned deployment of lithium ion batteries in a variety of electricity system storage applications, to provide ancillary services, capacity, energy, backup, and transmission and distribution system deferral. Projects that combine storage with wind or solar generation enable power generated at times of high renewable resource availability, when the value of electricity tends to be low, to be stored for use when higher demand and/or lower supply makes electricity more valuable. Such projects, which currently qualify for federal renewable energy tax credits for the overall project value, are already being developed as an alternative to gas-fired peaking plants to serve afternoon and evening loads.

Beyond its effect on battery costs, vehicle electrification also creates a significant amount of electricity demand for charging that may, with suitable incentives, be readily adjustable to fluctuations in wind and solar generation, providing flexibility to help balance electricity systems. In addition, vehicle batteries themselves can be an important storage resource for electricity systems. Battery and vehicle companies are already starting to consider how batteries salvaged from electric vehicles that are scrapped could find a second life as low-cost storage capacity for electricity systems. With an average battery capacity of about 70 kilowatt-hours per light duty vehicle, just 1500 vehicles could provide batteries capable of storing 100 megawatt-hours of energy. Massive amounts of vehicle to grid storage could also be made available by the owners of millions, or perhaps tens of millions, of electric vehicles in future active fleets if they are appropriately compensated for such uses.

Policy Challenges Surrounding Energy Transitions

In a well-known apocryphal tale, King Canute sets his throne by the seashore and commands the incoming tide to halt and not wet his feet and robes. Continuing to rise as usual, the tide washes over the king's feet and legs. Canute, who has staged the scene to rebuke the flattery of his courtiers, then leaps backwards, saying: 'Let all see how empty and worthless is the power of kings, for there is none worthy of the name, but God who heaven, earth, and sea obey by eternal laws.'

Notwithstanding the views of some economists, market forces do not have the status of eternal laws. However, energy policymakers must still have the judgement and humility to recognize that they, like the tides, can be very difficult to overcome. California, a leader of current efforts to promote electrified transportation in the United States, tried to implement a similar effort nearly 20 years ago, but had to retreat in the face of limitations on the availability of suitable batteries. Technology and markets can also pose challenge to policymakers who try to retard energy transitions whose time has come, as illustrated by the difficulties facing the current Administration's effort to support the U.S. coal industry.

Electric power generation is by far the dominant market for U.S. coal, accounting for between 92 to 94 percent of total U.S. coal use. Coal production and use declined dramatically over the past decade as coal's share of U.S. power generation fell from roughly 50 percent over

2005-08 to about 30 percent by 2017. With total electricity sales stagnant over this interval, the absolute level of coal-fired generation fell by 40 percent as natural gas and non-hydro renewables both gained generation share. Key factors explaining declining coal generation over the past decade include the significant reduction in natural gas prices relative to coal prices and increased generation from wind and solar, with growth in renewable generation initially driven by federal subsidies and state-level mandates but rapidly becoming more economically attractive as costs are reduced. There was little or no incremental effects from environmental regulation during this period, although the 2015-16 deadline for compliance with Environmental Protection Agency's Mercury and Air Toxics rule, which in many cases would require significant investments, did accelerate some plant retirements.

It is important to distinguish policy developments that are largely symbolic from those that could significantly affect coal use. For example, the Trump Administration is planning to replace the Clean Power Plan rule for existing fossil plants that was issued in 2015 and subsequently stayed by the Supreme Court. Analyses developed by the U.S. Energy Information Administration and others suggest that changes in the rule might slow, but not reverse, the decline in coal-fired generation.

Looking beyond the Clean Power Plan, several recent federal policy changes, including lifting a coal leasing moratorium, ending a review of royalty rates, and provision of expanded tax credits for carbon capture and sequestration (CCS) are also unlikely to improve coal's competitiveness as a fuel for domestic electricity generation. A Trump Administration proposal to require operators of wholesale electricity markets to enable full recovery of investment costs and a guaranteed return on equity to economically uncompetitive coal plant operators might have encouraged more coal-fired generation, but it was unanimously rejected by the Federal Energy Regulatory Commission.

States play a key role in many of the policy decisions that matter most for future coal use. Key state-level policies that shape the market for coal-fired generation include mandates for increased renewable generation, subsidies for generation at existing nuclear plants facing economic challenges, and energy efficiency programs that reduce electricity demand. States and regions differ significantly in their approaches and objectives, as illustrated by wide variation across the 37 states that have either a renewables mandate (29 states) or target (8 states). Policies to promote renewables or efficiency are constantly under review, with states considering proposals to either increase or reduce their stringency. Like market forces, state-level policies can either oppose or support the objectives of federal policymakers. Recent state-level enactments have generally increased mandates for renewable generation, reducing the need for generation from coal and other sources. However, some state regulators are partnering with the Trump Administration to enable some coal-fired plants to extend their operating lifetimes by reducing requirements for large investments in pollution control equipment.

Existing nuclear plants currently provide 20% of total U.S. generation. Like coal-fired plants, many nuclear generators are economically challenged by low natural gas prices, expanding renewable generation, and stagnant electricity sales. Several plants have already closed or set shutdown dates, while others have announced plans to do so unless they receive subsidies to support their continued operation. Both the Trump Administration and several states that rely heavily on nuclear power are interested in supporting existing nuclear power, albeit for different reasons, with the former motivated by concerns related to resilience and fuel security and the latter by its role as a major source of emissions-free generation. To date, Illinois, New York, and New Jersey have acted to provide zero-emission credits.

The effectiveness of energy policymaking, whether at the federal or state level, is often sensitive to the perceived durability of announced or enacted policies. Durability has been a particular challenge for federal energy policies, which have often changed dramatically with the outcome of presidential elections, as evident in the recent transitions from Clinton to Bush 43, from Bush 43 to Obama, and from Obama to Trump. Policies that are codified in legislation are inherently more durable than those implemented via executive authority or through the exercise of regulatory authority subject to wide discretion. As the Congress becomes increasingly gridlocked, successive Administrations have increasingly turned to the pen and the phone to pursue their energy priorities, with successive Administrations often acting to undo policies advanced by their predecessors. The situation is different at the state level, both because state policies are typically implemented through legislation and because energy policy preferences in many states are not subject to large changes with each election cycle.

A final set of energy transition challenges for policymakers at all levels involves implications for distribution infrastructure. Some types of energy distribution infrastructure, such as gasoline refueling pumps and stations, can adjust incrementally depending on the success of vehicles powered by alternative energy sources in increasing their share of vehicle fleets. Other legacy infrastructures, including the natural gas infrastructure used to distribute natural gas to residential and commercial buildings, could have more difficulty in rescaling as energy transitions occur. The cost of local natural gas distribution systems currently accounts for over half of the delivered cost of natural gas to buildings, which is mainly used for winter heating. Electricity already competes effectively with natural gas in many heating applications, as reflected in the rising share of buildings that use electricity as their primary heating fuel. As the electricity generation mix transitions to emissions-free sources, substitution of heat pumps and other electric technologies for natural gas furnaces in heating systems has been considered as a strategy for decarbonizing energy use in both new and existing buildings. As a transition from natural gas heating in existing buildings would likely take place over decades, local distribution systems would have to be kept in operation to serve their remaining customers even as the throughout on those systems steadily declines. Policy makers will face a significant dilemma in deciding whether distribution system costs should be borne solely by the shrinking set of customers remaining on the system or spread more widely. The former option would likely present severe affordability challenges for remaining customers, while the latter one can disincentivize customers from transitioning to cleaner energy.

Energy Policy That Drives Toward Results

Hal Harvey[1]

CEO, Energy Innovation LLC

Renewable energy and fossil fuel advocates have one thing in common – the unhealthy tendency to fall in love with a particular energy technology. Will nuclear power solve the world's problems? Are solar and wind the answer to everything? Can natural gas save the day? What about clean coal, biomass, or energy storage?

Each of these technologies has a cadre of vocal advocates, but they are all a bit myopic, because picking winners and losers based on such biases sells the country short. Technologies should be judged on their ability to power the economy in a manner that is **clean, safe, reliable, and affordable**. These universal values transcend political parties, and choices that ignore any one of these core goals fail that basic duty.

No Single Energy Technology is a Silver Bullet

Every energy technology has advantages and downsides. Policymakers must listen to energy advocates, but they must also demand tractable solutions to each technology's challenges.

Nuclear power, for example, offers tremendous energy density, and carbon-free, 24-hour power. But any honest assessment will also show profound problems—with cost, siting, waste, and nuclear weapons proliferation. If nuclear power has a future, it will only come about if these four issues are dealt with. A number of design ideas can help with each issue, but none of these have been tested, much less deployed at a reasonable cost. So the proper role for a nuclear advocate should be to be a genuine problem-solver, working to build a much more serious research and development program, rather than a one-note advocate.

Different challenges arise with solar energy and wind power. These clean energy technologies now provide the cheapest electricity ever offered, are cost-competitive with new natural gas generation, and in many regions of the U.S. building new solar and wind is cheaper than running existing coal-fired electricity generation, so that checks "clean" and "affordable" boxes. But solar and wind face issues with siting, variability, energy density, transmission, and more. Solutions exist to solve all of these problems, and each has been demonstrated somewhere, but no one has combined them for a 100 percent renewable energy grid.

Natural gas is plentiful and cheap, and remarkably accessible for heating, electricity production, and chemicals. But densely located fracking wells can threaten air and water quality, and if more than three percent of gas leaks anywhere in the system—from extraction and compression, to distribution and use—then gas is worse than coal for the climate. And even if gas leakage fell to zero, it still creates about half the carbon dioxide emissions of coal—not enough reduction to prevent global warming from reaching dangerous levels.

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Coal is perhaps the most hotly contested energy technology today, benefitting from a centuries-old system that was quite literally built around the energy source. A coal plant can run 24 hours, and the capital stock is mostly in place already. Calculations suggest enough coal reserves exist to power the world's energy systems for decades to come—but coal generates the most carbon dioxide, nitrous oxide, and sulfur dioxide emissions of any energy technology, and it is uncompetitive economically in U.S. power markets compared to natural gas and renewables: 22 gigawatts (GW) of coal-fired power plants retirements were announced in 2017, while coal power plant closures are expected to continue through 2020, and could set an all-time record in 2018.

Other energy technologies face similar biases, both in their favor and against. The key is to focus on public amenity: Energy must be reliable, safe, affordable, and clean. Set those standards, and watch innovation unfold.

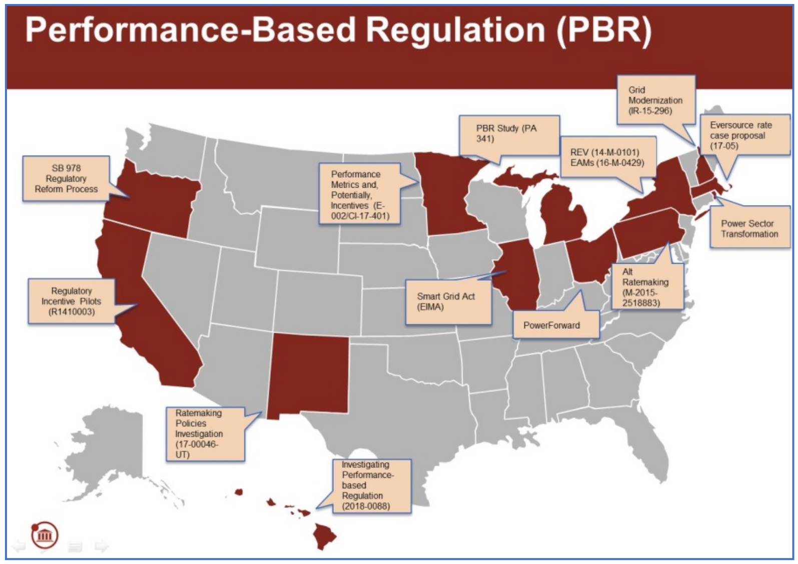
In Wyoming for example, home to 42 percent of U.S. coal output, billionaire Philip Anschutz, who owns conservative-leaning newspapers and has donated millions to Republican politicians, is building America's largest wind farm. This project will sell electricity to California via a new 700-mile transmission line, generate $8 billion in new investment, create hundreds of new construction jobs to replace lost coal mining jobs, and could herald a new economic boom for the state. A prejudice against wind power almost prevented this economic boom. Wyoming proposed a steep tax on wind power, seeking wind tax hikes from $1 per megawatt-hour to $5 (no other state taxes wind). "We don't want more wind," one state legislator reportedly said to a developer. "We want you to burn more coal." Luckily, both the developer and Wyoming's Republican governor understand that a good job is a good job, and if it comes from clean, cheap electricity production, so much the better.

No Single Energy *Policy* is a Silver Bullet, Either

Falling in love with a particular *policy* can also create blindness: Are tax credits the solution, or should one prefer energy subsidies? Should government support basic research, or applied? Do performance standards incentivize efficiency improvements, or simply raise costs? Should new technologies access markets, or should markets protect incumbents?

The intelligent way to answer these questions is, again, to test each idea against the same social goals—reliability, affordability, safety, and cleanliness. Affordability requires technology innovation and exploiting the dynamics of the free market. Clean power requires policy that puts a real value on avoiding asthma and climate change. Reliability and safety require research and development (R&D), and also a stronger alignment of both market forces and public values.

Of course, tensions exist between these goals: It may seem cheap to burn coal in an old power plant, but it is certainly not clean. And rising economic pressure from clean energy risks billions in stranded assets, which will have to be borne by utilities and their customers, just as it seemed cheap for years to buy Mideast oil until the Arab Oil Embargo laid bare our national energy security vulnerabilities. The best policies, though, hit all four goals.



For example, today at least 13 states are transforming utility business models to compensate utilities for the services they provide—rather than for the electrons they produce or the capital they deploy—through performance-based regulation (PBR).

PBR replaces capital expenditure as the key metric for success, and instead focuses utility managers on providing those core objectives. The utility uses whatever means makes the most sense to deliver the energy services consumers seek, selecting from energy efficiency and demand response, clean energy, grid upgrades, energy storage, and so on. Under PBR, utility regulators do not have to make technology choices, nor do line-by-line oversight of utility expenditures: Market incentives take care of that. Minnesota's e21 initiative shows how a collaborative PBR process can engage utilities, environmentalists, consumers, and government officials – and it has already guided several subsequent regulatory decisions including Xcel Energy's 2016-2020 rate plan.

A utility with performance incentives can "dispatch" efficiency resources to meet demand; trade power; buy fast-ramping but short-operating fossil, dispatch renewables like hydro, biomass, and geothermal that can be easily turned on and off to balance out the variability of renewables like wind and solar that cannot; install batteries; and give customers incentives to manage demand. Indeed, system optimization becomes the new utility business model in a 21st century power system, if the reward structure points the company in that direction.

A Portfolio of Essential Energy Policies

The clear lesson in technology and policy is to set ambitious goals, inscribed in policy that rewards performance, and let the dynamics of the market work toward these ends.

So what's the best way to that?

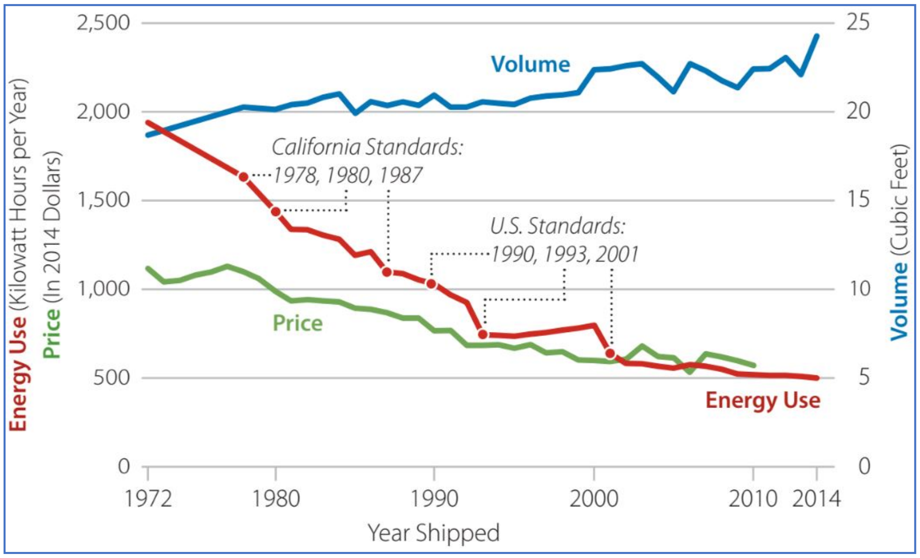
A policy portfolio including performance standards, economic signals, support for research and development, and supporting policies, is the most efficient and lowest-cost way to build an energy future. Properly designed, they reinforce and interact with one another.

A "portfolio," however, is not an excuse for a grab-bag of policies. Hundreds of policy options have little value, so the right policies must be selected for each sector, and then properly designed and implemented.

Performance Standards

Performance standards set quantitative targets at the device, fuel, or sector level. They specify what level of performance businesses or equipment must achieve, such as fuel economy standards for vehicles, or particulate emissions standards for coal power plants.

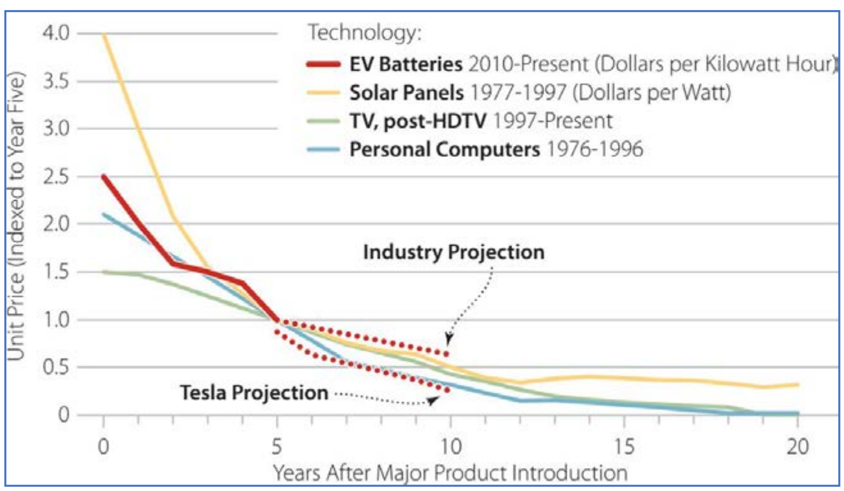
Performance standards are common and popular, in fire codes, food safety, child labor laws, water quality, air quality, and so forth. They reflect basic social values about products and the environment, and they affect business decisions and investments.



Well-designed performance standards set market guardrails, allowing competition within those guardrails, and incentivizing least-cost solutions to meet the constraint.

Performance standards are especially valuable for motivating low-cost energy efficiency reductions that are not price-responsive. For example, consumers are often uninterested in more efficient appliances or vehicles unless increased upfront prices are repaid in fuel savings in less than one or two years (i.e. they have a very high discount rate). Performance standards increase the availability and uptake of price-competitive efficient and low carbon options, making them consumer-ready.

Performance standards also spur technological innovation, because business investments take time and come with a degree of risk. For example, research that drives markedly higher fuel efficiency may cost auto manufacturers years and millions of dollars to succeed. Without long-term policy certainty, manufacturers may consider investing in that research far too risky, but with strong performance standards and a clear implementation timeline, companies have a strong incentive to invest in innovation.



Take the case of electric vehicles (EVs), widely recognized for their economic and environmental potential. Performance standards incent EV deployment because the near-term technologies are not the lowest cost options. Performance standards in California and other states have spurred huge investments in batteries, drivelines, and other technologies that are rapidly pushing down EV prices.

Performance standards have limitations, however. Many performance standards only target new products, which is a particular limitation for long-lived investments like building heating and cooling systems. They require regulators to understand the dynamic response that technology and business operations will have. Performance standards must be stringent enough to force energy innovation, but must be set so as to be cost-effective and have reasonable timing.

Economic Signals

Economic signals for climate policy come in two flavors (1) fees that discourage pollution, and (2) subsidies that encourage alternatives, such as incentives for cleaner energy or energy-efficient products.

The most widely discussed climate policy is carbon pricing, which creates a signal that radiates across all sectors of the economy, affecting both the purchase of goods and their use. It is technology neutral and generates an efficient source of revenue, which can be helpful for accomplishing other policy objectives, and it is increasingly embraced by conservatives.

Many other economic signals are similarly important. For example, power sector "feed-in tariffs" provide new technology power plants with a fixed payment for each unit of electricity they generate, and have been used to stimulate wind and solar power. Some 30 U.S. states have offered renewable portfolio standards to bring down the cost of renewable energy. EVs have enjoyed federal and state tax credits; nuclear power has had its insurance costs covered; natural gas and oil get accelerated depreciation and the deduction of intangibles.

The key in designing a good financial incentive is to make it phase down, then expire, as technology advances and prices drop. The planned phase-out of federal wind power tax credits are a good example, and should be followed across the whole suite of technologies.

Broadly speaking, economic signals are a helpful strategy for reducing emissions, but they are not a sufficient strategy either for short-run efficiency or long-run innovation. For example, well-known market failures and transaction barriers restrict the ability of economic signals to encourage adoption of low-cost – or even cost-saving – energy efficiency upgrades. Other examples include short payback horizons and inconsistent financial valuation, lack of upfront capital for investment, a failure for the investor to capture the benefits of the investment, and more. For these reasons, economic signals often work best when paired with performance standards.

Split incentives in rental properties offer a good example of the need for this combined approach: Renters pay utility bills, but owners make capital investments—such as a more efficient furnace. A landlord not paying utility bills has little reason to upgrade an apartment fitted with an inefficient water heater or refrigerator, but the renter is in no position to make a capital improvement on the building. The economic opportunity is missed, and economic signals alone won't fix it. In contrast, a good building code (a performance standard), properly enforced, can get the job done.

R&D Support

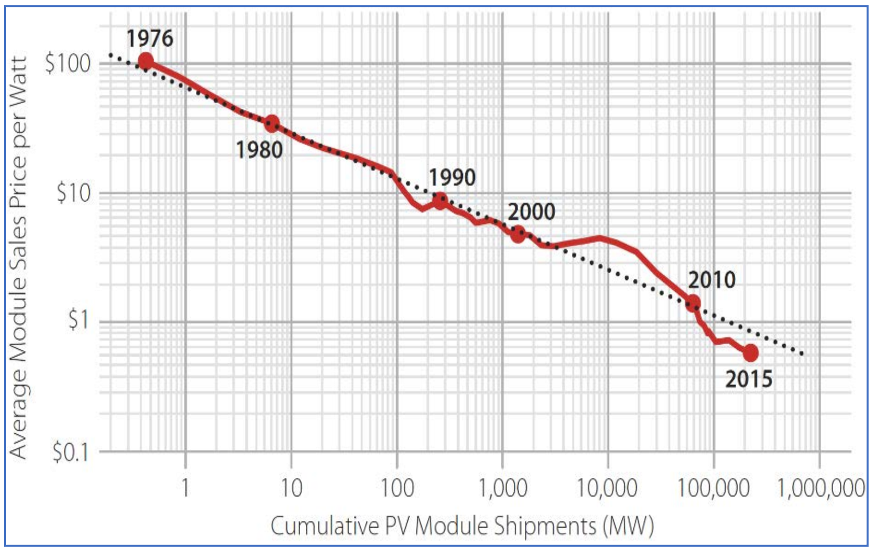
Clean technology provides valuable environmental, health, and economic benefits that are not all represented, at least in the short term, in the prices people pay in the marketplace. Similarly, technological advances from investment in R&D lower the cost of future emissions abatement, and can therefore decrease the cost of any policy portfolio.

These uncaptured spillover effects from R&D make the case for policy support, which can be direct (for example, government funding of research at universities or national laboratories) or may involve creating a policy environment that is favorable to private institutions doing their own research.

The key to deploying any technology is to achieve a decline in unit costs, which happens over the lifetime of a technology through learning in research settings, learning by doing in production and application, and economies of scale.

First, these price declines are driven by laboratory R&D, inventing and testing many iterations of a new technology. Then, in preparation for commercialization, a demonstration phase is necessary where engineering improvements help drive prices lower. As more units of the technology are deployed, price declines are driven by economies of scale and learning-by-doing.

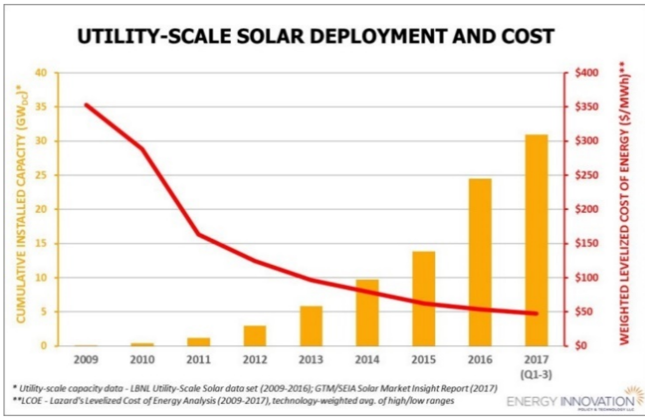
Once commercial viability is achieved with increasing market penetration, decreasing production costs follow from large-volume economies of scale and additional learning by doing. Price declines are not automatic: A technology must be actively researched (in early stages) then incrementally improved and deployed (in middle and later stages) to realize cost reductions.

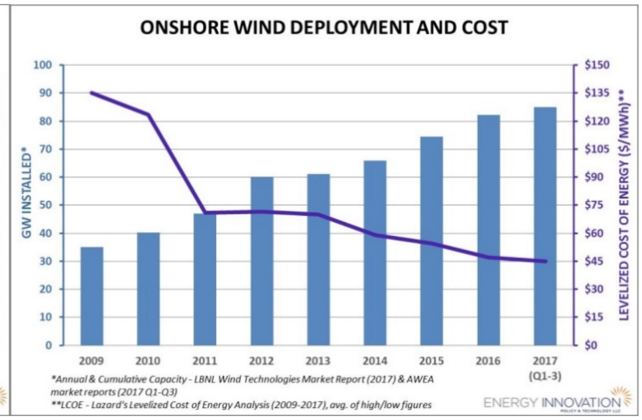


"Learning curves" describes these regular patterns of declining costs in new technologies. Information technology is famous for having exponential learning but energy technologies also exhibit regular patterns of improvement in performance and cost.

Solar energy is a good example. While it dates to the 1950s, for many years it was too expensive to be used commercially, except in very limited circumstances, such as powering satellites. The price per watt of crystalline silicon solar cells was $76.67 in 1977, but over time lab research (including learning from the semiconductor industry) drove down prices, and as prices declined, commercial applications for solar became feasible and deployment accelerated, starting a feedback loop that pushed prices down to $0.26 per watt in 2016, a 99.6 percent decline of in 39 years. This learning curve shows that every time the world's solar power has doubled, the cost of solar panels has fallen about 22 percent.

Here in the U.S., utility-scale solar costs fell from more than $350 per megawatt-hour (MWh) in 2009 to less than $50/MWh in 2017, and cumulative installations rose from 1 GW in 2009 to more than 30 GW cumulative installed capacity in the third quarter of 2017. Onshore wind costs declined from around $135/MWh in 2009 to less than $45/MWh in 2017, and cumulative installations rose from around 35 GW installed capacity in 2009 to more than 85 GW installed capacity in the third quarter of 2017.





Policy Design Principles

Selecting between the policy types discussed above is just the first step to a strong policy portfolio: Specific policies selected must be designed well to function effectively. Experience with designing and evaluating energy policy over many years has elucidated a set of policy design principles that are essential to achieve public goals.

Performance Standards

- **Create long term certainty to provide businesses with a fair planning horizon**: As a rule of thumb, in any given industry, performance standards should be known at least as many years ahead as it takes to complete a full product revision. In other words, to develop a new product, retool factories to produce it, update marketing materials, and so on. This timeframe varies by industry but will generally take between 3-10 years.
- **Build in continuous improvement**: A performance standard needs to have a mechanism for automatic tightening "built into" the law or regulation promulgating the standard so it does not become stagnant and ineffective. This might continue until the technology approaches fundamental limits, is replaced by another technology, or saturates its sector.
- **Focus standards on outcomes, not technologies:** Performance standards should be set based on desired performance outcomes rather than mandating usage of a specific technology, to give companies maximum leeway to innovate and apply solutions that achieve desired outcomes at least cost. This also reduces the burden on policymakers to keep up with technology developments in the fields they have adopted standards.
- **Prevent gaming via simplicity and avoiding loopholes:** Performance standards should be written to maximize simplicity and clarity, and to state in broad terms which targets must be achieved, rather than making exceptions or different rules for equipment with different features. Policymakers should also mandate real-world testing standards.

Economic Signals

- **Create a long-term goal and provide business certainty:** Subsidies should be generally designed to phase down over time. When possible, the endpoint or "goal" of an economic incentive should be selected and explicitly specified to help businesses understand policymaker intentions and make plans with this endpoint in mind.

- **Price in the full value of all negative externalities for each technology:** Milton Friedman persuasively argues that taxes or subsidies that reflect total social costs can find the most cost-effective ways to achieve an objective.
- **Use a price-finding mechanism**: Use a price-finding mechanism to identify the lowest incentive to achieve the desired policy objective. Let companies bid against each other for the lowest subsidy they will accept.
- **Eliminate unnecessary "soft costs"**: Continuously look for ways to streamline processes to develop technologies and reduce "soft costs" (significant regulatory inefficiencies or permitting challenges that raise costs, increase timelines, or discourage investment) and drive development for projects that achieve a desired policy objective.
- **Reward production, not investment, for technologies:** Base economic incentives on the amount of service a technology delivers, not on the amount of money invested, to ensure the incentives are only paid when the technology actually delivers.
- **Capture 100 percent of the market and go upstream or to a pinch point:** Administer economic signals as far upstream (further from the final point of sale) as possible to prevent leakage among consumers and businesses impacted by the tax.
- **Ensure economic incentives are liquid**: Economic signals offered in the form of subsidies should ensure that incentives are liquid and do not come with unnecessary transaction costs. For example, use grants or cash payments instead of tax credits, to reduce risk and complexity while ensuring government monies are used most efficiently.

  Economic Signals

- **Create long-term commitments for research success:** Ensure robust and continuous support for R&D to encourage companies to invest in the personnel and equipment needed to drive innovation.
- **Use peer review to help set research priorities:** Help guide funding priorities by bringing private sector expertise to bear on funding decision on early-stage technologies, markets, scalabilities, and other technical challenges to ensure R&D funds are spent wisely.
- **Use "state-gating" to shut down under-performing projects**: Establish certain milestones projects must hit before they are given funding, then review projects periodically to ensure they continue to be worth investing in, and defund projects that fail to meet critical milestones so resources can be reallocated.
- **Concentrate R&D by type or subject to build critical mass:** Concentrate funding on a specific initiative in more focused, granular institutions, possibly co-located with one another to empower researchers working on similar technologies to share information and collaborate efficiently.
- **Make high-quality public sector facilities and expertise available to private firms:** Allow businesses to partner with government-owned labs to conduct research together and overcome some cost barriers preventing companies from buying equipment and conducting advanced R&D. For example, Sandia National Labs helped Cummins engine develop the world's best diesel engine, using their advanced plasma technology. The environment benefits as does Cummins.

- **<u>Protect intellectual property without stymying innovation</u>:** Ensure patent systems are sufficiently strong and enforced to encourage innovation while preventing overly broad IP protections that encourage litigation and stifle innovation.
- **<u>Ensure companies can access high-level talent</u>:** Establish top-quality education programs and ensure immigration laws allow companies to hire science, technology, engineering, and mathematics talent from other countries.

Conclusion

Policymakers have many options when it comes to climate and energy policy, but these options generally fall into four categories: performance standards, economic signals, support for R&D, and supporting policies.

Performance standards set minimum performance requirements and can push more efficient and cleaner technology into the market place. They are particularly well suited to overcome significant market barriers or when information is hard to come by.

Economic signals, which either subsidize products and outcomes or tax inputs or emissions provide a strong market signal and encourage adoption of more efficient technology and less polluting behavior. They are particularly effective for industries that are highly price sensitive and where there are significant substitutes available.

Together, performance standards and economic signals reinforce one other to drive companies to innovate and produce better technology that makes its way into the marketplace and into the cars, factories, and power plants that make up the economy.

Support for R&D can lower the costs of performance standards and economic signals while making new technologies available. Supporting policies, which vary widely, are important as well, and can help increase information access and push new, more efficient technologies into use.

Performance standards, economic signals, and support for R&D are most effective when designed in accordance with a set of broadly applicable design principles. These relatively straightforward principles can help separate good policy from bad, while minimizing costs.

At the Forefront of the Clean Energy Transition

Ben Fowke

Chairman of the Board, President and CEO, XCEL Energy

Regardless of where you stand on the debate over the science of climate change, it is beyond question that global emissions of carbon dioxide pose a potential risk to the earth's climate.

Fortunately, for the utility industry, a clear path has emerged that addresses the risk of carbon emissions without compromising affordability or reliability.

Ten years ago, if you told me we could achieve more than 25 percent renewable energy on our system and still ensure the reliability that our customers have come to expect, I wouldn't have believed you.

Back in 2007, renewables only accounted for 9 percent of the energy on our system, and 4 percent of it came from hydroelectricity that had been around for decades. Wind power was still in its infancy, and solar accounted for less than one-tenth of one percent of our energy supply. Despite those low levels of renewables on our system, we were already the No. 1 utility wind energy provider in the country.

One of the great lessons I've learned as CEO of Xcel Energy is never bet against technology. In short, technology is the great enabler, and the primary reason why we're in the midst of the clean energy transition today.

Among the reasons we've been a national leader in wind energy since 2005 is our ability to successfully integrate wind onto our system and deliver it to our customers. This didn't happen by accident. It's not easy to manage the volatility of a variable resource like wind and still keep the lights on, but we can do it because we invested in some of the best wind forecasting technology in the world and proactively developed an industry-leading transmission system to bring carbon-free wind resources to the marketplace.

Technology advances are the catalyst for better equipment, falling prices and, frankly, a better environment. New wind turbines generate 50 percent more electricity than those built in 2009, and at 66 percent lower cost, according to the American Wind Energy Association.

Our decision to invest in wind energy and transition away from fossil fuels has led to a 35 percent reduction in carbon emissions since 2005 — a result far greater than what's targeted by the Paris Climate Accord. I'm pleased to report that we are on pace to reduce carbon emissions 60 percent by 2030 and have aspirations to do even more.

Excuse the pun, but it's energizing to be at the forefront of the clean energy transition. We have a great opportunity — and obligation to our customers and communities — to transform the energy supply in this country. If there is one certainty about clean energy, it's this: you can't be a clean energy leader by sacrificing affordability and reliability. You need all three components for it to work.

As I speak with stakeholders around the country, I've encountered a few myths about clean energy that I want to address for you:

Myth No. 1: Renewable energy is expensive. This is not true.

Improved technology has led to a significant decline in the cost to produce energy. If you look at the chart below, you can see that the cost to produce energy across the country has dropped significantly over the last decade.

Cost per megawatt hour		
	2007	**2017**
Universal large-scale solar	$207	$35*
Natural gas (CT)	$71	$28*
Wind	$53	$17
Coal	$18	$21

(Thermal dispatch costs. Source: EIA and LBL – *Solar and natural gas prices are 2016 numbers)

Wind energy, in particular, is less expensive than fossil fuels. As wind capacity factors continue to improve, I expect the cost of wind to remain below the cost of fossil fuels even as the tax incentives expire in the next few years.

Myth No. 2: Smaller is better. This is not true.

Scale matters — it always has and always will. It's one of the leading economic principles in a free market society and why the largest companies in the country can keep costs low for their customers.

The same concept comes into play for renewables, particularly solar. As you can see from the chart below, the cost range for the three types of solar — rooftop, community solar gardens and universal large-scale solar — vary dramatically:

Cost per megawatt hour	
Rooftop solar	$80
Community solar (third party)	$100 – $150
Universal large-scale solar	$30 – $40

(Source: Xcel Energy rates and data)

You can see that rooftop and mid-size community solar are considerably more expensive than the large-scale solar projects that we can build. Due to these overall higher prices, non-participants partially subsidize the cost for program participants. It may seem counterintuitive that community solar rates are higher than rooftop solar because community solar gardens obviously have larger scale. The reason third party-owned community solar is higher is that private developers take a large share of revenue and have successfully lobbied to keep the regulated prices higher.

As a large utility, we have the ability to take advantage of scale in large wind projects like Rush Creek, our newest wind farm in Colorado that will provide enough carbon-free energy to power approximately 325,000 homes per year when it comes online in October.

Myth No. 3: The more renewable energy you have, the better. Not necessarily.

As we all know, the wind doesn't always blow, and the sun doesn't always shine. That means we need to use additional base load energy sources like natural gas and nuclear to balance the system.

As the movement for clean energy expands, we are seeing numerous communities and businesses in our service territory pass resolutions or goals to achieve 100 percent renewable energy by a certain timeframe. This is a double-edged sword. The good news is that individual communities or businesses can hit this goal. The bad news is that 100 percent renewable energy for everyone on the grid is not plausible with current technology.

Renewable energy will continue to play a growing role on our system, but as we approach 100 percent, it becomes very expensive — to manage intermittency and build supportive infrastructure — to get to the finish line. That's why our goal at Xcel Energy is overall carbon reduction, not 100 percent renewable penetration.

Looking ahead

The power generation industry has done great work to reduce our carbon footprint in the last dozen years, and we believe we can help other industries as well. The transportation sector is now the largest carbon emitter in the country, according to the U.S. Energy Information Administration, and one ripe for its own clean energy transition.

A conventional gasoline-powered car emits 5.2 tons of carbon emissions per year. A similar electric vehicle charged on our system in 2016 emitted 1.5 tons of carbon emissions. By 2030, that number will drop to 0.4 tons as our product becomes cleaner and cleaner.

Think of the carbon-reduction possibilities with the electrification of the transportation sector.

Public policy can shape the future

One of the biggest drivers on our path forward is public policy at the local, state and federal levels. As you continue to deliberate energy policy now and into the future, I encourage you to reward carbon reduction across all sectors. We've made a lot of progress by focusing on low-priced technologies rather than increasing the cost of energy. Both state and federal policy makers should encourage and reward utilities for reducing carbon emissions and intensity while ensuring high reliability and keeping bills at or under the level of inflation.

It's also important to tackle the tough nuclear issues — in particular, used nuclear fuel storage at Yucca Mountain and encouraging innovation such as advanced nuclear fuel design and the development of small reactor technology.

As the production tax credit for wind energy begins to unwind, it's appropriate to redirect those incentives to encourage the development of the next generation of technologies: power to gas, fossil with carbon capture, dispatchable renewables and advanced nuclear, to name a few.

We also need to make it quicker and easier to build important infrastructure like natural gas pipelines and transmission lines.

We don't know exactly where technology will take us in the next 10 to 20 years, but my organization will continue to adopt technology at the speed of value. That speed can be accelerated with government investment and incentives. I suspect in the next 10-20 years we will see battery storage increasingly play a larger role on our system as the prices continue to drop. I think we will find new ways to integrate renewables and shift demand with supply. And I am sure new technologies will develop that will allow us to do even more than we thought possible.

I'm excited to see where the clean energy transition will take us next.

Ben Fowke is chairman, president and CEO of Xcel Energy, one of the largest public utilities in the country and at the forefront of the clean energy transition.

Energy Policy Challenges
For a Secure North America
Participants

August 15-19, 2018
Vancouver, British Columbia, Canada

Congressional Participants

Representative Julia Brownley

Representative Bradley Byrne
and Rebecca Byrne

Representative Earl “Buddy” Carter
and Amy Carter

Representative Lou Correa
and Esther Reynoso

Representative Ryan Costello

Representative Diana DeGette

Representative Dan Donovan
and Serena Stonick

Representative Elizabeth Esty
and Dan Esty

Representative John Garamendi
and Patti Garamendi

Representative Ann McLane Kuster
and Brad Kuster

Representative Doug Lamborn
and Jeanie Lamborn

Representative Rick Larsen
and Tiia Karlen

Representative Billy Long
and Barbara Long

Representative Alan Lowenthal

Representative Nita Lowey
and Stephen Lowey

Representative Jerry McNerney

Representative Don Norcross
and Andrea Doran

Representative Bobby Rush
and Paulette Rush

Non-Congressional Participants

Robert Bienenfeld
Assistant Vice President
Environment & Energy Strategy
American Honda Motor Company
Torrance, CA

Terry Chapin
Professor Emeritus of Ecology
Institute of Arctic Biology
University of Alaska
Fairbanks

James L. Connaughton
President & CEO
Nautilus Data Technologies
Pleasanton, CA

Gitane De Silva
Senior Representative to the U.S.
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Hal Harvey
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Gwen Holdmann
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Alaska Center for Energy & Power
University of Alaska
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Colette Honorable
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Bipartisan Policy Center
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International Council on Clean Transportation
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Sergio Marchi
CEO, Canadian Electricity Association
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Glen Murray
Executive Director
Pembina Institute
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Director, Geopolitics of Energy Project
Kennedy School of Government
Harvard University
Cambridge, MA

Carlos Pascual
Senior Vice President
Global Energy & International Affairs
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Foundation Observers

Jean Bordewich
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The William and Flora Hewlett Foundation
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Deborah Burke
Program Officer
Rockefeller Brothers Fund
New York

Sam Mar
Advisor
The Laura and John Arnold Foundation
Houston

Rapporteur

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National Science Foundation Research Fellow
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Deputy Director
Aspen Institute Congressional Program

Carrie Rowell
Conference Director
Aspen Institute Congressional Program

Pat Walton
Program Associate
Aspen Institute Congressional Program

Agenda

WEDNESDAY, August 15:

Pre-Dinner Remarks

THE GLOBAL ENERGY PICTURE AND NATIONAL SECURITY: THREATS AND OPPORTUNITIES FOR THE U.S.

The energy revolution of the past decade assisted by fracking technology has put North America into a position of energy abundance, which has transformed traditional energy and foreign policy. Concurrently, advancements in renewable energy and energy efficiency have shifted the makeup of energy consumption with implications for producers, consumers and government policy. Meghan O'Sullivan, author of *Windfall: How the New Energy Abundance Upends Global Politics and Strengthens America's Power*, will address these trends, their policy implications and what they portend for the future.

Meghan O'Sullivan*, Director, Geopolitics of Energy Project, Kennedy School of Government, Harvard University*

Working Dinner

Seating is arranged to expose participants to a diverse range of views and provide opportunity for a meaningful exchange of ideas. Scholars and lawmakers are rotated daily.

THURSDAY, August 16:

INTRODUCTION AND FRAMEWORK OF THE CONFERENCE

This conference, designed to incorporate both American and Canadian expertise, is organized into roundtable conversations and pre-dinner remarks. This segment will highlight how the conference will be conducted, how those with questions will be recognized and how responses will be timed to allow for as many questions and answers as possible. This format is important to enable full participation with so many knowledgeable and experienced people around the table.

Dan Glickman*, Executive Director, Aspen Institute Congressional Program*

Roundtable Discussion

THE ROLE OF TECHNOLOGY AND CONSUMER CHOICE IN ENERGY SUPPLY AND DEMAND

Technological developments are constantly impacting the energy industry and giving consumers a wider choice. From the use of "smart-meters" in homes, to in-home generation using competitive renewable technologies, to the advent of fracking which sparked an energy revolution in the U.S.—the continued contribution of technological improvements in the energy sector is a certainty.

- How can government best promote continued technological improvements that provides reliable, safe, resilient source of energy at an affordable cost without heavy intervention in the marketplace?
- Does the U.S. invest adequately in research and development?
- How are the responsibilities divided between public and private research?
- How does federal research bridge into the marketplace fairly without companies using public support for private gain?

Kelly Sims Gallagher, Director,
Center for International Environment & Resource Policy,
Fletcher School, Tufts University, Medford, MA
***James L. Connaughton**, President & CEO,*
Nautilus Data Technologies, Pleasanton, CA

Roundtable Discussion

THE FUTURE OF THE AUTO INDUSTRY: EVOLUTION OR REVOLUTION?

Major changes are predicted for the near future for the auto industry, with many policy implications. The U.S. and Canada are connected on many of these points with transnational manufacturing and the need to have vehicles that can comply with standards in both countries. The trends toward more electric vehicles and the emergence of autonomous cars raises many policy questions that lawmakers need to begin to consider. Should these trends be left entirely to the marketplace, or are there important roles for government? What role do states have in shaping transportation policies? For example, as California develops the next stage of its greenhouse gas standards, joined by another dozen states, will this *defacto* set a new national standard because of its market volume, and will it have a similar impact in Canada, given that over 40% of Canada's vehicle production is sold in the U.S.?

- Will better conventional vehicles dominate or will there be a rapid transition to electric vehicles?
- What role do federal passenger vehicle fuel economy standards play? Is this process effective? How do U.S. standards impact Canada?
- What impacts will Canada's carbon tax have on the U.S. market?
- What role will autonomous vehicles play, and when?
- Is there a federal role regarding needed infrastructure for widespread electric-charging of vehicles?
- Will shared—rather than owned—vehicles become more widespread, and if so, what are the implications?
- Do road building standards need adjustments for automated vehicles?
- Will urban mainstays such as parking garages and street parking become obsolete with autonomous vehicles?
- Will drivers be displaced as a profession, with commensurate impacts on the workforce?

***Robert Bienenfeld**, Assistant Vice President, Environment & Energy*
Strategy, American Honda Motor Company
***Drew Kodjak**, CEO, International Council on*
Clean Transportation, Washington, DC

Working Luncheon

Discussion continues between members of Congress and scholars on the challenges for the U.S. energy policy.

Individual Discussions

Members of Congress and scholars meet individually to discuss U.S. energy policy. Scholars available to meet individually with members of Congress for in-depth discussion of ideas raised in the morning sessions include Robert Bienenfeld, James L. Connaughton, Kelly Sims Gallagher, and Drew Kodjak.

Working Dinner
Scholars and members of Congress will explore topics covered in the conference. Seating is arranged to expose participants to a diverse range of views and provide opportunity for a meaningful exchange of ideas. Scholars and lawmakers are rotated daily.

FRIDAY, August 17:
Roundtable Discussion
CANADA'S APPROACH TO ENERGY CHALLENGES AND IMPLICATIONS FOR THE U.S.: CARBON TAXES, CARBON CAPS, OIL SANDS, PIPELINES, RENEWABLE INCENTIVES & TAX POLICY
Canada is in the process of instituting a nationwide price on carbon emissions. As the largest exporter of oil to the U.S., Canada is both in the forefront of trying to integrate policies that address pledges made in the Paris climate accords, while at the same time promoting pipelines and exploitation of oil sands.

- Why is Canada instituting carbon pricing while the U.S. has not yet taken that step—and what does this dichotomy mean for integrated cross-border commerce in energy?
- What are the motivations for Canada to institute a carbon price while it might make Canadian energy less competitive in the U.S.?
- Does lack of a carbon price give U.S. businesses a comparative advantage, or does it disadvantage American enterprises in any way?
- What is the future of the oil sands in a world of moderate oil prices?

***Glen Murray**, Executive Director, Pembina Institute, Calgary*
***Gitane De Silva**, Alberta's Senior Representative to the U.S.*

Roundtable Discussion
THE NORTHERN BELT & THE ARCTIC AND CLIMATE CHANGE: IMPACTS ON AGRICULTURE, FORESTRY, AND COMMERCE AND ITS RELEVANCE FOR THE U.S.
Climate change has had a more pronounced impact on northern climates. In Alaska the average temperature has risen at twice the average for the lower 48 states in the past six decades. This warming has positive and negative impacts which our scholars from Alaska will address.

- What are the principal effects of fast warming on the ecological and human environments in the north?
- Will warming in the north affect weather systems in the temperate or tropical latitudes?
- What are the implications of opening up the Arctic Ocean to commercial use and shipping?
- What adaptation policies can be implemented to better cope with these shifts in climate?

***Terry Chapin**, Professor Emeritus of Ecology,*
Institute of Arctic Biology, University of Alaska, Fairbanks
***Gwen Holdmann**, Director, Alaska Center for Energy and Power*
University of Alaska, Fairbanks

Working Luncheon
Discussion continues between members of Congress and scholars on the challenges for the U.S. energy policy.

Individual Discussions
Members of Congress and scholars meet individually to discuss U.S. energy policy. Scholars available to meet individually with members of Congress for in-depth discussion of ideas raised in the morning sessions include Terry Chapin, Gitane De Silva, Gwen Holdmann, and Glen Murray.

Pre-Dinner Speaker
NAVIGATING INTERSTATE REGULATIONS TO FOSTER SENSIBLE ENERGY USE
The federal government is responsible for regulating wholesale energy markets through the Federal Energy Regulatory Commission. How do legislators and regulators incentivize sensible energy use in the markets they regulate? How can interstate energy issues, such as Wyoming wind producers having challenges selling to California, be managed better? Former FERC member Colette Honorable will discuss the federal role in easing interstate commerce of energy.

***Colette Honorable**, Senior Fellow, Bipartisan Policy Center, former Federal Energy Regulatory Commission member*

Working Dinner
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SATURDAY, August 18:
Roundtable Discussion
NAFTA'S IMPACT ON ENERGY USE IN THE AMERICAS
Canada and the U.S. share the same electrical grid. There are numerous gas and oil pipelines that cross our international borders. Mexico imports large quantities of U.S. natural gas. All three countries have numerous intertwined energy connections.

- How does energy fit into the ongoing discussions of reviewing the NAFTA agreement?
- Is the cross-border commerce in energy immune from political vulnerabilities?
- How do overt or hidden subsidies of energy affect trans-border energy commerce?
- Is there merit for more explicit cooperation on energy production and consumption between Canada, the U.S., and Mexico?
- Should there be any limitations or standards regarding private sale or purchase of energy across these national boundaries?

***Carlos Pascual**, Senior Vice President, Global Energy & International Affairs, IHS Markit; former U.S. Ambassador to Mexico and Ukraine, Mexico City*
***Sergio Marchi**, CEO, Canadian Electricity Association; former Canadian Ambassador to the World Trade Organization, Ottawa*

Roundtable Discussion

CHANGING CONTEXTS FOR ENERGY
AND IMPLICATIONS FOR U.S. POLICY

A rich set of new energy supply and demand technologies is starting to disrupt conventional energy markets. Smart policy can accelerate the adoption of technologies that meet the four key consumer demands of reliability, safety, affordability, and low pollution.

- Which technologies are becoming affordable, or even cheaper than the incumbents? How will those technologies affect existing technologies and markets?
- Which policies are best designed to meet all four energy policy requirements? Which policies are most consonant with a free market driving decisions?
- How can policy ensure that the U.S. has a competitive lead in energy technology?

Howard Gruenspecht*, senior economist, MIT Energy Initiative;*
former Deputy Administrator, Energy Information Agency, Cambridge, MA
Hal Harvey*, CEO, Energy Innovation LLC, San Francisco*

Working Luncheon

Discussion continues between members of Congress and scholars on the challenges for the U.S. energy policy.

Individual Discussions

Members of Congress and scholars meet individually to discuss U.S. energy policy. Scholars available to meet individually with members of Congress for in-depth discussion of ideas raised in the morning sessions include Howard Gruenspecht, Hal Harvey, Sergio Marchi, and Carlos Pascual.

Pre-Dinner Speaker

THE FUTURE OF THE U.S. ELECTRICITY SYSTEM:
MEETING THE GOALS OF AFFORDABILITY, RESILIENCE, RELIABILITY, AND THE ENVIRONMENT

A reliable, predictable supply of electricity is a necessity of life in the 21st Century. Power outages wreak havoc, have costly consequences, and reveal a vulnerability that many think should be an anachronism. New technologies offer a rich menu of options for the electricity system, from zero-emissions power supply to a better-managed "digital grid." How is the utility business changing? What government policies can contribute to a secure and predictable delivery of electrical power? What is the best role for the federal government in the future of the electricity industry? Ben Fowke, CEO of a XCEL Energy, a major utility in the West and Midwest, will address these and other policy questions.

Ben Fowke*, Chairman of the Board, President and CEO, XCEL Energy, Minneapolis*

Working Dinner

Scholars and members of Congress will explore topics covered in the conference. Seating is arranged to expose participants to a diverse range of views and provide opportunity for a meaningful exchange of ideas. Scholars and lawmakers are rotated daily.

SUNDAY, August 19:

Participants depart Vancouver