MARCH 2019

Energy in America

The Changing Role of Energy in the U.S. Economy

AUTHORS
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A Report of the CSIS ENERGY AND NATIONAL SECURITY PROGRAM

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Executive Summary

The CSIS Energy and National Security Program, as part of its Energy in America initiative, held the first of two workshops devoted to the changing role of energy in the U.S. economy. The purpose of these workshops is twofold: to improve our understanding of the mechanisms through which energy impacts the U.S. economy at the local, regional, and national levels; and to evaluate the performance of policies designed to create economic opportunity in the energy sector. The first workshop focused on the former; a second, forthcoming workshop will focus on the latter. Participants in the first workshop were asked to consider energy's historical role in the U.S. economy and how it might change under low-carbon or high-energy-export scenarios. Workshop participants also were asked to examine the distributive impacts of energy policies and regulation, the significance of technological change and innovation, and the state of the energy community's understanding of climate impacts on local economies. Insightful papers were prepared and presented in each session and discussed at length. The workshop concluded with participants sharing their views on two major questions: what should the research community prioritize to advance our understanding of the changing role of energy in the U.S. economy; and what should policymakers better appreciate about the changing nature of energy in the U.S. economy?

What follows is a summary of that discussion, including excerpts from the papers produced to inform it and the key findings for policymakers and researchers emerging from the workshop. The workshop was conducted under Chatham House Rule and the summary report is written on a not-for-attribution basis. Under these constraints, we have identified a series of propositions, 13 in total, that we believe faithfully replicate the spirit, if not the letter, of the debate. Taken together, these propositions represent the emerging energy issues that policymakers might not be aware of and the areas where the research community could make further contributions. These propositions, which are taken up in greater detail below, are:

OIL AND NATURAL GAS DEVELOPMENT

I. The current performance of the U.S. economy appears, on net, to be less influenced by changes in the global price of oil than it historically has been;

II. The growth of domestic oil and gas production does not insulate domestic producers and consumers from international energy price developments;

III. Governments at the state and local levels frequently lack or fail to employ mechanisms to manage the cyclical extremes of energy development;

IV. Energy exports have significantly reduced the U.S. trade deficit but their ability to make further contributions is likely overstated due to export capacity constraints and countervailing increases in imports of non-energy goods and services;

COMPETITIVENESS AND INNOVATION

V. Domestic energy markets—fossil and non-fossil—increasingly will be influenced by energy and industrial policies promulgated abroad as foreign governments seek to enhance the competitiveness of their own industries;

VI. The stagnation of total domestic energy consumption over the last 15 years represents a fundamentally new context for understanding the current state and possible future of domestic energy markets;

VII. Domestic energy production and the policies that influence it are poorly suited for stimulating U.S. manufacturing activity;

VIII. Dominant narratives concerning the employment impact of a particular project or investment lack statistical rigor and can be a flawed way of assessing their value to society, but they remain an important component of local and national energy politics;

IX. Although innovation is central to the past, present, and future of the U.S. energy system, quantifying and understanding energy innovation remains fraught with difficulty;

SYSTEM TRANSFORMATION AND POLICY IMPACTS

X. Threshold effects, network effects, and other nonlinearities are poorly accounted for in contemporary studies of energy economics, and they represent a significant barrier to crafting and enacting wise energy policy;

XI. There is a disproportionate focus on the costs of carbon reduction policies, which are likely to be significantly less than the benefits;

XII. The prevalence of legacy energy infrastructure assets is likely to impede efforts to transition the nation's energy system;

XIII. Although the impact of energy policies, both current and proposed, is relatively minor on an aggregate basis, there are often considerable distributional consequences that can impede reform.

Introduction

Driven by shifts at home and abroad, U.S. production, trade, and consumption of energy has changed dramatically over the past two decades. In 2000, the United States was the world's largest energy consumer and its largest emitter of greenhouse gases—positions that it has since ceded to China in 2009[1] and 2005[2] respectively. To the great consternation of many policymakers at the time, the country seemed all but certain to increase its reliance on foreign energy supplies, with the Energy Information Administration (EIA) forecasting in 2000 that the American economy would, on a net basis, import nearly 16.9 million barrels of petroleum per day by 2020[3]—an estimate that, as of 2018, has been revised down to just less than 1.0 million barrels per day[4]. At the time, this pessimism reflected the relatively limited menu of U.S. energy options. Two decades ago, domestic oil and natural gas production was stagnating, solar and wind constituted less than one percent of the total energy mix[5], and the electric power sector was dependent on coal for 55 percent of generation[6] compared to 30 percent today.[7] Yet even with these seismic shifts, other elements remain essentially unchanged: despite rapid growth in renewables, the United States still relies on fossil fuels for the vast majority of its energy; most electricity continues to come from centralized sources; and the transportation sector still is dominated by liquid transportation fuels, with electric vehicles playing a small but growing role in the overall fleet.

It is important to reflect upon the ways in which U.S. energy trends and policy priorities are often related to the broader economic context in which they exist. For the first decade of this millennia, the global economy largely was driven by the growth of China and other emerging markets, with nearly a quarter of world GDP growth between 2000 and 2017

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1. Energy Information Administration, "International Energy Statistics," Raw Data, https://www.eia.gov/beta/international/data/browser/.
2. BP, *Statistical Review of World Energy*, Raw Data (London: BP Plc, 2017), https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.
3. Energy Information Administration, "Annual Energy Outlook," Raw Data (2000), https://www.hsdl.org/?view&did=15936.
4. Energy Information Administration, *Annual Energy Outlook with projections to 2050* (Washington, DC: EIA, 2018), https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf.
5. Energy Information Administration, "Supplement Tables to the Annual Energy Outlook 2002, Table 88 Renewable Energy Capacity, Generation, and Consumption," Raw Data (2002), https://www.eia.gov/outlooks/archive/aeo02/supplement/index.html.
6. Ibid.
7. Energy Information Administration, "Electricity Data Browser, Net Generation," Raw Data, https://www.eia.gov/electricity/data/browser/.

directly attributed to the former.[8] High commodity prices and concern over potential resource scarcity colored the U.S. perspective on its growing import dependence for energy resources like oil and natural gas. Resource scarcity also bolstered the rationale for the development of alternative energy resources such as nuclear power, biofuels, hydrogen, solar, and wind. In 2008, the global financial crisis, the Great Recession, and a decline in commodity prices created new imperatives to stimulate economic growth and reform those sectors—namely, the financial and housing markets—that posed a systemic threat to the global economy. The pre-crisis period of high prices and incentives for alternative energy, followed by several years of fiscal and economic stimulus, created an environment where renewable energy costs dropped, not only for relatively proven technologies such as wind turbines and solar photovoltaic panels, but also for their more nascent peers, including algae fuels, cellulosic ethanol, solar heat pumps, offshore wind, tidal power, and enhanced geothermal. U.S. unconventional oil and natural gas production, responsible for the largest increments of oil and gas production growth in history for several years in a row, also grew out of this period. Together, these energy and economic trends have fundamentally altered the American energy outlook from scarcity to abundance—energy is no longer assumed to be destined to be ever-more expensive and increasingly difficult to deliver but instead more readily available and from a diversified portfolio of sources.

Today, the United States and the global economic context have grown more complex. Although the world has grown more prosperous and has seen record numbers of people lifted out of abject poverty, the rise of economic inequality within developed countries has challenged political agendas around the world. In the United States, this concern typically manifests in debates over jobs and wage stagnation. Even with rates of unemployment and GDP growth that are the envy of much of the developed world, economic malaise continues to pervade much of the public discourse, with dismal long-term growth prospects for unskilled workers and a likely global economic slowdown proving particularly worrying. Energy, however, has been a source of largely good news for the U.S. economy, with cheap energy prices, an increasingly diverse pool of sources and suppliers, and—until recently—lower greenhouse gas emissions all providing a welcome exception to an otherwise bleak economic outlook. But the overriding atmosphere of economic anxiety has also altered public expectations of the role that energy should play in both the U.S. economy and society writ large. Whether as an input, an end product, or a source of externalities, energy increasingly is expected to serve as a creator of jobs and an enabler of local economic opportunity—a reality that, fair or not, is relevant for public policymakers and energy companies alike.

The U.S. energy sector will be forced to reconcile two somewhat conflicting trends. The first is the growing volume of energy exports and the country's status as a net energy exporter. The Trump administration has sought to enhance the competitiveness of U.S. hydrocarbon exports by reducing regulations, cutting taxes, and promoting bilateral export deals abroad. The second is a push—albeit one currently not emanating from the White House—to combat climate change by transitioning to a low-carbon economy. Although these two forces are not necessarily incompatible, several of the key mechanisms used

8. Exclusive of Hong Kong SAR and Macao SAR. Source: World Bank, DataBank, Raw Data, https://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.MKTP.CD&country=.

to advance them are. Most notably, many of the same federal regulations the Trump administration is rolling back to promote greater hydrocarbon exports are the same that were driving a low-carbon transition. However, a combination of factors, including the declining cost of renewable energy technology, lower-carbon business strategies throughout much of the private sector, and subnational carbon policies and incentives, continue to build support for a low-carbon transition.

Therefore, the relationship between energy and the U.S. economy likely will be influenced by the same combination of market, policy, and technological forces that are shaping it today. Before turning to the question of whether and how policymakers and companies can create more durable economic benefits from energy related policies and investment, it is important to investigate the ways in which we currently understand and analyze the possible national and regional level changes underway today and their interaction with existing policies and programs.

The following ideas summarize areas discussed at the workshop about our understanding of the ways in which the relationship between energy and U.S. economy is evolving and what that might mean not only for policymakers but also for energy experts and researchers. They fall into three categories based on the themes they represent: oil and natural gas development, competitiveness and innovation, and, finally, system transformation and policy impacts.

Oil and Natural Gas Development

Though their primacy increasingly has been challenged by the rise of alternatives, oil and natural gas continue to dominate the energy system, meeting more than 66 percent of U.S. primary energy needs[9] and attracting 40 percent of international energy investment in 2017.[10] For at least the near future, the performance of the domestic U.S. energy system will continue to be closely intertwined with the availability and stability of its oil and natural gas supplies. Although participants held a variety of views on the future relationship between oil and natural gas development and the U.S. economy, nearly all agreed that the deluge of new supplies has forced a fundamental reassessment of U.S. energy priorities. A sampling of these forces is provided below.

PROPOSITION I: The current performance of the U.S. economy appears, on net, to be less influenced by changes in the global price of oil than it historically has been.

Just as the U.S. oil market changed dramatically following the shale revolution, with production growing from 5.9 million barrels a day in 2000 to an estimated 11.9 million barrels per day in January 2019,[11] so too has the susceptibility of the U.S. economy to oil price fluctuations changed. Recent estimates of the elasticity of U.S. GDP with respect to global oil prices have ranged from -0.006 to -0.029, compared to a prevailing range of -0.012 to -0.078 from the early 1970s to early 2000s—suggesting that whereas a 10 percent increase in the price of oil used to be expected to trigger between a 0.12 percent and 0.78 percent decline in GDP, today that same 10 percent increase would lead to GDP only contracting by roughly half that, between 0.06 percent and 0.29 percent.[12]

This is unsurprising. Although American consumers generally see their purchasing power diminished by higher prices at the pump, the rise of domestic production creates—or enlarges—a countervailing section of the economy that *benefits* from price increases. As Baumeister and Killian show in their analysis of the 2014 oil price decline, although the fall in prices "produced a cumulative stimulus . . . by raising private real consumption and

9. Energy Information Administration. "U.S. Energy Facts Explained: Consumption & Production," May 16, 2018, https://www.eia.gov/energyexplained/?page=us_energy_home#tab1.
10. International Energy Agency, "Table 1.1 Energy Investment by Fuel and Region," *World Energy Investment 2018* (Paris: OECD, 2018), https://www.iea.org/wei2018/.
11. Energy Information Administration, "Weekly U.S. Field Production of Crude Oil," Raw Data (Washington DC: EIA, 2018), https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=WCRFPUS2&f=W.
12. Stephen P. Brown and Hillard G. Huntington, "Assessing the U.S. Oil Security Premium," *Energy Economics* 38 (2013): 118–127, doi: 10.1016/j.eneco.2013.03.010.

non-oil-related business investment . . . [t]his stimulative effect . . . has been largely offset by a large reduction in real investment by the oil sector."[13] Further evidence of the increasing insulation of U.S. GDP from oil prices also can be seen in the decline of U.S. oil expenditures. Although the country consumes almost as much oil as ever—19.96 million barrels per day in 2016, compared to an all-time high of 20.80 in 2005—the bill for that oil has fallen in both absolute and relative terms, with oil expenditures declining from $596.3 billion (or 4.6 percent of GDP) to $548.3 billion (or 2.9 percent of GDP) over the same 2005 to 2016 period.

Some economists have argued, however, that a more inelastic domestic GDP-to-oil relationship could have resulted also from the confluence of less immediately relevant factors. As Krupnick et al. point out in their research, the differences between these estimates may reflect secular changes to the structure of the economy such as "increased global financial integration, greater flexibility of the US economy . . . reduced energy intensity . . . increased experience with energy shocks, and improved monetary policy." They also suggest that the changes might be because of improvements in macroeconomic modeling, particularly with advances in "dynamic stochastic general equilibrium (DGSE) models and extracting macroeconomic oil price shocks from time series data."[14]

The sensitivity and vulnerability of the U.S. economy to oil price variation is important because some of the most significant shifts in federal energy policy historically have occurred as a reaction to oil market crises and the fear that volatile prices might impede economic decision-making. Examples include the 1973 OPEC embargo's triggering of the Carter administration's pivot to conservation, efficiency standards, and petroleum alternatives and the Great Recession's precipitation of both the American Recovery and Reinvestment Act of 2009 and the push for more stringent vehicle efficiency and emissions standards promulgated in the early part of the Obama administration.

One potential consequence raised during the workshop was if the U.S. economy as a whole is less dependent on the vagaries of global energy prices, then it stands to reason that the priorities of both U.S. foreign policy and U.S. energy policy could shift, with the former concerned less with the stability of global oil markets—though not completely detached—and the latter possibly deemphasizing the relative importance of developing fossil fuel alternatives for energy security reasons. Workshop participants did not, however, universally support this theory, not least because U.S. foreign policy priorities are set by more than energy considerations—although it was acknowledged as a familiar refrain in policy circles. The theory also was assailed on economic grounds by a handful of participants, who noted that although the U.S. economy was more insulated from global price shocks, it was not completely immune and that the United States was unlikely to achieve the capacity levels needed to allow it to completely offset a significant supply disruption elsewhere in the world by boosting its own production. This suggests that **efforts to minimize oil-related expenditures and coordinate emergency oil stockpiles still are likely to be worth pursuing.**

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13. Christiane Baumeister and Lutz Kilian, "Lower Oil Prices and the U.S. Economy: Is This Time Different?", Brookings Papers on Economic Activity, Brookings Institute, Fall 2016, https://www.brookings.edu/bpea-articles/lower-oil-prices-and-the-u-s-economy-is-this-time-different/.
14. Alan Krupnick et al., "Oil Supply Shocks, US Gross Domestic Product, and the Oil Security Premium," *Resources for the Future*, 2017, 1–2.

Moreover, although the weakening relationship between global oil prices and aggregate U.S. economic performance provides several benefits for both domestic consumers and producers of energy, the further growth of fossil fuel production carries potential risks of its own, such as retarding the development of alternative energy technologies, producing appreciative pressure on the U.S. dollar, undermining the political rationale for climate action, and inducing greater volatility into the budgets of fossil-fuel producing jurisdictions.[15,16,17,18] Although not all of these risks may ultimately materialize, **policymakers should preemptively consider palliative policy responses—many of which have potential co-benefits—such as incentives for alternative energy research and development (R&D), the fiscal sterilization of new resource revenues, enhancing the competitiveness of non-energy industries, and maintaining adequate fiscal reserves.**

PROPOSITION II: The growth of domestic oil and gas production does not insulate domestic producers and consumers from international energy price developments.

Although known and appreciated by most firms, practitioners, and analysts, the majority of public officials and their constituents are likely less aware of how domestic prices will continue to be informed—with linkages of varying directness—by supply and demand conditions abroad. Evidence of the relationship between foreign and domestic prices can be seen in price and production series produced by the major statistical agencies. Although the level of domestic energy use in aggregate has remained relatively unchanged since 2000,[19] volatility in gross U.S. energy expenditures still is largely driven by swings in the global price of oil and, to a lesser extent, the still largely domestically defined price of natural gas.

The general convergence of domestic and international prices does not, however, preclude the possibility of energy price dislocations. A commodity can be said to be globally priced if price disparities between different markets for that commodity can be eliminated through the process of arbitrage.[20] For much of the modern history of U.S. oil market, this condition largely held, as the price paid by U.S. consumers for oil was reflective of not only supply and demand conditions at home but also those abroad. This linkage between local and international oil markets was, however, disturbed by the largely unexpected growth of domestic unconventional production in 2011. Although the benchmark price of oil in Europe—known as Brent—and the benchmark price of oil the United States—known as West Texas Intermediate (WTI)—had rarely differed by more than five dollars between 2000 and 2010, by late 2010 the Brent-WTI spread had grown to more than $27 per barrel and spent much of 2018 at around $10 per barrel.[21] Notably, it wasn't the volume of new

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15. Juan Roberto Lozano-Maya, "Shale Gas Development Within the Global Energy Transition: Friend or Foe?" Atlantic Council, December 16 2016, https://www.atlanticcouncil.org/blogs/new-atlanticist/shale-gas-development-within-the-global-energy-transition-friend-or-foe.
16. Adams Nager, "Is the United States Immune to Dutch Disease?" Information Technology & Innovation Foundation, January 17, 2017, https://itif.org/publications/2017/01/17/united-states-immune-dutch-disease.
17. For a contrasting view, see Hilde C. Bjørnland et al., "Dutch Disease Dynamics Reconsidered," CAMP Working Paper Series 4, Feb. 2018, https://brage.bibsys.no/xmlui/bitstream/handle/11250/2483401/WP_CAMP_4_2018.pdf?sequence=1&isAllowed=y.
18. See chapters 8, 9, and 10 of Daniel Raimi's *The Fracking Debate: The Risks, Benefits, and Uncertainties of the Shale Revolution*.
19. Energy Information Administration, *September 2018 Monthly Energy Review* (Washington DC: EIA, 2018), https://www.eia.gov/totalenergy/data/monthly/archive/00351809.pdf.
20. See Nikos Tsafos, "Is Gas Global Yet," Center for Strategic and International Studies, March 23, 2018, https://www.csis.org/analysis/gas-global-yet.
21. Energy Information Administration, "Petroleum & Other Liquids: Spot Prices," Raw Data (Washington DC:

oil production per se that broke the link between the two commodities; rather, it was the inability of this new oil to escape the country and reach global markets thanks to the 1975 Energy Policy and Conservation Act's ban on crude oil exports—a prohibition that was lifted in 2015. Despite the thirst of buyers in Europe, Asia, and elsewhere for American crudes and products, U.S. production quickly surpassed the capacity of the midstream infrastructure—pipelines, rail lines, waterways, and shipping terminals—designed to carry it, leaving it trapped (at least temporarily) in the country and depressing domestic prices. Although the dearth of midstream infrastructure has been—and is still being—addressed by a new wave of construction, the lag between the development of new production sources and the ability to integrate those sources into the global market likely will lead to periodic price dislocations in the future. Should the ability to build midstream infrastructure stall on a more permanent basis—because of local or wider-spread opposition to pipeline projects à la Canada—more sustained price dislocations could occur, harming both fuel markets and local communities.

More generally, energy developments beyond U.S. borders remain important to the U.S. energy system and shape the prices faced by domestic consumers. This reality (also referred to in the proposition above) should inform current thinking on the role of energy in U.S. foreign policy formation, and **energy decisionmakers ought to pay particular attention to managing expectations of what "energy independence" or "energy dominance" might actually be able to deliver in concrete terms.** It also suggests that **emergency supply mechanisms—most notably the Strategic Petroleum Reserve—and cooperation with other major consumer nations still will be needed.**

PROPOSITION III: Governments at the national, state, and local levels frequently lack or fail to employ mechanisms to manage the cyclical extremes of energy development.

The challenges facing local decisionmakers in commodity-exposed communities have grown increasingly visible as the development of unconventional fossil fuel resources has accelerated. First, energy development is physically disruptive—particularly in communities with no prior history of oil and gas production. In addition to the actual excavation and construction of drilling sites, towns will also have to manage the impacts resulting from increases in population, crime, traffic congestion, road wear, local pollutants, water usage, and electricity demand. Most public services can scale somewhat in proportion to escalating needs for these services, as noted in Richard Newell and Daniel Raimi's 2018 work demonstrating that "increased revenues have outweighed greater demand for public services."[22] However, in many instances, recent experience suggests that the expansion of services can lag behind because of the mismatch between when impacts are felt and when the activities responsible are taxed, and pre-existing limits of local government resources.[23]

Second, communities with significant oil and gas activities are particularly susceptible to sudden declines in the prices of those commodities. This mechanism is relatively

EIA, 2018), https://www.eia.gov/petroleum/data.php.
22. Richard G. Newell and Daniel Raimi, "The Fiscal Impacts of Increased U.S. Oil and Gas Development on Local Governments," *Energy Policy* 117 (2018): 14-24, doi:10.1016/j.enpol.2018.02.042.
23. Daniel Raimi, *The Fracking Debate: The Risks, Benefits, and Uncertainties of the Shale Revolution* (New York: Columbia University Press, 2018).

straightforward: a decline in prices lowers the pre-tax earnings of commodity producers that operate in the community and reduces the severance fees and royalties that are they are liable for. This in turn diminishes both the tax base and government takings, and by extension the ability of local governments to make outlays and meet their financial obligations. When coupled with the de facto or de jure balanced budget requirements of many local governments, price declines often require governments to cut expenditures to make up the difference. Fortunately, local governments are not completely without options. As Raimi points out in his paper, local governments can preemptively minimize volatility by tying their takings to the scale of fossil fuel investment in an area—such as the number of operating wells—rather than the actual value of production, or by utilizing savings/federal assistance to help bridge the gap between receipts and outlays—though such measures are neither costless nor perfect substitutes for high commodity prices. It is doubtful, however, that such volatility-minimizing strategies necessarily are superior to more traditional production value-based taxes, as they prevent public entities from capturing the full value of the resource rents generated. Some workshop participants suggested that local governments also could consider directly hedging energy-derived tax receipts similar to the way in which the Mexican Finance Ministry's PEMEX hedges its production[24]—though it is not clear that most jurisdictions' oil and gas revenues comprise a significant enough stream of income to justify the minimum costs of creating and administering hedging instruments.

Finally, local governments also must contend with the less obvious challenge of managing the upside of oil and gas production. Just as with the reverse, managing the upside of oil and gas development is complicated by the inability of government planners to predict future receipts from such a volatile industry. Budget surpluses also can lead to politically contentious outcomes. For example, sudden influxes of fossil fuel-derived revenues have the potential to undermine fiscal discipline by masking chronic imbalances in local budgets and allowing governments to postpone necessary reforms—a phenomenon strikingly familiar to what studies of political economy often term the "resource curse."[25] Similarly, new energy revenues also can compound existing concerns about distributional equity. Whether the proceeds are used to fund an expansion of government services or to reduce taxes, some citizens and firms inevitably will be made relatively better off than others, though government policy can significantly influence the progressivity or regressivity of the ultimate outcome. There are also questions of temporal distribution, as governments must decide to what extent the gains should be apportioned between current and future generations. Different approaches to this issue can be seen in the designs of revenue allocation mechanisms of state and local governments. Most channel revenues into savings funds that in turn reinvest the proceeds in treasuries and other financial products, but how those earnings from the funds are themselves spent can vary considerably, with states like North Dakota and Wyoming preferring to fund services—particularly education, which can be seen as an investment in future generations—over the long term and others preferring to directly redistribute earnings to citizens, as is the case with Alaska's Permanent Fund. Last, the economies of oil- and gas-producing locales also are frequently distorted by the

24. Paul O'Donnell, "Size Matters: Surviving a Pricing Downturn," IHS Energy, 2016.
25. See Jeffrey Frankel's "The Natural Resource Curse: A Survey" for a concise picture of the resource curse literature at https://www.nber.org/papers/w15836.

tendency of fossil fuel project costs to be frontloaded towards the beginning of projects, which are themselves highly correlated with the commodity prices. This means that during a price collapse, municipalities are harmed by both the decline in direct takings from hydrocarbon projects and a decline in the wider tax base.

Taken together, these difficulties suggest that most local governments may fail to capture the full benefit of regional energy development or that energy development could even prove ultimately detrimental to local communities if not managed appropriately. Managing such complex development is tricky because, as Raimi points out, policymakers face difficult choices "in how to manage these revenue streams as they seek to promote investment while providing quality public services such as education, transportation, public safety and more."[26] Given the complexity of the task and the unfamiliarity of many communities with oil and gas development, it stands to reason that **there is room for the development of further policy options designed to allow under-resourced local governments to better manage energy resource development.**[27]

PROPOSITION IV: Energy exports have significantly reduced the U.S. trade deficit but their ability to make further contributions is likely overstated due to export capacity constraints and countervailing increases in imports of non-energy goods and services;

The contribution of energy exports and imports to the U.S. trade deficit—the difference between the value of a country's exports and the value of its imports—is well known and can be easily computed using data from major statistical agencies.[28] According to Nikos Tsafos's calculations, not only has "America's trade deficit in energy . . . shrunk by 87 percent in recent years" largely because of the collapse in the price of oil, but this deficit "could plausibly turn into a surplus over the next 5 to 10 years."[29] The conceptual relevance of trade deficits is, however, regarded somewhat dubiously by most, but not all, mainstream economists, because they typically have little relationship to productivity and, by extension, wages and returns on capital. For example, according to a poll by Chicago Booth's IGM Forum, only five percent of economists surveyed agreed that "[a] typical country can increase its citizens' welfare by enacting policies that would . . . decrease its trade deficit."[30]

If true, then it logically follows that energy can only do so much on its own. Although energy exports make Americans richer, some of that wealth is spent importing foreign goods, offsetting part of the impact. As Tsafos points out, "the non-energy trade deficit has widened . . . [and] as a result, there is barely a change in America's trade balance."[31] Furthermore, the trade balance is ultimately governed by a variety of factors of which

26. Daniel Raimi, "State and Local Public Revenues from Oil and Gas Production," *The Changing Role of Energy in the U.S. Economy: Energy in America* (Washington, DC: CSIS, 2019), 1, https://csis-prod.s3.amazonaws.com/s3fs-public/190125_Raimi_RevenuesfromOilGas.pdf.
27. See the forthcoming Energy Workshop II working paper series tentatively titled *Energy as a Source of Economic Growth and Social Mobility* for a more developed treatment of this subject.
28. For non-proprietary options, see the Federal Reserve Economic Database (FRED), the Energy Information Administration (EIA), the Bureau of Economic Analysis (BEA), and the United Nations Conference on Trade and Development (UNCTAD).
29. Nikos Tsafos, "What Are the Positive and Negative Economic Implications of a Net Export Scenario?", *The Changing Role of Energy in the U.S. Economy: Energy in America* (Washington, DC: CSIS, 2010), 2, https://csis-prod.s3.amazonaws.com/s3fs-public/190125_Tsafos_EconomicImplications.pdf.
30. "Trade Balances," IGM Forum, Chicago Booth, December 9, 2014, http://www.igmchicago.org/surveys/trade-balances.
31. Tsafos, "What Are the Positive and Negative Economic Implications of a Net Export Scenario?", 3.

energy is but a minor one.[32] Treating energy exports as a panacea for wider balance of trade concerns therefore is misguided because trade deficits are related only tenuously to overall economic productivity and because energy is incapable of shifting the balance on its own. It also suggests that the trade implications of an energy project or deal ought to be only one of many factors that policymakers consider when examining a project's merits.

Finally, it is important to recognize that the value of U.S. energy exports is determined not only by the quantity of exports sold but also by the price at which they are sold. Although the quantity of energy produced certainly responds to government incentives, its global prices are set by the world market and are therefore less likely to be influenced by domestic policy. As Tsafos writes, "Trade changes should not be equated with specific energy prices. High oil prices might incentivize oil and gas production . . . but U.S. consumers will still be exposed to global prices. Tsafos concludes that "the interplay between America's net export position and specific fuel prices is thus complex and subject to many factors beyond American shores."[33] This suggests that **the policy imperative to utilize energy to remedy trade imbalances is misplaced as a strategic objective or at the very least has some limitations in what it can reasonably be expected to achieve.**

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32. Other elements include the rates of "income injection" from investment and government spending and "income withdrawal" from savings and taxation, monetary policy, foreign exchange rates, trade regimes, and the geographic disposition of supply chains.
33. Tsafos, "What Are the Positive and Negative Economic Implications of a Net Export Scenario?", 2.

Competitiveness and Innovation

With its high reliance on physical and intellectual capital, massive markets, and numerous market participants, the energy sector has, to some extent, always been susceptible to disruption, whether from the introduction of new technologies or changes in business strategies. For example, and as noted by several of the papers, the availability of distributed energy resources and increased avenues of competition have challenged the traditional utility business model for power generation—a disruption that is only likely to intensify as improvements in power storage technologies allow future storage assets to compete directly with generating assets. But the energy sector is not an easy one for new entrants: capital intensity, difficult to achieve economies of scale, and the presence of monopolistic or quasi-monopolistic actors creates conditions that prevent all but the most well-capitalized or politically well-connected entities from thriving. Although energy firms and energy technologies always have competed against one another for market share, social license, and political support, the confluence of several forces seems likely to change both the intensity and nature of this competition.

PROPOSITION V: Domestic energy markets—“fossil” and “non-fossil”—increasingly may be influenced by energy and industrial policies promulgated abroad as foreign governments seek to enhance the competitiveness of their own industries.

Energy long has been a sensitive area of American politics, given its strategic importance, geopolitical dimensions, and central role in the domestic economy. The globally traded nature of energy resources means that the United States always has been at least somewhat influenced by the energy and industrial policies of countries with whom it traded. The United States increasingly is influenced by the energy and industrial policies of countries with whom it trades, as both an importer and an exporter of a wide range of energy resources and technologies. Moreover, as energy consumption, energy sector investment, and new energy technology manufacturing increasingly happen in other parts of the world, the United States may find itself less able to influence and compete in various markets. There are three ways in which this influence might be felt—all of which are likely to require a policy response.

The first stems from the current administration’s goal of increasing energy commodity exports. The Trump administration has declared its intent to export more energy commodities—particularly oil, natural gas, and coal—and has taken steps to rhetorically and diplomatically support that trade. It is not clear, however, that the United States can sell those commodities in all the export markets it has targeted. U.S. natural gas has a hard time competing in Europe and Asia, for example, and the administration is looking for countries in those regions to erect trade supportive policies to improve U.S. standing. It is not guaranteed that those regions will take the steps necessary to make U.S. exports competitive.

The second is the perceived—or actual—lack of U.S. competitiveness in markets for new energy technologies such as electric and autonomous vehicles, small modular nuclear reactors, and batteries. The rise of foreign influence over key energy technologies could, because of political sensitivities, trigger a policy response. Given the prevailing pugilistic tendencies in international trade policy, the United States might impose tariffs and non-tariff barriers on foreign energy products such as solar panels, turbines, or EVs that it believes benefited from undue government support. Alternatively, it could also lead the government to conclude that domestic U.S. firms ought to be supported through direct subsidy schemes, on the grounds that future markets are too important to be left to the whims of international commerce. But it is not immediately apparent that the increasing importance of foreign energy technologies necessarily is negative for the country as a whole. Several experts noted that the abundance of cheap wind turbines and solar panels imported from competitors in East Asia and Europe enabled the growth of domestic renewable operations—albeit sometimes at the expense of domestic renewable equipment producers. The country's future response likely will reflect its future energy priorities, as a more tolerant policy could be justified if the goal is to accelerate renewable energy production.

The third and final area concerns foreign direct investment in the United States. Experience with the U.S. response to foreign influence in its energy sector has been mixed. The country's energy market is among the most liberal in the world, with a flexible mineral rights regime, clear regulatory environment, and minimal barriers to investment. However, the United States has blocked energy sector investments deemed to interfere with U.S. national security interests through the Committee on Foreign Investment in the United States (CFIUS). The CIFIUS process is likely to see its jurisdiction strengthened and expanded through the Foreign Investment Risk Review Modernization Act (FIRRMA) because of concerns that foreign direct investment may affect more than simply national security and that economic concerns now may be grounds to block activity.

If the energy sector is meant to be a strategic area of competition for the United States in the future, policymakers would do well to devise a strategy to determine which sub-sectors and technologies should be regarded as advancing not only the commercial competitiveness of its enterprises but the strategic competitiveness of the country as a whole.

PROPOSITION VI: The stagnation of overall domestic energy use represents a fundamentally new context for understanding the current state and possible future of domestic energy markets.

The stagnation of domestic primary energy demand, as seen in the statistical series produced by the EIA, is a well-known phenomenon within energy circles but has yet to be fully internalized by wider policymaking circles. According to the assembled experts, most firms are keenly aware of it and have adjusted their business models accordingly—with several pointing to the preference among utilities for smaller incremental builds and the rise of U.S. energy exports as perhaps the most obvious signs.

Should this trend continue, as most experts and firms expect, it would represent a significant departure from the past two centuries of continually growing U.S. energy consumption. Utilities, for example, were far more willing to invest in larger plants when they could be reasonably confident that continuing demand growth would help the market absorb new capacity. But against a backdrop of stagnant or even declining demand, competition between both firms and fuels is likely to intensify, which could slow investment and lead to further rationalization and consolidation in the sector. Slowing domestic energy demand also must be factored into the statistical models used not only by governments to forecast supply and demand balances but also by boardrooms throughout the country to estimate the returns on various investments. A stagnant domestic market also changes the relative importance of foreign customers. Faced with a saturated domestic market, domestic energy firms are increasingly likely to seek new opportunity in fast growing emerging markets as they seek to offload surpluses of oil, petroleum products, natural gas, and, to a lesser extent, electricity.

At the conclusion of the workshop, participants identified two areas that are not only likely to be particularly affected by the stagnation of domestic energy demand but also in need of further study. First, the electric power sector—whose returns have hitherto been predicated on building and providing new generation—will have to contend with a number of challenges arising from the confluence of plateauing demand and increasing competition. The issue is further compounded by various state-level policies seeking to, among other things, drive more and more renewable energy onto the system, improve energy efficiency, address social equity concerns, and accommodate cheap natural gas. This already has contributed to not only the closing of coal-fired power plants but also nuclear retirements. **Further business, policy, and regulatory model challenges are likely to arise and interact with one another and will require ongoing study as the system continues to change.** A second research area that most experts agreed warranted additional study is the rise of policy and commercial objectives designed, at least in part, to spur additional demand, most notably electrification policies. Growing electricity demand by electrifying the transport sector, for example, is one way to achieve environmental objectives as well as drive new demand growth for utilities and other power market participants. **Whether and how deeply the U.S. economy will electrify and how much additional electricity demand that will create (or not) is a growing area of interest among researchers and will be increasingly important for policymakers to better understand.**

PROPOSITION VII: Domestic energy production and the policies that influence it are poorly suited for stimulating U.S. manufacturing activity;

The role of energy in creating jobs and economic opportunity particularly in U.S. manufacturing and industrial base has become an important part of U.S. energy politics with elected officials and various energy industry sectors claiming the ability to attract investment, spur economic growth, and create jobs in old or new versions of industry. Despite the recognized popularity of this idea, many workshop participants highlighted the unsuitability of energy policy for furthering various employment and manufacturing goals and voiced concern that these shortcomings are poorly appreciated by the general public and wider policymaking community. The primary faults are twofold: first, the industrial energy prices paid by a state's manufacturing firms are only weakly influenced by the volume of energy produced within that state because of the increasingly global nature of energy pricing and the idiosyncrasies of midstream and downstream operations further down the value chain. Second, energy expenditures are a relatively small share of most U.S. manufacturers' variable costs—though it should be noted that they are notably more significant for a narrow group of energy intensive manufacturers such as petrochemical producers, miners, and shippers. Questions linger, however, as to the extent to which industrial operations have based past siting decisions on the energy production of the surrounding area and whether this relationship between manufacturing location and energy production will strengthen or weaken in the future. These questions would prove fruitful areas for further research.

Nonetheless, if this proposition is true, as most of the evidence suggests, then the existence of energy production—whether "green" or "conventional"—is not in and of itself a sufficient condition for the creation or maintenance of a manufacturing base. Furthermore, when coupled with the ongoing secular decline of U.S. manufacturing employment, this suggests that lowering energy expenditures for domestic manufacturers is unlikely to reverse the prevailing secular decline of U.S. manufacturing employment. Notably, it was even suggested during the panel that manufacturing employment levels are, on average, possibly less responsive to swings in energy prices than other non-energy sectors.

PROPOSITION VIII: Dominant narratives concerning the employment impact of a particular project or investment lack statistical rigor and can be a flawed way of assessing their value to society, but they remain an important component of local and national energy politics.

Accounting for roughly six percent of U.S. GDP, the energy sector has a similarly large employment footprint, with the U.S. Energy and Employment Report (USEER) estimating that more than 4.31 million Americans worked in the traditional energy sectors of fuels, electric power generation and transmission, and distribution and storage in 2016. According to Joe Hezir's 2018 analysis, not only are these sectors growing but "the growth of employment in energy sectors continues to exceed the overall growth rate of the economy"—though the pace of growth has slowed somewhat in recent years.[34] Although these macro-level statistics—collected by U.S. Bureau of Labor Statistics, the Department of Energy, the National Association of State Energy Officials, and the Energy Futures Initiative—are reasonably rigorous, the accuracy of project-level employment figures is somewhat circumspect. The immediate employment impact of a proposed project consequently is unlikely to be a useful or accurate proxy for its economic benefit to society at large. It therefore stands to reason that alternative metrics, such as tax base impacts, distributional consequences, and service quality ought to be relatively more important in the public discourse than they are at present.

The problems with energy job accounting—particularly at the project level—are numerous. First, when it comes to energy jobs, there is a fundamental tension between good public policy and good economics, and it isn't clear which should have priority. From a purely

34. Joseph Hezir, "U.S. Energy Employment," *Energy in America: The Changing Role of Energy in the U.S. Economy* (Washington, DC: CSIS, 2019), https://csis-prod.s3.amazonaws.com/s3fs-public/190128_Hezir_U.SEnergyEmployment.pdf.

economic perspective, valuing a project based upon the number of jobs it creates is somewhat dubious. Energy, after all, is simply the capacity to do work. According to this view, energy is not ipso facto valuable but rather derives its value from its ability to be input into other processes that provide goods and services that individuals and firms do value. Put another way, like other factors of production, the objective should be to maximize its productivity or the ratio of British Thermal Units (Btus) per job, not the jobs per Btu. As an example, consider agriculture, which we can think of as resulting from two factors of production: land and labor. Surely, an economist would argue, we would regard a project or technology that reduced the number of laborers needed to till an acre of crops—or conversely, increased the number of acres a single laborer could till—as a societal good: not only does society have more, but its workers are now more valuable and, by extension better paid. Energy, like capital, labor, and the land used in our example, is simply a factor input—or so the argument goes.

But elected officials are not charged with the same responsibility for maximizing efficiency as economists. And even if they were, experience shows that representatives often feel compelled to provide their constituents with actual jobs or express a policy in terms of the expected jobs impact of a given policy, to advance their agenda—which may be about creating jobs in and of itself. Despite its numerous methodological problems, the job number remains one of the most popular, and politically viable, metrics used to evaluate projects in the public discourse. Given its understandable popularity, it is not clear how other more useful measures can be advanced. Several workshop participants suggested the development of other employee or labor-centered metrics that can marry the understandable interest in worker welfare with policymaking utility.

A second problem arises from the numerous technical difficulties associated with even the official statistics, and what is known about the employment footprint of the energy industry is somewhat lopsided. Although it is easy to pick out in the Bureau of Economic Analysis's (BEA) North American Industry Classification System (NAICS) database the number of fossil fuel jobs with relative precision, it is exceptionally difficult to calculate the number of green jobs from the data with any comparable level of granularity. Furthermore, as Hezir notes, "[w]hile the NAICS industry code structure is updated every 5 years, it nonetheless does not align well with the current energy markets and business models."[35] For example, NAICs is unable to account for incidental energy efficiency jobs—an increasingly important energy sector—nor the numerous energy-related contractors that energy firms contract out to, resulting in "serious undercounting [that] exists in virtually every energy sector from coal mining to wind farms."[36] Moving beyond official government statistics, the accuracy of employment figures becomes even more uncertain. Although project sponsors typically have a reasonably accurate estimate of the number of full-time equivalents that a project ultimately will require to run, many prefer to tout the far larger, but temporary, number involved in the project's construction. Similarly, many proponents estimate the number of induced or indirect jobs created by the project—such as the number of additional waiters that are needed to staff restaurants in a newly busy town—but such calculations are fraught with difficulty. Although mainstream

35. Ibid.
36. Ibid.

labor economics holds that such employment multiplier effects exist, even the general magnitude of the relationship remains highly controversial.[37]

Finally, even if the number of jobs created is assumed to be a useful metric and accurate data exist, the metric's use raises a number of thorny issues. As Gruenspecht argues, "Identifying net job gains associated with policy-driven energy-related activities can be challenging, as the state of the overall economy and whether the costs associated with particular programs or initiatives are reflected in the loss of other jobs can play a role. In some cases, job losses may be less visible than job gains."[38]

PROPOSITION IX: Although innovation is clearly central to the past, present, and future of the U.S. energy system, quantifying and understanding energy innovation remains fraught with difficulty.

A significant portion of the climate debate has fixated on the roles that energy technologies might play in the future—and they are by no means certain. Will, for example, cost-effective Carbon Capture Utilization and Storage (CCUS) techniques be developed? Will battery costs fall enough to allow storage assets to compete with generators on the grid? The answers to these and other questions are unknowable today but can have significant implications for policy. If, for example, CCUS techniques are viable, then it stands to reason that coal and natural gas could play a larger role in the future U.S. fuel mix than is commonly assumed. If battery costs become truly competitive, then one potential outcome could be for U.S. research priorities to deemphasize the relative importance of generation technologies. This technological uncertainty can, in turn, engender further uncertainty in both government policies and private sector strategies. For policymakers, uncertainty over how certain technologies or investments will pan out can make it difficult to craft forward-looking policies. For the private sector, an uncertain policy environment can make it difficult for private parties to justify investments in speculative R&D and cutting-edge projects. Experts described the difficulty of crafting energy policies and making business decisions against the backdrop of constant technological change as exceptionally difficult. As Joe Hezir notes in his 2018 paper, although innovation-derived uncertainty is a well-known difficulty throughout economics, "this challenge is particularly acute in the U.S. energy sector where the tension between technological innovation, government regulatory activity, and policy uncertainty creates greater instability."[39]

More urgently, uncertainty in the energy sector can have significant implications for the pace of technological change. As Aldy argues, "[t]o the extent that uncertainty characterizes the expected profile of energy and climate policies over time . . . the investment in new technologies can be inhibited,"[40] as investors demur on technologies that may not enjoy future government support or require a specific market environment in order to prosper. This is particularly relevant to climate technologies, with Aldy concluding that "[w]ith greater policy clarity about long-term energy and climate

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37. See Greenstone, Hornbeck, and Moretti's "Identifying Agglomeration Spillovers: Evidence from Million Dollar Plants," *Journal of Political Economy*, March 2008, https://www.nber.org/papers/w13833.pdf.
38. Howard Gruenspecht, "The Present and Future Role of Energy in the U.S. Economy," *Energy in America: The Changing Role of Energy in the U.S. Economy* (Washington, DC: CSIS, 2019), 3, https://csis-prod.s3.amazonaws.com/s3fs-public/190125_Gruenspecht_EnergyinUSEconomy.pdf.
39. Hezir, "U.S. Energy Employment."
40. Joseph Aldy, "The Economic Implications of a Low Carbon Future," *Energy in America: The Changing Role of Energy in the U.S. Economy* (Washington, DC: CSIS, 2019), http://csis-prod.s3.amazonaws.com/s3fs-public/190125_

objectives, entrepreneurs and innovators may have stronger incentive for orienting their efforts towards energy and decarbonization efforts."[41]

The importance of innovation and research is widely known, but the exact mechanics are poorly understood within the discipline of energy economics and economics more generally. The literature generally attributes this to several inherent complexities. First, R&D creates "positive externalities" that result from a mismatch between social and private returns on the knowledge generated by R&D investments.[42] More specifically, R&D generally contributes to the larger scientific community's understanding of a particular issue. Although this is desirable for society writ large, the inability of R&D sponsors to recoup the full extent of the benefits produced by their investment means that less R&D is performed than would otherwise be the case if the benefits could be fully internalized. This is particularly true of "basic science" research, which frequently lacks obvious commercialization opportunities but is nonetheless necessary for the advancement of science as a whole. As a market failure, this mismatch in incentives creates a natural role for government intervention, which typically has taken the form of research grants for universities and support for the Department of Energy's network of Energy National Laboratories.

Second, R&D as a practice is poorly suited for quantification. Much research literature has focused on the role and extent of "learning curves" that represent how experience, economies of scale, or technological innovation can change the relationship between a unit of production (say, a Megawatt or MW of solar power) and the cost needed to produce it—though workshop participants noted that useful empirical studies of learning curves are still relatively rare and need further study. The Department of Energy has used several metrics that attempt to describe innovation, ranging from simplistic statistics such as the volume of projects supported, the follow on-funding attached, patents filed, companies backed, and peer-reviewed articles published, to more abstract measures such as the "Technical Readiness Level" of technology projects.[43] But workshop participants noted that even the combination of these metrics is unlikely to capture the true economic value of a project, because of the difficulty of assessing the full extent of the wider benefits to society and the inherent unknowability of the future of these technologies. Several participants recommended that **energy economists redouble their efforts to educate policymakers on the inherent limits of innovation quantification efforts**, but some experts noted that the wise management of public R&D is, in the words of one anonymous attendee, "ill-fitted for the congressional process." Because of competing funding priorities, the uncertainty inherent in any scientific effort, and ideological differences concerning the proper role of government, energy R&D in practice frequently is politically contentious, even if support for the principle of innovation largely remains bipartisan.

Aldy_LowCarbonFuture.pdf,5.
41. Ibid.
42. Erik Dietzenbacher and Bart Los "Externalities of R&D Expenditures," *Economic Systems Research* 14, no. 4 (2002): 407-425, DOI: 10.1080/0953531022000024860.
43. W. J. Carmack et al., "Technology readiness levels for advanced nuclear fuels and materials development," United States, 2016, https://www.osti.gov/servlets/purl/1364025.

System Transformation and Policy Impacts

The energy system is a vast structure through which countless participants—governments, producers, consumers, utilities, civil society groups, and financial intermediaries, to name a few—interact and determine the price, distribution, and usage of energy. Like any large body, the energy system is prone to a degree of institutional inertia, but this does not mean that systemic change is impossible or even improbable. Given the pace of technological innovation, the rise of populist political sentiments, and the looming threat of climate change, the central question of systemic energy transformation is arguably no longer one of "if" but "when." Although fixing any date, let alone a single one, to the transition is far beyond the scope of this paper and the workshop that informed it, participants stressed that this transition is unlikely to resemble its historical predecessors and is already being shaped by several uncertainties.[44] For example, past transitions in energy systems also were marked by changes in the composition of and competition between dispatchable fuel types. This transition, however, is largely driven by the rise of and change in variable resources. Does this suggest that the looming transition will adhere to fundamentally different dynamics than in years past and, if so, what does that imply about the capacity of regulators to manage it? If, for example, storage assets are able to further challenge the utility business model, will that fundamentally change the way that power is commodified and traded? Or is the current system of pricing capable of incorporating these changes? These issues represent just some of the conundrums that a systemic energy market transformation poses to regulators and market participants. Although resolving all of the issues in a comprehensive manner is beyond the scope of this paper and the workshop that informed it, experts focused on a few issues that were particularly pressing, which are taken up in greater detail below.

PROPOSITION X: Threshold effects, network effects, and other nonlinearities are poorly accounted for in the contemporary studies of energy economics, and they represent a significant barrier to crafting and enacting wise energy policy.

Evaluating the impact of energy policies on the macroeconomy is made more difficult by the existence of—and interaction between—a number of complicating factors which,

44. For example, the transition from human and animal power to coal, or from coal to oil.

although not necessarily unique to energy economics, are nonetheless more pronounced than in many other disciplines. As such, any effort to better comprehend the impact of proposed energy policies must be accompanied by at least an appreciation of the constraints that energy economists face, five of which were identified by the assembled experts as particularly pressing:

1. network effects, such as those influencing the adoption of distributed solar technologies, which capture the positive externality incurred by an asset or activity by the addition of more users of that asset or activity;
2. threshold effects, which occur when the magnitude, direction, or frequency of a relationship that is assumed to exist between two or more factors changes suddenly after passing a given level, such as the behavior of melting polar ice caps, or debt-to-GDP threshold effects[45];
3. irreversibility, which occurs "where the nature of a relationship changes depending on the direction in which a variable is moving,"[46] such as the effect of fatal level of pollutants on wildlife, or final investment decision making;
4. nonlinearities, which capture complex relationships—such as threshold effects and irreversibilities—that are not one-for-one, such as the relationship between temperature and greenhouse gases in climate science, or technological change and growth in macroeconomics; and
5. uncertainty, which involves the persistence of unknown, imperfect, or asymmetric information.

These effects are well known to energy economists, but they remain difficult to model with any degree of accuracy. During their deliberations, panel members regularly identified the discipline's inability to model network effects as a particularly problematic shortcoming. In his paper, Joe Aldy concluded in his discussion of climate technology adoption that "most economic models do not account for such network economics and hence overestimate costs."[47] Similarly, Amir Jina's 2018 modeling thus far excludes the nonlinear impact of adaptation to climate change because of its complexity—although forthcoming research from the Climate Impact Lab likely will incorporate this phenomenon into their work.

Policymakers should be aware that models, by their very nature, offer directional insights but should not be used to pin down specific details with any degree of accuracy. Because of their difficulty, many models ignore networks, threshold effects, nonlinearities and the like not because of malice but because of modeling constraints and a preference for historically informed empirics. This is not to imply that modelers and economists are unaware of their presence, as stressed by several participants at the meeting. Rather, they represent a caveat that, once again, is not unique to the study of energy but part and parcel of any statistical exercise. Nonetheless, these complexities also represent a valuable frontier in energy

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45. Carmen M. Reinhart, Vincent R. Reinhart, and Kenneth S. Rogoff, "Public Debt Overhangs: Advanced-Economy Episodes since 1800," *Journal of Economic Perspectives* 26, no. 1 (2012): 69–86.
46. Roger Perman, Yue Ma, James McGilvray, and Michael Common, *Natural Resource and Environmental Economics, 3rd edition* (Pearson Addison, 2003).
47. Aldy, "The Economic Implications of a Low Carbon Future," 5.

research, with experts identifying network effects as a particularly important area needing further exploration given the increasing role of networks and winner-take-all business models in energy markets, the significant economic rents that they can produce, and their incompatibility with the perfect competition assumptions that many models use.

As a partial remedy to these complications, one participant suggested that **modelers ought to make greater use of scenario planning—how markets might respond given a specific set of assumptions—and sensitivity analyses—how different uncertainties affect the model's results.** By expanding the use of these techniques in mainstream energy studies, modelers can not only make their contributions more accommodating of uncertainty and variation but also more useful to policymakers by providing probabilistic distributions that estimate the relative chances of various outcomes rather than a simple range. In recent years, groups such as the EIA and the International Energy Agency (IEA) have utilized such approaches to test their models and update their technological change assumptions, the latter of which, in some notable examples, have not kept pace with actual technological change. Several experts also suggested that **the discipline as a whole could do a better job of incorporating the insights of non-economists.** Although improvements in modeling will obviously be essential, energy economists and policymakers could benefit from the work of behavioral economists, sociologists, psychologists, legal scholars, and management theorists. It is also essential to acknowledge that uncertainties and imperfections do not invalidate the underlying work and that further research in this area is intended to be additive and constructive.

PROPOSITION XI: There is a disproportionate focus on the costs of carbon reduction policies, which are likely to be significantly less than the benefits.

Most economists and climate policy professions recognize carbon instruments, whether promulgated as a carbon tax or a cap-and-trade system, as the most economically efficient way to address climate change. In a rare moment of consensus, a prominent group of economists, including 27 Nobel Prize recipients and four Federal Reserve chairmen, expressed support for a carbon tax and dividend program, in the *Wall Street Journal*.[48] More broadly, according to one survey of leading economists by Chicago University's IGM Forum, 90 percent of economists strongly agreed or agreed that carbon taxes "would be a less expensive way to reduce carbon dioxide emissions than would a collection of [regulatory] policies."[49] The expert community's enthusiasm for carbon pricing, however, has not been embraced by a sufficient share of the U.S. electorate or elected officials, as demonstrated by the defeat of Washington state's proposed "carbon fee" in the 2018 midterms,[50] and the increasing polarization of climate change policy along partisan lines.[51]

Much of the backlash against a carbon tax springs from the fact that the measure is exactly that: a tax. Because the United States has yet to pass a carbon tax at the state or federal

48. George Akerlof et al., "Economists' Statement on Carbon Dividends," *Wall Street Journal*, January 16, 2019, https://www.wsj.com/articles/economists-statement-on-carbon-dividends-11547682910.
49. "Carbon Tax" IGM Forum, Chicago Booth, December 20, 2011, http://www.igmchicago.org/surveys/carbon-tax.
50. Joshua Rhodes, "Despite the Blue Wave, the U.S. Failed to Pass Its First Carbon Tax," Axios, November 12, 2018, https://www.axios.com/despite-the-blue-wave-the-us-failed-to-pass-its-first-carbon-tax-5973f142-362f-4fec-9445-5d4bfeff0c2c.html.
51. "Global Warming Concern Steady Despite Some Partisan Shifts," Gallup, March 28, 2018, https://news.gallup.com/poll/231530/global-warming-concern-steady-despite-partisan-shifts.aspx.

level, the precise level of such a tax has yet to be determined. Whereas Washington State voters were asked to consider a $15 per ton "fee," economists have recommended a range of taxes. One literature review conducted by Richard Tol found an average suggested tax of between $232 per ton with a zero percent "discount rate"—a rate that implies that benefits accruing to current and future generations ought to be equally important—and $18 per ton with a three percent discount rate—a rate that implies that benefits accruing to future generations are less important than those accruing to current generations and ought to be "discounted" accordingly.[52] Viewed in absolute terms, such a tax would undoubtedly prove significant, with one study co-produced by Columbia University, the Tax Policy Center, the Baker Institute, and the Rhodium Group finding a total cost to the U.S. economy of $80, $240, and $340 billion per year with a tax of $14, $50, and $73 per ton respectively.[53]

Most experts—including those at the workshop—contend that although these costs are not insignificant, the benefits are more than commensurate. Typically, carbon tax benefits are calculated as the value of avoiding, deferring, or mitigating the economic damages caused by climate change. These damages in turn typically are decomposed into their effects on the amount and productivity of labor and capital inputs, and on total factor productivity—the latter effectively serving as a stand-in for the role played by management practices, human capital, and technology. The mechanisms by which climatic changes can influence these elements are numerous, with participants identifying a few as particularly significant, including lower crop yields, increased mortality rates, accelerated depreciation rates for capital, intensified natural disasters, and limited workable hours for manual laborers. The combined impact of these effects can be significant, with Jina and the Climate Impact Lab finding in 2018 that "a business-as-usual emissions scenario would on average cost the US economy approximately 1–4 percent of GDP annually by the end of the century."[54] Fortunately, the study also suggests that much of the economic damage can be ameliorated and that "[l]imiting emissions to an RCP 4.5 (medium mitigation) scenario would reduce those [damages] to approximately 0.1 – 1.5 percent of GDP"[55]—generating savings that most experts believe should be more than enough to offset the cost of the carbon tax needed to generate the cuts.

Although the basic arithmetic of a cost-benefit analysis is relatively straightforward, workshop participants identified several factors that should be considered when translating the economic theory of carbon taxation to political reality. First, it was stressed that **policy discussions ought to be cognizant of climate-related economic impacts at both national and subnational levels**, with Jina writing that "aggregating damages to a national level masks substantial subnational redistribution of the costs of climate change. The local damages from climate change show that costs may be severe in the South . . . and particularly severe in poorer counties."[56] These disparities suggest that **universal, one-size-fits-all responses to climate change are likely to be inappropriate, and that**

52. Richard Tol, "The Economic Effects of Climate Change," *Journal of Economic Perspectives* 23, no. 2 (Spring 2009): 29–51, Table 2.
53. Noah Kaufman and Kate Gordon, *The Energy, Economic, and Emissions Impacts of a Federal US Carbon Tax* (New York: The Center on Global Energy Policy, Columbia University, 2018), https://energypolicy.columbia.edu/sites/default/files/pictures/CGEP_SummaryOfCarbonTaxModeling.pdf.
54. Amir Jina, "Economic Benefits and Trade-offs of Climate Policies," *The Changing Role of Energy in the U.S. Economy: Energy in America* (Washington, DC: CSIS, 2019), 5, https://csis-prod.s3.amazonaws.com/s3fs-public/190125_Jina_EconomicBenefits.pdf.
55. Ibid.
56. Ibid.

the adaptation and mitigation approaches of local communities should be tailored to their unique circumstances and proportional to the expected local threat. Second, in addition to refocusing on the benefits of carbon pricing, **policymakers also should consider possible uses for the revenue raised by a carbon pricing mechanism.** Experts suggested that the revenue could be used to, among other things, pay into a government's general fund to support its day-to-day activities; fund specific environmental or climate change projects; offset reductions in other distortionary taxes; or finance a dividend by returning the revenue to citizens in the form of a direct transfer or income tax reduction. Finally, some—but not all—workshop participants argued that policymakers should be prepared to accept that the climate change policies that are adopted may be economically suboptimal. Although carbon taxes may be theoretically optimal—which is to say that they achieve emissions reductions at the lowest marginal abatement cost—the concentrated costs and diffused benefits that they likely would produce have all the signs of a posing a classic collective action problem for decisionmakers. Hitherto, the most successful clean, low-carbon programs in the United States have been advanced through less-than-efficient initiatives such as tax credits, fuel efficiency standards, and product bans. It is also unclear how a carbon pricing mechanism would interact with existing climate and energy policy regimes, with Aldy writing that "the outstanding question is whether . . . such policy substitutes for much of the status quo set of energy and climate policies."[57]

PROPOSITION XII: The prevalence of legacy energy infrastructure assets is likely to complicate efforts to transition the nation's energy system.

Infrastructure emerged as a key priority during the 2016 presidential election and continues to capture the attention of policymakers across the political spectrum. To some extent, this is driven by the perceived gravity of the issue. Although the country's energy infrastructure is arguably more modern than its public transportation, water, and levee systems, the perception, accurate or not, persists that the sector remains decrepit, with the American Society of Civil Engineers giving the domestic energy sector a "D+" largely because of its old electricity transmission system, lingering capacity bottlenecks, and susceptibility to disruption.[58] The logical implication of this debilitation is that something ought to be done. On both sides of the aisle, energy infrastructure is viewed as an opportunity to alter or preserve the future development of the wider U.S. energy ecosystem. This proposition, however, suggests that no matter which sentiment ultimately prevails, it is possible that efforts could founder on the idiosyncrasies of domestic energy infrastructure, unique characteristics that could accelerate transitions in some areas while retarding it in others. Similarly, as Gruenspecht writes, "[w]hile some legacy infrastructures, such as gasoline refueling pumps and stations, can adjust incrementally . . . others, including the infrastructure used to distribute natural gas . . . could have more difficulty in rescaling."[59]

Participants identified at least three pathways through which legacy energy infrastructure could affect an energy transition. First, legacy infrastructure is, by definition, composed of mature capital assets that typically already have recouped their initial capital expenditures

57. Aldy, "The Economic Implications of a Low Carbon Future," 5.
58. "2017 Infrastructure Report Card," American Society of Civil Engineers, 2018, https://www.infrastructurereportcard.org/.
59. Howard Gruenspecht, "The Present and Future Role of Energy in the U.S. Economy," 6.

and other fixed costs. Theoretically, these mature assets need only to generate revenues to cover operating expenses, a stark contrast to newer investments that have yet to recover the initial sunk costs associated with any investment. Although changes in the domestic energy market may mean that newer infrastructure is economical over the long run, it is likely that operators of existing infrastructure will be reluctant to retire such assets as long as they continue to offer stable returns in the short run. Second, as long as these assets are valuable to their owners, these owners will have every incentive to preserve them through the political process. This dynamic creates an incumbent constituency that is likely to seek the maintenance of the status quo and, by extension, to slow the modernization of the country's energy infrastructure. Finally, several participants speculated that because several mature utility assets—natural gas distribution networks and electricity grids—require a minimum user base in order to remain economically viable, that these assets may be retired faster than is commonly expected, as the erosion of an asset's userbase begets a decline in quality of the service provided to the rest of the userbase, further accelerating the collapse. The threat posed by such a cascading failure could, however, lead decisionmakers to consider policy options to subsidize or spread the cost of the system.

Although these first two pathways are informed by past and present experience with similar infrastructure assets in other sectors—such as water, sanitation, public transportation, and telecoms—and are relatively well known, the magnitude and implications of a userbase decline as outlined in the third is less understood. The issue is further complicated by the difficulty of modeling infrastructure retirements. Generators, for example, can be retrofitted to prolong their useful life and pipelines can be reversed or reconfigured to carry different petroleum products. The political viability of government-led infrastructure revitalization seems similarly uncertain. **Workshop participants repeatedly stressed that the confluence of overlapping regulatory regimes, rising environmental and safety standards, increasing chances of litigation, intensifying activist pressure, and lower risk appetites among investors has made the construction of infrastructure exceedingly difficult in the United States, unlike in many other developed countries. This should be addressed not only within the existing regulatory regime but also in the research agendas of the expert community.** Participants also paid particular attention to how existing infrastructure assets and their owners can inhibit new development. With their understandable preference for the status quo, owners of legacy assets are an important incumbent constituency that cannot easily be discounted. So too are those consumers who are most vulnerable to service disruptions. Balancing their interests against those advancing the energy transition will prove a difficult but necessary undertaking.

PROPOSITION XIII: Although the impact of energy policies, both current and proposed, is relatively minor on an aggregate basis, there are often considerable distributional consequences that can impede reform.

Energy is clearly a consequential public policy issue, and by affecting the choices and attitudes of both energy producers and consumers, policy interventions can alter the technology and investment choices of market participants. Although these decisions can materially affect the economy in aggregate, workshop participants were particularly interested in the distributional impacts of energy policies. More specifically, it has grown increasingly apparent that policymakers should be cognizant of an intervention's relative progressivity—meaning that it imposes a higher burden on taxpayers with higher incomes—or regressivity—meaning that it imposes a higher burden on taxpayers with lower incomes. Notwithstanding the normative implications of the perceived “fairness” of proposed policies, the distributional impact of energy policies is likely to become increasingly important in determining the political viability of the measures and in ensuring that they are tailored to each region’s particular circumstances. These interventions can be divided into three broad categories: energy regulations, which set down rules whose statutory authority is ultimately derived from legislation; energy tax preferences, which reduce taxes to less than would otherwise be collected; and energy taxes more generally.

The economic impact of the first category of these interventions, regulations, is perhaps the least understood by economists. Because of the considerable number of ways that regulations can be configured, most assessments of regulatory economic impacts require case-by-case assessments—unlike studies of taxes and taxes preferences, which typically hew closely to well-trod methods of evaluation. In his paper, Metcalf provides a brief survey of the literature of a handful of such cases. First, Metcalf points to the work of Davis and Knittel, who find that because corporate automobile fuel economy (CAFE) standards apply to only new cars, “the regulation creates an incentive to hold onto an existing car longer . . . [driving] up used vehicles prices,” [60] which disproportionately hurts lower income citizens—the primary buyers of used cars. This finding is by no means new,[61] but it seems particularly salient today given the Trump administration’s push to freeze CAFE standards at their 2020 level.[62] Metcalf finds similarly regressive impacts in the literature on energy efficiency standards in building codes, which lead to “non-trivial” reductions in housing square footage that disproportionately affect lower income Americans[63] but an ambiguous to mildly progressive redistributive impact of state-level pricing regimes for regulated natural gas.[64]

Energy tax preferences represent a second silo of energy interventions. Continuing his survey of the existing literature, Metcalf points out that the largest category of preferences—production and investment credits for renewable energy, EVs, and weatherization—can be particularly regressive. For example, according to Borenstein and Davis’ 2016 evaluation of these preferences, the bottom 60 percent of American taxpayers “have received about 10 percent of all credits, whereas the top quintile has received about 60 percent.”[65] Of these preference programs, credits for electric vehicles have proved particularly regressive, with Bornestein and Davis finding that the top 20 percent of taxpayers “has received about 90 percent of all credits.”[66] Although some preferences—

60. Lucas Davis, and Christopher Knittel, "Are Fuel Economy Standards Regressive?" *Journal of the Association of Environmental and Resource Economists* (May 2016), doi:10.3386/w22925.
61. See Kwoka’s 1983 paper concluding that CAFE standards are economically equivalent to a subsidy for efficient vehicles or a tax on inefficient vehicles. John Kwoka, “The Limits of Market-Oriented Regulatory Techniques: The Case of Automotive Fuel Economy,” *The Quarterly Journal of Economics* 98, issue 4 (1983): 695–704.
62. “The Safer Affordable Fuel-Efficient ‘SAFE’ Vehicles Rule,” NHTSA, September 21, 2018, https://www.nhtsa.gov/corporate-average-fuel-economy/safe.
63. Christopher D. Bruegge et al., “The Distributional Effects of Building Energy Codes,” NBER Working Paper No. 24211, 2018, https://ideas.repec.org/p/nbr/nberwo/24211.html.
64. Severin Borenstein and Lucas Davis, “The Equity and Efficiency of Two-Part Tariffs in U.S. Natural Gas Markets,” *Journal of Law and Economics* 55 (February 2012).
65. Severin Borenstein and Lucas Davis, “The Distributional Effects of U.S. Clean Energy Tax Credits.”, NBER Working Paper No. 21437, July 2015, https://www.nber.org/papers/w21437.pdf.
66. Ibid.

most notably those supporting the leasing of solar power systems—are relatively more progressive, Metcalf nonetheless concludes that "many of the subsidies to energy production and efficiency skew towards higher income households."[67]

Current economic research, however, suggests that energy taxes are relatively more equitable and progressive in their distribution. Of the various energy excise taxes levied in the United States, gasoline taxes are arguably the most important and are certainly the largest, providing more than $37.8 billion in federal revenues during FY 2017.[68] Although Metcalf found that "[w]hen gasoline taxes are considered in isolation, most studies find them to be regressive,"[69] determining the exact degree of regressivity is complicated because of several confounding factors. First, many distributional analyses determine a household's relative poverty or wealth by its annual income. Annual income, however, can be a misleading metric, as a not insubstantial number of "low income" households in fact are those of students and retirees, who are likely to have—or have had—significantly higher average annual income over their lifetime, thereby overstating the tax's regressivity. Second, such analyses must often grapple with variations in regional driving habits, as households in rural areas are understandably more likely to drive than their more urban peers. Finally, such analyses frequently neglect how revenues raised by energy taxes are recycled back into the economy, a tendency that Metcalf stresses "presents an incomplete picture" of a measure's ultimate distributional impact.[70] For example, although a gasoline tax whose revenue is used to offset a complementing decrease in income tax rates for wealthy households can be steeply regressive, such a tax can be deeply progressive if the gasoline tax instead is used to fund flat rebate.

This latter point has significant implications for the larger carbon tax debate. According to Metcalf and several other workshop participants, the perceived regressivity of a carbon tax or cap-and-trade mechanism—both of which would effectively levy a tax on the amount of carbon in a given fuel—has emerged as a particularly pernicious barrier to the adoption of a U.S. carbon tax. Several participants, however, argued that a carbon pricing mechanism could be progressive if the revenue it raised was used to pay for cuts in other distortionary taxes, such as personal income taxes.[71] Participants also suggested that even if the revenue raised by a carbon instrument went unused, it still was unlikely to be as regressive as is commonly feared. As Metcalf argues, in addition to the aforementioned difficulty with measuring income, many analyses are unlikely to fully account for the offsetting impact of transfer payments. These transfers—such as retirement and disability insurance benefits, medical benefits, unemployment insurance, and education assistance—typically are indexed such that the value of benefits increases in response to an increase in prices, whether for energy or other goods.

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67. Gilbert Metcalf, "Distributive Impacts of U.S. Energy Policy," *The Changing Role of Energy in the U.S. Economy* (Washington, DC: CSIS, 2019), 2, https://csis-prod.s3.amazonaws.com/s3fs-public/190125_Metcalf_DistributiveImpacts.pdf.
68. Office of Management and Budget, "Table 2.4—Composition of Social Insurance and Retirement Receipts and of Excise Taxes: 1940–2023," Raw Data (2018), https://www.whitehouse.gov/omb/historical-tables/.
69. Metcalf, "Distributive Impacts of U.S. Energy Policy," 2.
70. Ibid.
71. Participants also noted that the revenue raised by a carbon instrument was likely to be essential to its broader political success, as it could fund transfers to politically important constituencies or cuts in other distortionary taxes, such as corporate taxes.

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