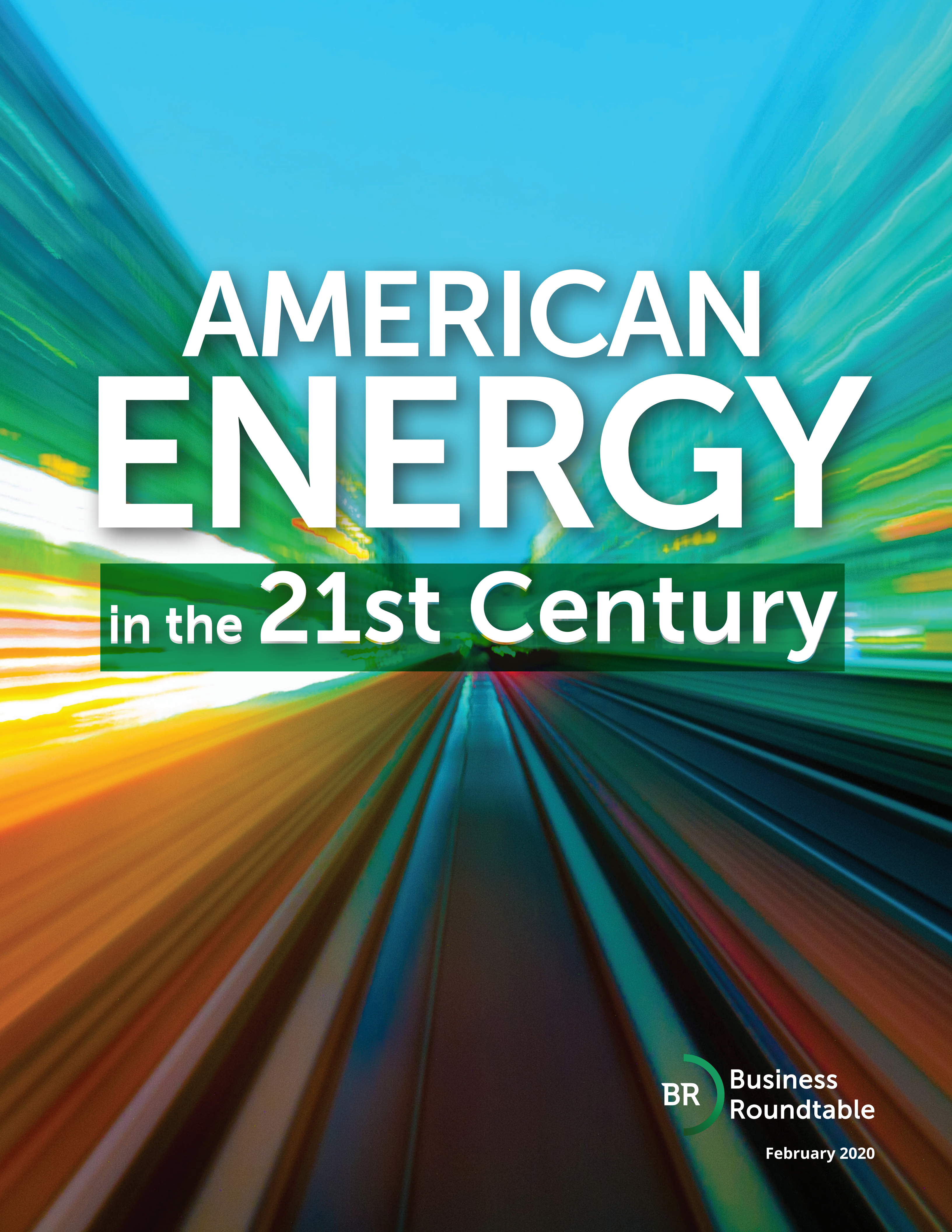

AMERICAN ENERGY in the 21st Century

Business Roundtable

February 2020

Business Roundtable

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AMERICAN ENERGY in the 21st Century

Contents

EXECUTIVE SUMMARY

The United States is in the midst of both an energy boom and a pivotal period of transition. To maintain global leadership and meet the growing global demand for energy, the United States must continue to deliver diverse, affordable and reliable energy to businesses and consumers, while also addressing the risks that global climate change poses to the environment, economy and public health. This report reviews major trends in U.S. energy technologies and resources, discusses the implications of those trends for the U.S. energy and economic landscape, and assesses the potential of a number of cutting-edge energy technologies in meeting these objectives.

Emerging Trends

The U.S. energy sector is in a period of transformation, as a confluence of trends — some well established and some only beginning to gather momentum — reshape the energy sector. Scientific evidence increasingly shows a rise in global surface temperatures linked to human activity. As a result, the call for collective action to reduce greenhouse gas (GHG) emissions; limit the global temperature increase; and address the environmental, economic and health risks posed by the changing climate is mounting. At the same time, an unprecedented surge in U.S. oil and gas production has structurally altered both the domestic and global energy landscapes. Research; supportive policies; investment; and deployment of lower-emissions fuel sources, zero-emissions renewable energy and innovative energy technologies such as battery storage are accelerating and driving the increased cost competitiveness of these fuels and technologies. Meanwhile, sustained advances in energy efficiency have drastically reduced the economy's energy consumption, while cutting-edge digitalization technologies and processes are changing how energy is produced and consumed. These crosscutting trends have the potential not only to disrupt and reshape the energy sector but also to drive fundamental changes in how the U.S. economy interacts with energy.

Implications for the New Energy Landscape

The implications of these trends extend well beyond the energy sector. Indeed, the entire U.S. economy's relationship with energy production and consumption is shifting, as economic growth has been decoupled from GHG emissions and abundant shale gas production and cost-competitive renewable energy have reoriented the nation's fuel mix.

Looking ahead, robust domestic oil and natural gas production will continue to drive growth in the manufacturing sector and across the economy and to support expanding global energy consumption even as demand grows for lower-emissions energy options. Energy infrastructure systems are straining to accommodate booming domestic energy production and new demands that renewable resources and distributed energy resources deployment are placing on the electric grid. In the electricity sector more broadly, many utilities are facing significant pressure from changing technologies; a shifting generation portfolio; and rapidly evolving regulatory, consumer and investor preferences. In the industrial and manufacturing sectors, companies continue to find innovative solutions to improve energy efficiency and reduce the emissions intensity of energy consumption, including investing in onsite generation from carbon-neutral energy sources such as solar and biomass. And in the transportation sector, a range of emerging technologies are poised to reshape the future of travel. These trends will affect every corner of the energy industry and U.S. economy, challenging policymakers and the industry to adapt and innovate.

Breakthrough Technologies

Despite significant recent advances in energy technologies and innovation, currently deployed technologies will likely be insufficient to produce the scale of emissions reductions needed to fully meet the long-term climate challenge. Securing the ability to provide the diverse, affordable and reliable supplies of energy that are needed to sustain economic growth and address global climate change will require a supportive policy environment that eliminates barriers to and accelerates the development and deployment of new technologies that could fundamentally change the U.S. (and global) energy landscape. Forecasting the development and deployment of these nascent technologies involves some measure of speculation and should therefore be done with humility. Some technologies may not fulfill the promise they appear to hold, and others may exceed it, while entirely new technologies may yet emerge. What is certain, however, is that new technologies will inevitably emerge that will reshape existing trends and give rise to new ones.

Technologies explored in this report include:

- **Carbon capture, utilization and storage,** which will be essential for mitigating electricity and industrial sector emissions and for direct air capture of carbon dioxide;
- **Hydrogen,** which has wide-ranging applications including as a means for energy storage and transmission, an alternative transportation fuel, an industrial feedstock, etc.;
- **Advanced digitalization,** which enables networked advances in data analytics and connectivity to make energy systems more efficient, reliable and sustainable;
- **Substitute materials,** which can provide important alternative inputs to renewable energy technologies and replace heavier materials in the transportation sector; and
- **Advanced small-size nuclear energy,** which could provide increased flexibility, dispatchability, energy density and safety.

Recommendations

Looking ahead, the 21st century energy future clearly reveals the importance of forward-looking policies that help unlock meaningful GHG emissions reductions while ensuring continued economic growth. Providing robust, affordable energy for the world while reducing emissions and facilitating consumer choice is a considerable challenge — one that requires technological innovation, sound policies, and political and corporate commitment.

As the nation's business leaders, the CEO members of the Business Roundtable understand the opportunities and challenges presented by this changing energy landscape. Public policy should enable companies and individuals to harness new opportunities with strong infrastructure and a stable and predictable regulatory regime that boosts investment and catalyzes solutions.

In light of these considerations, the Business Roundtable offers the following recommendations:

- **Support federal climate policy that aligns with scientific consensus and promotes collective actions that will lead to the reduction of GHG emissions.**
- **Foster energy innovation by boosting federal funding for investments in a diverse portfolio of precommercial energy and climate research and development activities,** with a focus on strategic investments in basic research. Specifically, the federal government should develop a strategic, coordinated approach for energy and climate research and development, including a clear articulation of near-, medium- and long-term research priorities; specific objectives and benchmarks for research activities; a predictable funding stream; and effective coordination and collaboration across agencies and federal labs.
  - Improve collaboration among federal research labs, universities and the private sector to accelerate the transition of promising technologies from the lab to commercialization in the marketplace.
- **Empower energy consumers by setting transparent, cost-effective energy efficiency standards** through open, collaborative processes and ensuring the coordinated, timely and comprehensive adoption of new standards.
- **Adopt a technology-neutral framework for removing barriers and accelerating the deployment and application of all technologies that can provide substantial reductions in GHG emissions.**
- **Provide predictable and stable regulatory and tax regimes for investments in energy and innovative technologies.**
- **Adopt transparent, predictable and expeditious permitting review procedures for the energy infrastructure needed to support the 21st century energy ecosystem,** including access to affordable and reliable energy, a transition to low-carbon energy, and meaningful deployment of innovative and emerging energy technologies.

INTRODUCTION Meeting Tomorrow's Energy Challenges

America's energy sector drives job creation, growth and competitiveness throughout the economy. Delivering diverse, affordable and reliable energy to U.S. businesses and consumers is essential to maintaining economic growth while improving standards of living. At the same time, advancing these objectives while reducing environmental impacts and addressing the global climate challenge is imperative. Technology and sensible, supportive government policies offer a path to successfully managing these forces and factors within the U.S. and global energy systems.

The United States today is in an enviable position with respect to its energy future, even as it is undergoing dramatic shifts in how energy is produced and used. Unprecedented U.S. oil and gas production has structurally altered both the domestic and global energy landscapes. Increasing attention to global climate change and to how and where energy is sourced, combined with supportive public policies, has reduced costs and spurred dramatic increases in renewable energy deployment and advances in storage technology. These trends have the potential to fundamentally change the way the energy system operates.

Within this dynamic landscape, balancing the nation's energy, economic and environmental needs while addressing global climate change requires a continued focus on developing and deploying new technologies. These energy innovations will have even more impact when supported by policies, infrastructure and stable regulatory regimes that enable companies and individuals to harness and maximize their potential, including stable and adequate returns on investment.

As the nation's business leaders, Business Roundtable CEOs understand the opportunities and challenges presented by the changing energy landscape and recognize that a diverse portfolio of energy resources will be needed to meet the globe's growing demand. Addressing the challenges and capitalizing on the opportunities require policies that bring together the public and private sectors to collaborate on innovation through research and development, promote the deployment of advanced technologies, and enhance environmental performance — with the aim of achieving a truly competitive and environmentally sustainable economy.

EMERGING TRENDS Changes in Technology and Resources

The U.S. energy sector is in a period of transformation. Scientific evidence increasingly shows a rise in surface temperatures linked to human activity. As a result, the call for collective action to address the risks to the environment, the economy and public health posed by the changing climate is mounting. At the same time, an unprecedented surge in U.S. oil and gas production has structurally altered both the domestic and global energy landscapes and shifted America's energy position from one of scarcity to one of abundance. Research; supportive policies; investment; and deployment of lower-emissions fuel sources, zero-emissions renewable energy and innovative energy technologies such as battery storage are accelerating and driving the increased cost competitiveness of these fuels and technologies. Meanwhile, sustained advances in energy efficiency have drastically reduced the economy's energy consumption, while cutting-edge digitalization technologies and processes are being integrated across the energy sector. These crosscutting developments have the potential not only to disrupt and reshape the U.S. energy sector but also to drive fundamental changes in how the U.S. economy and energy consumers interact with energy.

Global Climate Change

The need to mitigate the current and future impacts of global climate change is creating conditions that catalyze technological innovation and a global policy conversation around energy production and consumption. According to the United Nations' Intergovernmental Panel on Climate Change (IPCC), impacts on natural and human systems from climate change are already observable, and additional adverse impacts will be experienced even if countries succeed in limiting global temperature change to at most 2 degrees Celsius above preindustrial temperatures — one of the stated goals of the Paris Climate Agreement.[1]

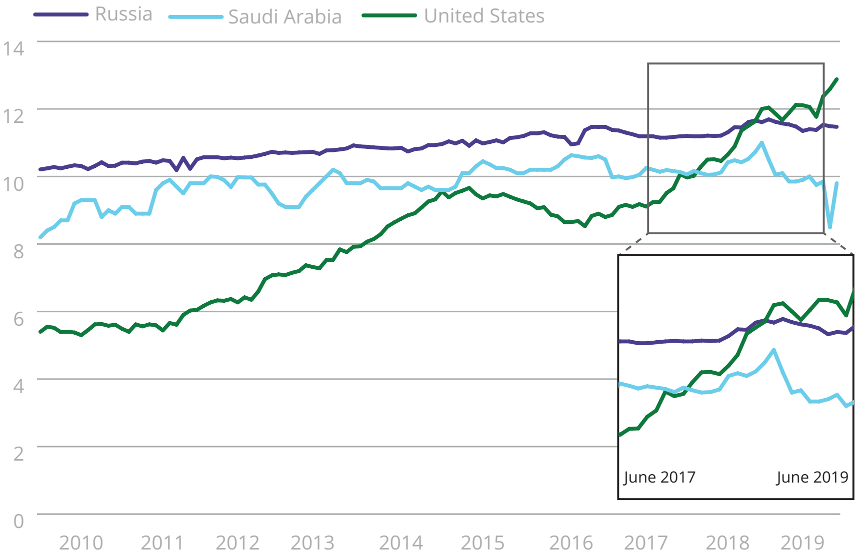
However, global energy demand is projected to continue expanding for electricity in particular, as heating systems and vehicle fleets are electrified.[2] Against this backdrop, solving the dual objectives of meeting energy demand and maintaining economic growth while addressing the environmental, economic and health risks due to global climate change will become increasingly challenging.

The import and impact of global climate change as a broadly disruptive trend to the global and U.S. energy sectors and to the economy over the coming decades should not be underestimated. This trend will drive and shape the deployment of renewable resources, the role of lower-emissions natural gas in the global fuel mix, growing interest in electrification and advanced biofuels in the transportation sector, further investment in efficiency technologies, and efforts to build a more resilient energy system. While cost and feasibility considerations must continue to be factors, global climate change will be a defining trend in the energy sector for decades to come.

Booming Domestic Crude Oil and Natural Gas Production

The energy conversation in the early to mid-2000s was characterized by concerns about America's ever-increasing reliance on imported oil and natural gas. Roughly a decade into the shale revolution, those concerns have faded. Advances in horizontal drilling and hydraulic fracturing technologies have lowered production costs over the past decade and enabled the development of previously uneconomic or technically inaccessible oil and gas resources. In 2018, U.S. natural gas production was up more than 50 percent and crude oil production more than 100 percent from a decade ago,[3] with approximately 70 percent of natural gas and 60 percent of oil production coming from shale or tight oil and gas resources.[4]

FIGURE 1. Monthly Crude Oil Production
Million Barrels Per Day



NOTE: Production for the United States includes crude oil and condensate, the total for Saudi Arabia includes only crude oil, and the total for Russia includes petroleum and other liquid fuels, due to disaggregation in U.S. Energy Information Administration (EIA) data sources. Levels are EIA estimates.
Source: U.S. Energy Information Administration, Short Term Energy Outlook (Release Date: November 13, 2019), Tables 1, 3b and 3c

These technology and resource developments are reshaping the energy landscape both domestically and abroad. At home, natural gas provides an affordable feedstock for American manufacturing, lower-emissions fuel for electricity generation, and an affordable source of process heat for industry and home heating. In fact, natural gas prices have hovered at levels roughly five times lower than they were in 2005, when domestic prices peaked.[5] Internationally, crude production at the rate of more than 12 million barrels per day has positioned the United States as the world's leading producer of crude oil.[6, 7] In addition, U.S. shale production represents a significant source of global incremental supply and has contributed to a flattening oil cost curve as more supply can be brought online in response to relatively small price increases.[8] In 2017, the United States exported more natural gas than it imported for the first time in more than 60 years.[9]

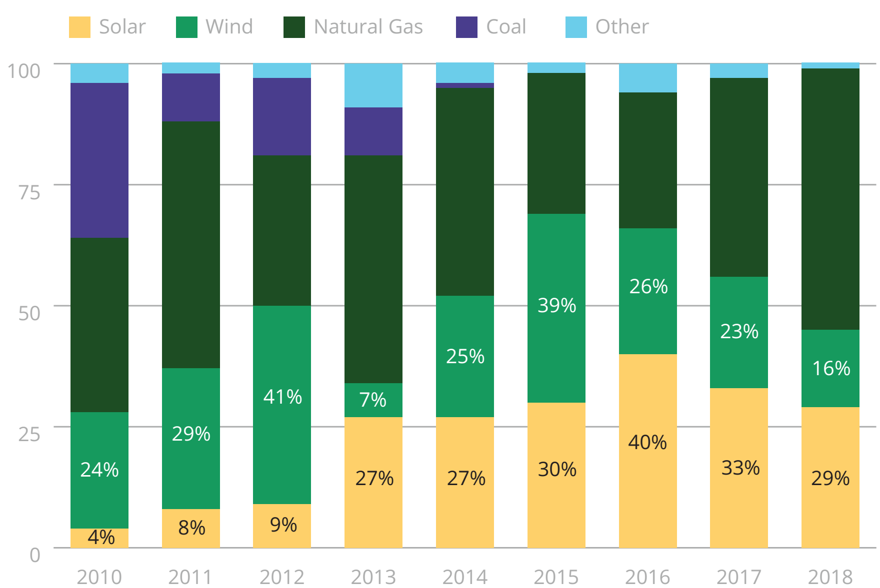
Looking ahead, the United States is projected to account for 85 percent of growth in world oil production and 30 percent of global natural gas production through 2030.[10, 11] In the context of expanding global demand for oil and gas, robust U.S. energy production not only strengthens the country's energy self-sufficiency and security (although the United States is very much still a part of and affected by world energy markets) but it also strengthens the role of the United States as a leading global energy provider and shifts the balance of geopolitical energy considerations.

Cost-Competitive Renewable Energy

Accelerating renewable energy deployment for electricity generation has been one of the leading stories of 21st century American energy. Once considered uncompetitive with conventional fuels and suitable only for niche applications, renewable energy — particularly wind and solar — has become highly competitive and is gaining momentum.

FIGURE 2. Annual U.S. Electricity Generation Capacity Additions

Share of Total Capacity Additions

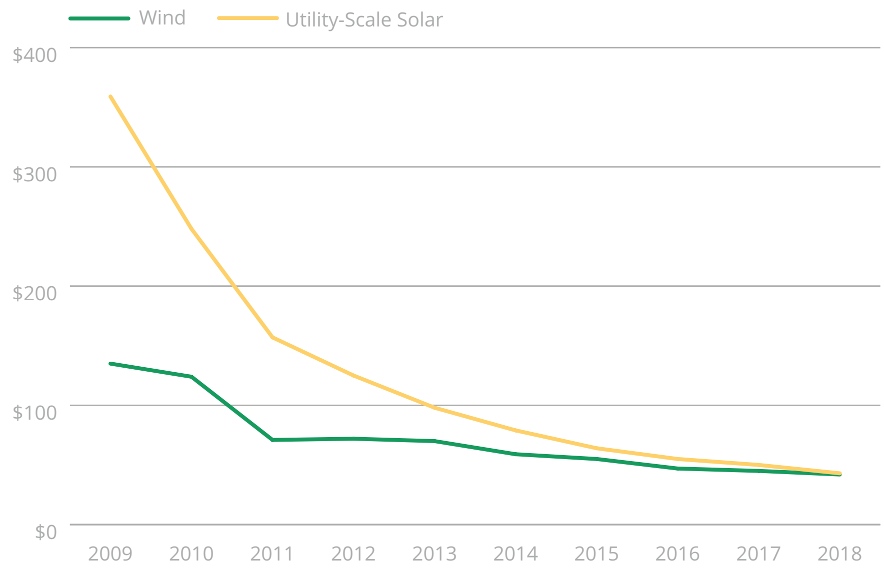


Source: Solar Energy Industries Association, Solar Market Insight Report 2018 Year in Review. *https://www.seia.org/research-resources/solar-market-insight-report-2018-year-review*

Although nonhydro renewable energy still accounts for a relatively small share of total U.S. electricity generation — wind and solar together accounted for a little more than 8 percent of net electricity generation in 2018 — installed wind capacity has increased by nearly 60 percent over the past five years while installed solar capacity has increased by more than 600 percent during the same period.[12] In fact, wind and solar have accounted for the largest share of new U.S. generation capacity in five out of the past nine years,[13] and generation from all renewable sources exceeded coal generation for the first time in April 2019.[14] Looking forward, total U.S. wind and solar generating capacity is expected to more than triple between 2019 and 2050.[15]

FIGURE 3. Unsubsidized Levelized Cost of Energy (LCOE) — Wind/ Solar Photovoltaic

Mean LCOE $ Per Megawatt-Hour



Source: Lazard, Lazard's Levelized Cost of Energy Analysis — Version 12.0, *p. 7. https://www.lazard.com/media/450784/lazards-levelized-cost-of-energy-version-120-vfinal.pdf*

These trends have been driven by a mutually reinforcing network of favorable policies (primarily federal tax incentives and state renewable portfolio standards), advances in solar and wind turbine technologies, expanded global supply chains, and mounting concerns over global climate change and associated shifts in consumer preferences. For example, corporate power purchase agreements for renewable electricity generation reached 6.5 gigawatts (GWs) of renewable energy capacity in 2018, up from less than 1 GW in 2013.[16] Together, these drivers create a virtuous cycle in which policy incentives drive supply and early deployment, which drive advances in material and production technologies and reduce the cost of installed renewable generation, which in turn spur further demand and grow the market. The unsubsidized costs of installed wind and solar have declined dramatically over the past decade: The cost of crystalline utility-scale solar photovoltaic (PV) generation dropped 88 percent between 2009 and 2018, while the cost of wind generation declined by 69 percent.[17] The result is that new solar and wind generation are increasingly cost competitive and have even reached grid parity with some traditional fuels.[18]

Of course, renewable electricity generation is not without its challenges. Wind and solar generation are variable and do not always correspond to peak electricity demand (e.g., wind tends to peak at night, while solar generation typically peaks during midday). Prime locations for utility-scale wind and solar generation can be far from load centers, while distributed residential and commercial solar installations present their own challenges in terms of grid and load management. The long-term trajectory and momentum of renewable energy deployment depends on how these challenges are addressed. Nonetheless, renewable energy — excluding conventional hydropower — is projected to double as a share of net generation between 2018 and 2040, from a little more than 10 percent in 2018 to more than 20 percent in 2040.[19]

Alternative Transportation Fuels and Technologies

One of the most striking trends currently taking shape in the U.S. transportation sector is expanding fuel diversity, driven by the slow but steady integration of alternative fuels and propulsion systems. Historically, the conversation around alternative transportation fuels has centered on biofuels, with significant integration of ethanol and biodiesel into the fuel mix for the passenger and heavy-duty vehicle fleets. More recently, however, the focus has expanded to encompass a wider array of alternative fuel options, including advanced biofuels (e.g., cellulosic biomass, organic waste, algae), natural gas, hydrogen and electricity.

Electricity in particular has recently gained significant momentum as an alternative fuel source. Electricity is used to power battery electric vehicles (BEVs), which run on a single electric propulsion system, as well as plug-in hybrid electric vehicles (PHEVs), which incorporate traditional internal combustion engine technology in a dual-propulsion system. Although current U.S. electric vehicle (EV) penetration and new sales rates are low, EVs (including BEVs and PHEVs) are forecast to account for somewhere between 19 percent and 30 percent of U.S. car sales by 2030–40, driven by declining battery costs, favorable policies and changing consumer preferences for lower-emissions transportation options.[20] Projected momentum for EVs is even stronger in the international passenger vehicle market: The most optimistic outlook predicts that more than half of international passenger vehicle sales and more than 30 percent of the global passenger vehicle fleet will be electric by 2040.[21]

In terms of commercial and fleet vehicles, more than one-half of light and nearly one-third of medium commercial vehicle sales in China, the United States and Europe (the three largest markets for EVs) are projected to be electric by 2040.[22] Municipal bus fleets are already beginning to incorporate electric buses, with some forecasts suggesting that U.S. electric bus purchases could reach anywhere between 27 percent and 60 percent by 2030.[23]

Advanced biofuels and natural gas also have an important role to play in reducing transportation sector emissions and diversifying the liquid fuel mix. In particular, heavy-duty transportation modes such as trucking, shipping and aviation are more difficult to electrify than light-duty vehicles given the high battery energy density that would be required to support long-distance travel. Moreover, heavy-duty vehicles tend to turn over more slowly than light-duty vehicles, which increases the imperative to find lower-emissions fuels that can be used in existing fleets. While deployment of advanced biofuels remains fairly limited, demand for lower-emissions fuels in the trucking, shipping and aviation sectors is beginning to catalyze a breakthrough in ongoing research and commercial-scale deployment efforts. In fact, a U.S. company has recently begun producing commercially available jet fuel from municipal solid waste (household garbage).[24]

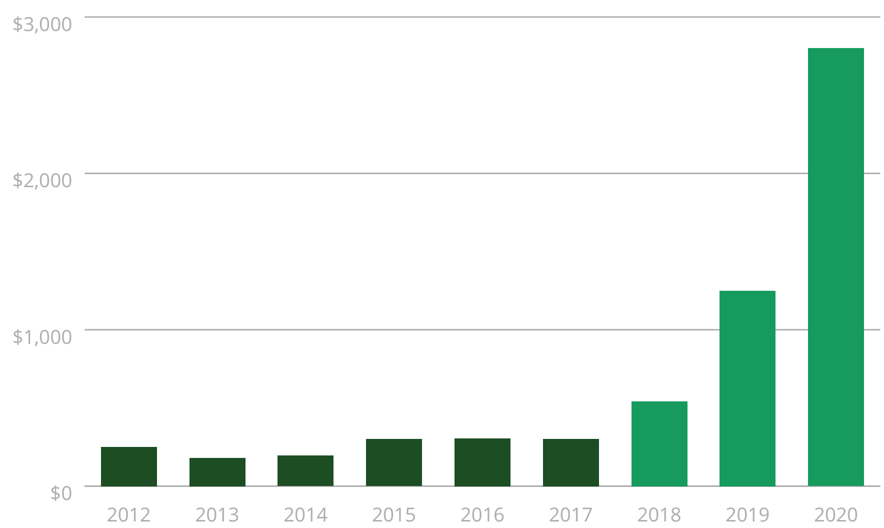
The use of natural gas in the U.S. transportation sector has expanded concurrently with the rise of low-cost, abundant domestic natural gas in the United States — particularly across nonpassenger vehicle modes. Heavy-duty vehicles and municipal bus fleets in particular are integrating more natural gas, with 28.5 percent of transit buses now running on natural gas.[25]

Finally, hydrogen is a fuel that is typically used in stationary power sources but is also being explored by some auto manufacturers as an alternative fuel for powering EVs. A limited number of fuel cell EVs are currently being produced and sold in select markets that have the necessary fueling infrastructure.

Advances in Energy Storage

One of the most-watched trends to unfold in the electricity sector over the past decade has been the maturation and deployment of energy storage technologies — at both distributed and utility scale — propelled by favorable policies, amenable state utility commissions, sharply falling costs and the expansion of distributed energy resources (DERs). While a diverse set of storage options has emerged — including a range of battery technologies, compressed air, thermal storage, flywheels and pumped hydroelectric storage — lithium-ion batteries currently lead the way in terms of progress toward lower costs and broader deployment.

FIGURE 4. **U.S. Annual Energy Storage Market Size**
Million $



NOTE: Market size represents energy storage system deployment revenues and is estimated for 2018–20.
Source: GTM Research, U.S. Energy Storage Monitor: Q3 2018 Executive Summary, *p. 11, September 2018*

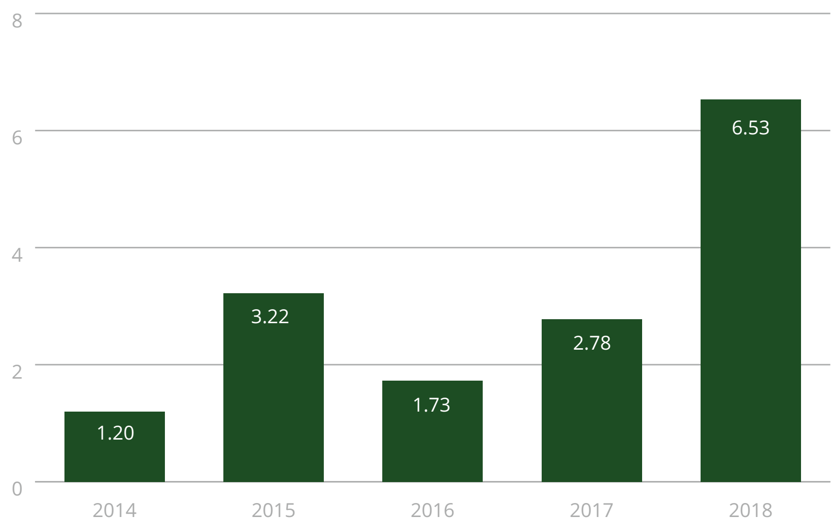
Between 2010 and 2018, the price of lithium-ion batteries fell 85 percent, thanks to advances in chemistry and battery technology, improvements in the production process, manufacturing economies of scale, and growing competition among global manufacturers for market share.[26] Some forecasts suggest that prices could fall by half by 2030, as demand picks up for batteries in the vehicle and stationary storage markets.[27] Price declines of this scale can drive massive expansions in deployment. From mid-2017 through the end of 2018, the U.S. energy storage market grew by 200 percent in terms of megawatt-hours (MWh) deployed, with much of that growth occurring in behind-the-meter applications such as EVs and stationary source DERs.[28]

Utility-scale battery storage is progressing more slowly than these behind-the-meter applications, as installed costs remain relatively high and the business case is less clear for some utilities — particularly deregulated utilities that are unable to sell generation back to the grid. Specifically, the unsubsidized levelized cost of storage for utility-scale lithium-ion storage systems ranges between $108 and $140 per MWh.[29] Even so, installed utility-scale battery storage has roughly doubled since 2015,[30] and several recent proof-of-concept use cases suggest that utility-scale storage may have potential.[31]

Distributed Energy Resource Deployment

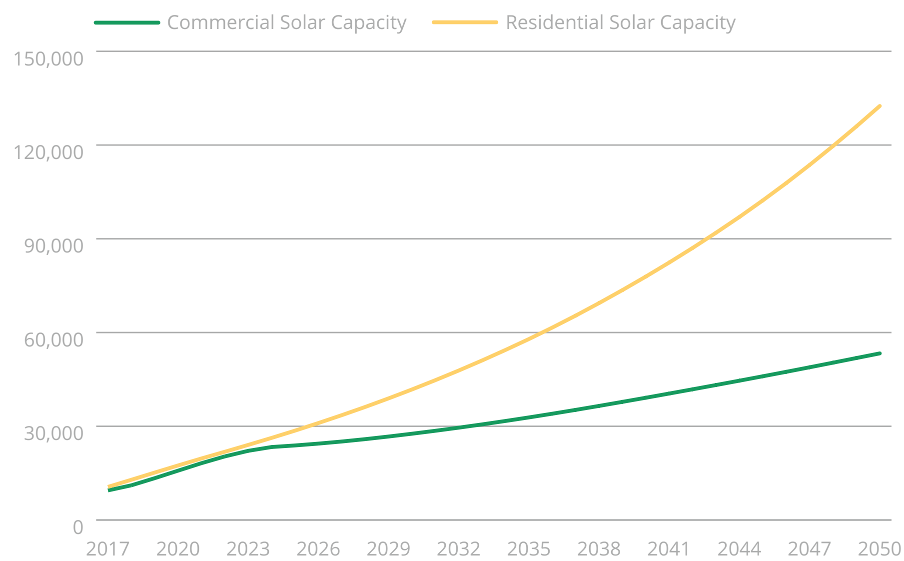
Storage technology and renewable energy are part of the vanguard of DER technologies that are decentralizing energy supply as the U.S. electricity grid shifts from more centralized generation to incorporating both centralized and decentralized DER generation. For example, the U.S. residential solar market has grown by about 44 percent each year since 2005,[32] with more than 1.8 million residential solar PV systems installed as of late 2018.[33] All told, DERs, including distributed solar, distributed storage, small-scale combined heat and power (CHP), residential smart thermostats, and EVs, provide roughly 46 GWs of flexible capacity to the U.S. grid — a figure that is expected to more than double to 104 GWs by 2023.[34] For context, this figure would represent slightly less than 10 percent of current total utility-scale generating capacity.[35]

FIGURE 5. **Annual Renewable Energy Capacity Contracted by Corporations**
Gigawatts



NOTE: Excludes onsite generation (e.g., rooftop solar) and deals with operating plants.
Source: Business Renewables Center, BRC™ Deal Tracker Corporate Renewables Deals. https://businessrenewables.org/corporate-transactions/

FIGURE 6. Solar Generation Capacity Projections by Sector
Megawatts



Source: U.S. Energy Information Administration, Annual Energy Outlook 2019, *Table: Residential Sector Equipment Stock and Efficiency and Distributed Generation and Table: Commercial Sector Energy Consumption, Floorspace and Equipment Efficiency and Distributed Generation*

As evidenced by the increase in corporate renewables procurement, end-use consumers are pushing for more choice, more control and cleaner sources for their electricity, which increasingly entails the integration of onsite energy resources. While combined CHP systems and small wind installations in the commercial and industrial sectors are expected to grow, forecasts are most robust for distributed solar deployment. Specifically, distributed solar capacity in the United States is expected to grow 8 percent per year in the residential sector and 5 percent per year in the commercial sector through 2050.[36]

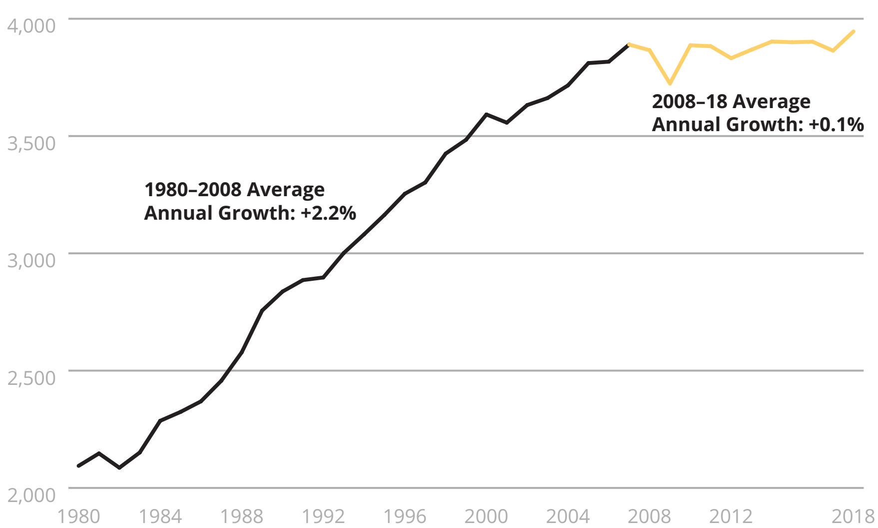
This expansion of DER technologies and the associated increase in behind-the-meter activity is prompting changes in critical aspects of how the electricity grid and utility sector function.[37] For example, DERs are giving rise to advanced microgrids — localized grids that can disconnect from the bulk power grid and autonomously provide power.

Improvements in Energy Efficiency

Sustained advances in energy efficiency technologies, in combination with wider deployment of those technologies across the transportation, industrial and commercial sectors, have caused primary energy demand in the United States to flatten since the mid-2000s — a dramatic trend shift relative to historical norms. In the transportation sector, fuel efficiency of new light-duty passenger vehicles increased by 24 percent between 2006 and 2015.[38] In the industrial sector, energy use was 6 percent lower in 2018 than it was in 1998, despite higher output.[39] Perhaps most significantly, thanks to energy efficiency improvements, electricity consumption in the United States was virtually flat between 2008 and 2018. This compares to average annual growth of 2.2 percent in electricity consumption between 1980 and 2008 and average annual gross domestic product (GDP) growth of 1.6 percent between 2008 and 2018 — including negative growth during the 2008–09 recession.[40]

FIGURE 7. **Total U.S. Electricity End Use**

Billion Kilowatt Hours Per Year



Source: U.S. Energy Information Administration, September 2019 Monthly Energy Review, *Table 7.1: Electricity Overview*

This development sets the United States apart from the rest of the world — particularly developing economies.[41] While U.S. primary energy consumption is projected to grow by just 1 percent through 2040,[42] global demand, buoyed by robust demand in countries that are not part of the Organisation for Economic Co-operation and Development, is expected to increase by 28 percent over that same period — a trend with interesting implications for global energy markets.[43]

Digitalization and Advanced Data Analytics

Many of the advances in the 21st century U.S. energy landscape have come about not only because of advances in energy technologies but also thanks to breakthroughs in information and communication, analytics, and control technologies. Together, these breakthroughs are enabling a new era of energy digitalization, dominated by crosscutting digital tools and platforms — including artificial intelligence, blockchain, the Internet of Things (IoT) and big data analytics — that can be applied to the energy system in myriad ways.[44]

Advances in computing and machine learning have enabled automation and advanced functionality to be embedded within energy production sites, delivery systems and distribution networks. In the oil, gas and mining sectors, technologies such as artificial intelligence and drones are helping companies better understand subsurface conditions; improve operations, maintenance and safety; and reduce environmental impacts.

In the electric utility sector, increasingly affordable and sophisticated sensing, communications and controls technologies have improved grid resilience; made demand response more powerful; increased the deployment of smart devices (e.g., thermostats, smart meters) in homes and buildings; and helped accelerate the evolution of a multidirectional, distributed and dynamic smart grid.[45] Many of these personal and home devices are connected to communications networks — creating an IoT that unlocks a wide variety of services and applications. The vast volume of data generated by smart meters, IoT devices, grid sensors and other technologies will only grow as the grid modernizes, creating opportunities for new grid management services and approaches for optimizing energy use.

STATE OF PLAY Implications for the New U.S. Energy Landscape

The impact of these trends is multifaceted. Robust domestic oil and natural gas production will continue to drive economic growth and support expanding global energy consumption even as demand grows for lower-emissions energy options. Energy infrastructure systems are straining to accommodate booming domestic production and new demands that renewable resources and DER deployment are placing on the electric grid. In the electricity sector more broadly, many utilities are facing significant pressure from changing technologies; a shifting generation portfolio; and rapidly evolving regulatory, consumer and investor preferences. And in the transportation sector, a range of emerging technologies have the potential to reshape the future of travel. These trends will affect every corner of the energy industry and U.S. economy and will challenge policymakers and the industry to adapt and innovate.

U.S. Economy

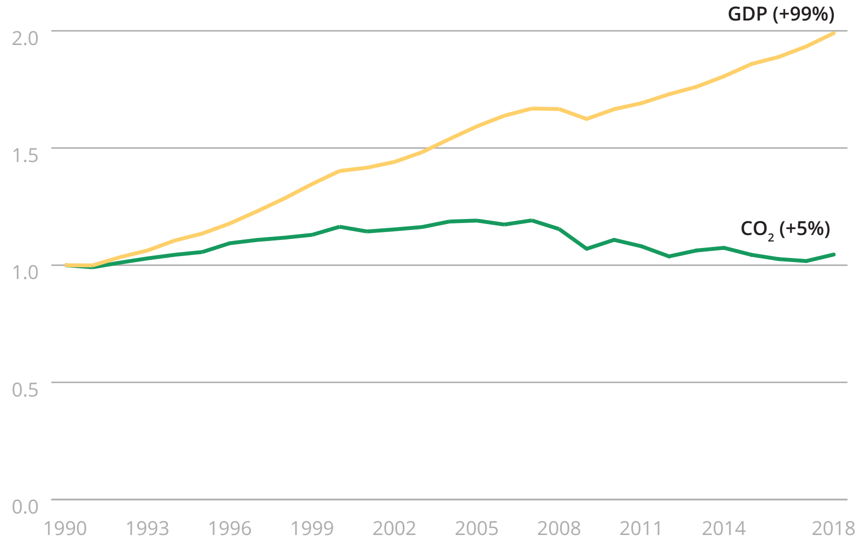
The developing technology and resource trends in the American energy landscape have important implications well beyond the energy sector. Indeed, the entire U.S. economy's relationship to energy production and consumption is shifting. Energy-related emissions are trending down, American households are spending less on energy costs, imports of foreign oil are down, and exports of domestically produced oil and natural gas are up.

Within this broader economic context, two shifts are particularly worth noting: (1) At a macro level, one of the most significant energy stories in the United States over the past several decades has been the decoupling of economic growth from greenhouse gas (GHG) and other conventional pollutant emissions; and (2) at a more micro level, perhaps no industry has benefited from the American energy renaissance as much as the manufacturing industry.

Decoupling of Economic Activity and Emissions

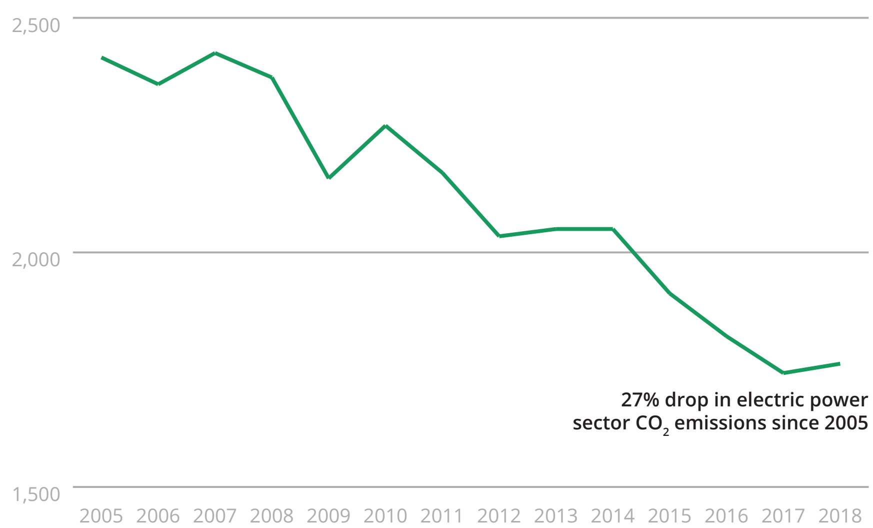
Beginning in the early 1990s, U.S. GDP growth started to outstrip growth in carbon emissions. This trend has become even more pronounced since emissions peaked in 2007, with growth in economywide carbon emissions trending negative while GDP continues to expand.[46] Although every sector of the economy emits less carbon dioxide today than in 2007, the reduction has been particularly pronounced in the electric utility industry, thanks to the integration of renewable energy and natural gas. In fact, increased electricity generation from natural gas (up 100 percent over 2005 levels) has helped drive a 27 percent decline in power sector carbon dioxide emissions since 2005.[47]

FIGURE 8. **Decoupling of GDP and Energy-Related Carbon Emissions**
Indexed to 1990 Levels



Source: U.S. Energy Information Administration, September 2019 Monthly Energy Review, *Table 11.1: Carbon Dioxide Emissions From Energy Consumption by Source; Bureau of Economic Analysis, NIPA Table 1.1.6: Real Gross Domestic Product, Chained Dollars, last revised October 30, 2019*

FIGURE 9. **Total Carbon Dioxide Emissions: Electric Power Sector**
Million Metric Tons of Carbon Dioxide



Source: U.S. Energy Information Administration, September 2019 Monthly Energy Review, *Table 11.6*

Integration of no- and low-emissions fuels aside, sustained improvements in energy efficiency across the economy have resulted in virtually flat energy demand since 2005 and electricity demand since 2010, and they have indirectly improved emissions intensity.[48] By 2040, additional gains in energy efficiency and fuel economy, combined with structural changes in the economy, are expected to drive overall energy intensity to roughly 33 percent below what it was in 2018.[49]

Manufacturing Sector Renaissance

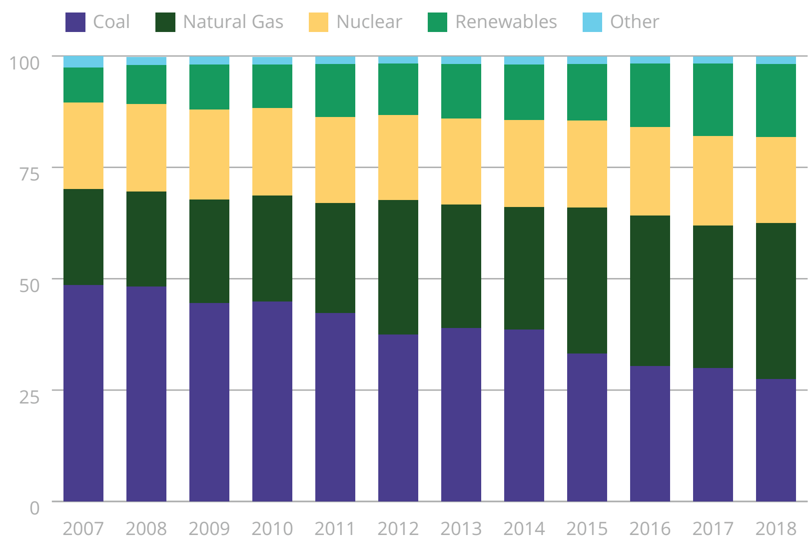
The shale revolution has fundamentally recast the role of oil and natural gas in America's energy landscape and other sectors of the economy. As a result of the growth in oil and gas, natural gas liquids (NGL) supply has increased — a critical feedstock for many manufacturing sector industries (e.g., petrochemicals). Specifically, U.S. liquid fuel production more than doubled between 2009 and 2018, with increases in NGL production accounting for roughly 30 percent of this growth.[50] Growth in NGL production is expected to continue over the next decade, with end-use applications to help support a sustained renaissance in American manufacturing.[51]

At the same time that it has benefited from a resurgence thanks to affordable natural gas, the U.S. manufacturing sector has experienced a reduction in energy intensity. Manufacturing industries account for roughly three-quarters of industrial sector energy consumption, which in turn accounts for one-third of total energy consumed in the United States.[52, 53] However, from 2010 to 2014, the sector's fuel consumption increased at roughly half the rate of its real gross output, resulting in a 4.4 percent decline in fuel intensity.[54] These improvements have been driven in large part by cost pressures from highly competitive global markets, with U.S. manufacturers motivated to find innovative solutions to reduce energy costs. In addition to investments in energy efficiency, U.S. manufacturers are ramping up onsite generation capacity to reduce energy and emissions intensity. These efforts increasingly incorporate low- and no-carbon fuels such as biomass, solar and natural gas.[55]

Nation's Fuel Mix

The rise in shale gas production and increasingly cost-competitive renewable energy are combining to reorient the nation's fuel mix, particularly within the electricity sector. Coal's share of U.S. electricity generation fell steadily from 50 percent in 2005 to 28 percent in 2018. Over that same period, renewables' share (including hydropower) nearly doubled to 16 percent, and natural gas's share increased from 18 percent to more than one-third.[56] In fact, electricity generation from renewable sources surpassed coal generation for the first time ever in April 2019, with renewables accounting for 23 percent of monthly generation as coal generation declined to 20 percent.[57]

FIGURE 10. **Total Net Generation by Source**
Share of Total



Source: U.S. Energy Information Administration, September 2019 Monthly Energy Review, *Table 7.2a*

Looking forward, a handful of overlapping trends will continue driving shifts in the nation's fuel mix. In the near term, natural gas is expected to continue growing as a share of U.S. power generation due to its low cost and its emissions advantage relative to coal. In the longer term, renewable energy is expected to continue to decline in cost and expand its share of the generation portfolio as improvements in battery and other storage technology make variable renewable generation a dispatchable resource and as technological and chemical advances continue to drive down the costs of wind and solar energy.

Energy Infrastructure

American energy infrastructure is struggling to keep up with a changing energy landscape. Historic levels of oil and natural gas production and fundamental changes in the nation's electricity fuel mix are creating new economic opportunities and a path forward to more affordable, lower-emissions energy options. However, these opportunities will not be fully realized without the infrastructure necessary to support the 21st century American energy landscape. Transparent markets must provide the right incentives, and policies must facilitate the deployment of new pipelines, reorientation and redeployment of older pipelines, rail transport capacity, energy export terminals, long-distance transmission grids, and local distribution lines.

Oil and Gas Infrastructure

The booming oil and natural gas industry is contending with inadequate take-away and transmission capacity, as infrastructure has failed to keep pace with domestic energy production. This failure has led to supply constraints in certain regions — for example, in early 2019 two utilities in the New York City area stopped accepting new natural gas customers, citing insufficient local supply lines to meet peak demand.[58] Another negative side effect is significant price deviations from the national Henry Hub spot price. Natural gas prices fell into negative territory at a trading hub in West Texas in spring 2019, while prices in Southern California soared to $23 per million British thermal units.[59] Despite the evident need, pipeline construction faces continual opposition in many locations from landowners along the routes and from activist groups that point to potential environmental consequences.

In addition to meeting domestic demand for heating and electricity, new and expanded infrastructure is needed to deliver natural gas feedstocks to manufacturing facilities to support and sustain the U.S. manufacturing renaissance. Finally, adequate export terminal capacity for domestic natural gas is needed to respond to global energy demand and position the United States as a leading global supplier.

Electricity Infrastructure

Growing DER and renewable energy deployment are placing stress on an aging grid that was largely constructed in the 1950s and 1960s and designed for one-way power flows from large, centralized generation stations.[60] The grid management challenges posed by distributed, intermittent and variable resources — often far from load centers — are significant. Projections that renewable energy will make up a growing share of the country's generation portfolio in the coming years will materialize only if significant additional investments are made in the nation's transmission and distribution grid infrastructure. For instance, a 2014 study estimated that PJM — a regional transmission organization that spans 13 states — would need between roughly 1,000 and 3,000 miles of additional or upgraded transmission lines to accommodate a generation portfolio with 30 percent renewable energy.[61]

In response to these challenges, several states are pursuing initiatives to update their utility regulations, while regional transmission organizations are considering pathways for modernizing the transmission grid. At the same time, many utilities are deploying a range of advanced sensors and control systems as underlying components of smarter grids. These sensors and systems provide real-time insights into grid conditions, improve reliability, enhance responsiveness to disruptions and outages, and support further integration of distributed energy.[62, 63, 64] However, solutions to upgrade long-distance transmission infrastructure at scale remain challenging. Building transmission lines is a time-consuming process given the difficulty of securing rights of way and the necessary permits. A path forward will require creative and collaborative solutions from utilities, regulators and local communities, including ideas such as using existing rights of way along railroad corridors to build new high-voltage transmission lines.

Electric Utility Industry

Many electric utilities are facing significant pressure from changing technologies; a shifting generation portfolio; and rapidly evolving regulatory, consumer and investor preferences. Customers are pushing for more choice, more control and cleaner sources for their electricity — increasingly demanding their own bespoke mix of electricity via local energy resources. Growing DER deployment is forcing some utilities to grapple with new rate structures and valuation of transmission to avoid the "utility death spiral," in which reductions in consumer reliance on the grid lead to fewer kilowatt hours across which utilities can spread their fixed costs, leading to higher rates that in turn incentivize further reductions in grid reliance, and so forth.

Higher penetration of renewable resources also poses challenges for the utility industry — and for the electricity grid in particular. Specifically, the variability of wind and solar energy generation may make aligning generation and demand difficult as renewable deployment expands. And because renewable-generated electricity is not dispatchable (i.e., not available on demand), grid operators are challenged to manage dispatchable load (typically, fast-ramping natural gas generation) around renewable generation. Additionally, the variability of wind and solar energy means that power systems with high shares of these resources must also have greater overall installed capacity than more diversified systems to maintain sufficient dispatchable capacity. For these reasons, a renewables-heavy grid will require greater use of flexible, fast-ramping resources — complemented by the deployment of advanced smart grid technologies — or more cost-effective utility-scale energy storage options.[65]

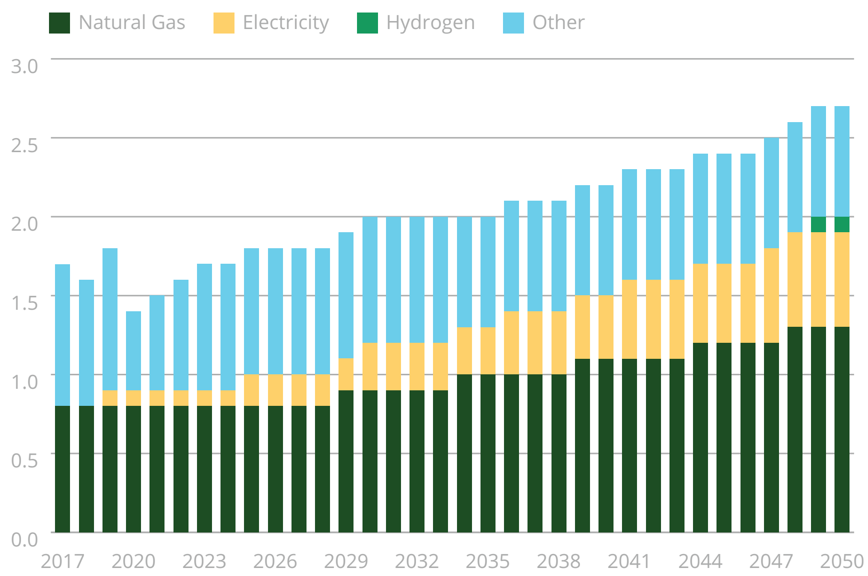
A scenario in which the trajectory of EV deployment generally tracks with current forecasts entails additional implications for the electric utility industry. EV batteries represent a potentially widespread DER that, when connected to the grid, could provide supplemental energy storage, frequency regulation and other grid services. While vehicle-to-grid technologies are currently in pilot or conceptual phases, accelerating EV penetration could push these technologies toward maturity state and deployment more quickly.

Finally, the growth in variable renewables, storage, DERs and digitalization is beginning to spur changes in how electricity is consumed. For instance, demand response and load shifting will play an increasingly important role in America's energy future. Smart appliances and devices in buildings could be key enablers of enhanced demand response, and the increased digitalization of the grid will be critical for improving efficiency and balancing power supply and demand. These developments represent a paradigm shift from the traditional utility model; rather than supply chasing load, this model involves load moving to match supply.[66]

Ground Transportation

As the transportation landscape continues to evolve, a range of emerging technologies have the potential to reshape the future of transportation. The electrification of transportation, and passenger vehicles in particular, is one of the most highly anticipated trends in the transportation sector. While more conservative outlooks expect gasoline vehicles to remain dominant through at least mid-century, growing deployment of EVs and other alternative fuel vehicles, combined with further advances in fuel efficiency, could have implications for U.S. oil consumption and transportation sector emissions over the longer term.[67]

FIGURE 11. Projected Transportation Sector Consumption of Nonmajor Petroleum and Alternative Fuels
Quadrillion British Thermal Units



NOTE: "Other" includes residual oil fuel, other petroleum and propane. "Natural Gas" includes pipeline and distribution fuel natural gas, as well as compressed/liquefied natural gas.
Source: U.S. Energy Information Administration, Annual Energy Outlook 2019, *Table 2*

In fact, U.S. motor gasoline consumption is expected to decline by 26 percent between 2018 and 2050, reflecting fleet efficiency improvements due to fuel economy standards.[68] Similarly, increases in fuel economy standards will help reduce the growth of heavy-duty vehicle energy consumption over the same period, despite an expected uptick in freight truck travel.[69] Advances in diesel engine technology are also driving improvements in fuel efficiency and emissions intensity in the trucking sector.[70] And as the transportation sector's use of alternative fuels — including electricity, natural gas and advanced biofuels — increases, motor gasoline's and distillate fuel's combined share of the transportation fuel mix is expected to decline 10 percentage points, from 84 percent in 2018 to 74 percent in 2050.[71]

LOOKING AHEAD Breakthrough Technologies

Despite significant recent advances in energy technologies and innovation, currently deployed technologies will likely be insufficient to produce the scale of emissions reductions needed to limit the rise in surface temperature to the levels called for by the IPCC.[72] Securing the ability to provide the diverse, affordable and reliable supplies of energy that are needed to sustain economic growth while also addressing global climate change will require a supportive policy environment that eliminates barriers to and accelerates the development and deployment of new technologies, some of which could fundamentally change the U.S. (and global) energy landscape. Forecasting how these nascent technologies will develop and deploy, as well as their potential impacts, involves some measure of speculation and should therefore be done with humility. Some technologies may not fulfill the promise they appear to hold, and others may exceed it, while entirely new technologies may yet emerge. Business Roundtable believes that the following technologies warrant particular attention but should be considered in the context of this inherent uncertainty. What is certain, however, is that new technologies will inevitably emerge that will reshape how energy is produced and consumed.

Carbon Capture, Utilization and Storage

The Promise

Tackling climate change will require reducing not only the rate at which GHGs are generated but also the rate at which GHGs accumulate in the atmosphere. Carbon capture, utilization and storage (also referred to as "carbon capture," "CCS" or "CCUS") refers to a suite of technologies that selectively capture carbon dioxide from flue gas or directly from the atmosphere and then either repurpose the captured carbon dioxide for fuel, other commodities or products production or store it.

Robust, affordable CCUS can be paired with fossil fuels — including natural gas — in a future of lower carbon power. CCUS can also significantly mitigate industrial process emissions and is the only option for fully abating process-related carbon dioxide emissions in industries such as cement production.[73] In addition, CCUS is a vital component of "negative emissions technologies" (e.g., bioenergy with carbon capture and storage, direct air capture) that remove and sequester carbon dioxide from the atmosphere.[74] Analysis by the International Energy Agency has found that CCUS will play a critical role in achieving substantial emissions reductions in the industrial sector on a scale that would place industry on a path consistent with the Paris Agreement target. In fact, CCUS is already a cost-effective solution for some industries.[75]

The Path Forward

CCUS already has a solid base of experience and infrastructure. One well-established use for captured carbon is enhanced oil recovery (EOR). In fact, carbon dioxide is a commonly used agent to improve the oil production at conventional and unconventional deposits, with more than 100 EOR projects currently active in the United States.[76] Looking ahead, as demand for carbon dioxide for EOR grows and CCUS is deployed more broadly as a mitigation strategy, many more thousands of miles of pipeline will need to be added to the existing 5,000 mile high-pressure pipeline network.[77] In addition, the past few years have seen the successful launch of the first commercial carbon capture system at a U.S. coal-fired power plant and promising initial testing of a new type of natural gas plant that captures and reuses carbon dioxide emissions to drive the plant's turbine.[78, 79] Meanwhile, a 2018 extension and expansion of the 45Q tax credit for CCUS is expected to spur significantly more activity in this area by 2030.[80]

While progress to date is encouraging and some form of CCUS has been practiced safely for decades, many CCUS technologies in the development pipeline have yet to exhibit operation at scale. Fewer than two dozen large-scale CCUS facilities are operating globally,[81] and CCUS developments in the power and industrial sectors are far from reaching the scale and affordability needed to meet clean energy goals.[82] Projects face a number of hurdles, including unique environmental permitting requirements, uncertain long-term liability, financing challenges around novel commercial projects with high capital costs and the slow development of climate policies around the world.[83]

Hydrogen

The Promise

Hydrogen is a flexible energy carrier that can be produced from a range of primary energy sources and consumed across sectors. In the United States, 10 million metric tons of hydrogen are produced annually, the vast majority of which are produced through steam-methane reformation of natural gas.[84] Low-carbon hydrogen could be produced from fossil fuels using this and other methods with the addition of CCUS to the process.[85] There is also growing interest in applying wind- or solar-powered electrolysis to produce zero-carbon renewable hydrogen and using hydrogen conversion to enable long-distance renewable energy transport.[86]

Because of its flexibility and wide array of potential applications, hydrogen can be a key part of a future energy system that has significantly lower levels of emissions of GHGs and other air pollution. It has wide-ranging applications, including as a means for energy storage and transportation, an alternative fuel for powering vehicles, a scalable solution for building heating, a key input to heat-intensive industrial processes, and even an alternative feedstock for some types of industrial production (e.g., for steel). The flexibility of hydrogen means that the promise it presents is broad and varied in scope and nature.[87]

For example, hydrogen-powered fuel cell EVs represent a promising alternative fuel option for niche transportation modes that are not as well suited to battery technologies, including heavy-duty and long-haul vehicles that require longer drive ranges and shorter refueling times.[88] Large-scale hydrogen fuel cells also have potential to provide increased grid-scale storage capacity compared to lithium-ion batteries over the lifetime of a facility (although current hydrogen storage technology comes with an efficiency penalty compared to battery storage that results in increased energy loss).[89]

The Path Forward

The "hydrogen economy" has been part of the U.S. energy conversation for decades. However, forward-looking activity that would enable the energy system integration of hydrogen in the ways described in the previous section does not exist on the scale necessary for implementation. Realizing the promise of hydrogen would require massive investments in the deployment of hydrogen infrastructure and the scaling up of manufacturing capacities, as well as new technologies to lower the cost to produce, transport, store and dispense hydrogen.[90]

Beyond the need to broadly enhance the current scope and scale of technology development to unlock the full potential of hydrogen, the promise of this technology faces additional challenges from the competitive energy landscape. Hydrogen will have to compete against other technologies, some of which are expanding their market share and rapidly reducing costs, across a variety of sectoral contexts.[91] Still, there is reason for cautious optimism about the future of hydrogen given its potential to enhance energy storage performance, with near-term integration into energy systems focused on deployment in heavy-duty transportation and large-scale industrial applications where hydrogen has performance advantages over competing technologies and where there is an opportunity to more rapidly achieve economies of scale.[92]

Advanced Digitalization

The Promise

Digitalization (i.e., innovations in business models and practices resulting from digital technologies) spans a wide range of potential energy sector applications and will have far-reaching impacts in energy and nonenergy contexts. Autonomous vehicle deployment, intelligent homes, on-demand additive manufacturing (i.e., 3D printing), big data analytics, blockchain artificial intelligence and machine learning will all help shape the United States' energy future.

The networked advances in data analytics and market connectivity will make energy systems around the world more efficient, reliable and sustainable over the coming decades by reducing vehicle fuel use, optimizing building energy performance, decreasing oil and gas production costs, improving grid response to disruptions and demand, and deploying connected smart sensors.[93, 94, 95] One estimate expects that the annual benefits to the energy sector from digitalization will roughly double between 2017 and 2025, with the fastest growth in technologies and services that deliver greater consumer control and flexibility for managing residential electricity use.[96]

Novel applications of existing digital technologies may facilitate or even accelerate improvements to consumer control in a more decentralized energy system. For example, blockchain's distributed and secure transaction capabilities could help efficiently distribute flexible demand by enabling localized energy trading and other new market functions.[97] Meanwhile, advances in areas such as autonomous vehicles — which rely on multipurpose technologies that support functions as disparate as traffic signal sensing and distributed solar grid integration — could reshape future energy infrastructure.[98] In doing so, they will have transformative potential for areas beyond the conventional scope of energy technologies (e.g., vehicle ownership/ridesharing, travel costs, logistics networks).

The Path Forward

The promise of digital technologies for the energy sector will come with significant market disruptions. Early-stage industry adoption of digital tools suggests that the level of disruption could be transformational and that changes in the sector may accelerate as new applications proliferate. Yet, this process will not be linear and will take time to gain momentum, as adoption of digital tools and platforms is still nascent and faces a number of challenges. For example, much of the data generated by energy providers and users remains siloed and is held as proprietary by companies; standards and certification systems, including those around data security and fraud prevention, are still in the early stage and are inconsistent across energy products and jurisdictions; and many energy supply chains remain opaque. Moreover, new challenges will arise stemming from the increasingly digital and networked nature of energy production, consumption and transportation. The security challenge facing U.S. critical infrastructure will evolve and expand as new vulnerabilities emerge along new cyber threat vectors.

Overcoming these challenges will require coordinated action by multiple stakeholders at the national and state levels (e.g., Congress, federal agencies, regional transmission organizations and independent system operators, state utility regulators) and across various policy, regulatory and market dimensions.[99] Most importantly, policies and regulatory approaches must be sufficiently flexible to accommodate the rapid and hard-to-predict evolution of digital and communication technologies and find ways to balance data access with privacy and security imperatives.[100]

Substitute Materials

The Promise

Recent and future advances in materials science could have important implications for the U.S. energy sector in a variety of ways. Many clean energy technologies, including batteries, solar panels and wind turbines, rely on near-critical minerals (e.g., lithium and neodymium) that pose supply and cost challenges, even as materials science advances have reduced reliance on such minerals for other uses (e.g., permanent magnets and lighting).[101] In the transportation sector, a key method for improving vehicle efficiency is “lightweighting,” which replaces heavier materials (e.g., steel) with lighter ones (e.g., cellulosic fiber, various polymers and alloys) to decrease the energy required to move and accelerate a vehicle.[102] Lightweighting also holds potential for the aviation sector: Incorporating substitute materials produces lighter fuselages, which can be supported by smaller wings, which results in lighter overall aircraft. In the construction sector, industrial processes related to cement production and manufacturing lead to GHG emissions for which mitigation options are significantly limited in the absence of high-quality, alternative materials.[103]

The substitute materials developed through materials science research can provide high value when it comes to enhancing and expanding existing systems and products. They have the potential to mitigate existing constraints to the full-scale deployment of clean energy technologies and drive significant reductions in fuel consumption without sacrificing safety in the transportation sector.[104, 105] Similarly, they can help decrease GHG emissions from industrial processes for which emissions reductions are particularly challenging to achieve. The promise of these materials lies in their ability to creatively and efficiently expand emissions reduction channels.

The Path Forward

Efforts are underway to diversify or develop substitutes for the near-critical mineral supplies that are core to many clean energy technologies. Ongoing materials science research also holds promise for lightweighting in the transportation sector to improve fuel efficiency, though it still requires additional testing and further steps toward feasibility and utilization.[106] In the construction sector, materials science research is advancing efforts to unlock GHG emissions reductions by replacing clinker in Portland cement or developing alternative products using various additives and binders.[107]

These examples represent a few of the many possibilities illustrating how substitute materials could affect energy and emissions, though each example faces unique challenges and different time horizons for full feasibility. For example, certain substitute materials require additional testing to ensure that they meet the intended goal (e.g., lightweighting). Meanwhile, other materials require new or modified government standards or regulations to enable greater commercial use.

Advanced Nuclear

The Promise

Nuclear power currently provides more than half of America's carbon-free power.[108] However, the current generation of nuclear power plants is struggling to stay economically competitive, and attempts to build new plants have faltered.[109] Advanced nuclear energy — which encompasses both small modular reactors (SMRs) and nonlight water reactors — has an important role to play in a lower-carbon power system.

Advanced nuclear technologies are characterized by flexibility, dispatchability, high energy density and increased safety. They encompass a range of applications and can be used in both electric and nonelectric contexts without producing any carbon emissions.[110] These benefits — which essentially amount to the ability to provide load-following generation or energy storage — mean that advanced nuclear reactors could represent an important complementary energy source in a future with higher rates of variable renewable resource deployment.[111] In particular, SMRs have the potential to use factory-based and advanced manufacturing techniques to unlock new markets in smaller grids and reduce the high upfront capital requirements of traditional nuclear plants.[112] The smallest of these reactors, known as microreactors, effectively act as a nuclear-powered battery.[113] Other developing reactor designs and concepts will be able to produce high-temperature process heat for industrial and chemical processes,[114] allow for different reactor sizes and more passive safety features, and significantly reduce nuclear waste products.[115]

The Path Forward

Dozens of companies across the United States are pursuing advanced nuclear concepts, including at least five that are already working with the Nuclear Regulatory Commission. As of early 2018, more than 70 advanced nuclear projects were under development by companies, universities and national labs across North America.[116] There has been progress (with bipartisan support) at the Nuclear Regulatory Commission, at the Department of Energy and in Congress to support advanced reactor designs and development.

However, significant challenges to commercial deployment remain. For instance, while SMRs will theoretically bring down the capital costs of building new nuclear, these savings will be realized only if the SMRs are produced in sufficient quantities to achieve economies of scale. And SMRs have yet to be commercialized in any country. Other advanced nuclear options also face cost constraints, particularly in current market conditions with low-cost natural gas. To realize a future in which advanced nuclear development advances at scale, the United States will need to manage challenges posed by resource needs, limited facilities, technical limits and outdated regulations. Advanced nuclear also faces challenges competing on a cost basis with natural gas, leading some advanced reactor developers to prioritize cost-competitive designs.[117] Given these challenges, the deployment of advanced reactors is projected to unfold over a long time horizon. While the first advanced reactors could be online by the mid-2020s,[118] goals for mature versions of reactor concepts have timelines on the scale of decades.[119]

CONCLUSION AND RECOMMENDATIONS

Looking ahead, the 21st century energy future clearly reveals the importance of forward-looking policies that help unlock meaningful GHG emissions reductions while ensuring continued economic growth. These policies should be coordinated and comprehensive, reflecting the full scope of resource potential, emerging technologies and the climate change challenge. The United States should capitalize on the advantages of its existing leadership in the research, development and commercialization of crosscutting energy technologies as it accelerates efforts to develop a portfolio of affordable, diverse and efficient options for meeting economic, environmental and energy challenges. Improving energy efficiency, increasing utilization of renewables, continuing to advance technology and engaging globally are vital to an effective, long-term response to global climate change. At the same time, the United States must continue to provide affordable, reliable supplies of energy for a growing economy.

As the nation's business leaders, the CEO members of the Business Roundtable understand the opportunities and challenges presented by today's changing energy landscape. Public policy should enable companies and individuals to harness new opportunities with strong infrastructure and a stable and predictable regulatory regime that boosts investment and catalyzes solutions. Ensuring robust, affordable energy for the world while reducing emissions and facilitating consumer choice is a considerable challenge — one that requires technological innovation, sound policies, and political and corporate commitment.

In light of these considerations, the Business Roundtable offers the following recommendations:

- **Support federal climate policy that aligns with scientific consensus and promotes collective actions that will lead to the reduction of GHG emissions.**
- **Foster energy innovation by boosting federal funding for investments in a diverse portfolio of precommercial energy and climate research and development activities,** with a focus on strategic investments in basic research. Specifically, the federal government should develop a strategic, coordinated approach for energy and climate research and development, including a clear articulation of near-, medium- and long-term research priorities; specific objectives and benchmarks for research activities; a predictable funding stream; and effective coordination and collaboration across agencies and federal labs.
  - Improve collaboration among federal research labs, universities and the private sector to accelerate the transition of promising technologies from the lab to commercialization in the marketplace.
- **Empower energy consumers by setting transparent, cost-effective energy efficiency standards** through open, collaborative processes and ensuring the coordinated, timely and comprehensive adoption of new standards.

- **Adopt a technology-neutral framework for removing barriers and accelerating the deployment and application of all technologies that can provide substantial reductions in GHG emissions.**
- **Provide predictable and stable regulatory and tax regimes for investments in energy and innovative technologies.**
- **Adopt transparent, predictable and expeditious permitting review procedures for the energy infrastructure needed to support the 21st century energy ecosystem,** including access to affordable and reliable energy, a transition to low-carbon energy, and meaningful deployment of innovative and emerging energy technologies.

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