The Patchwork Quilt:
Business Complexities of Decarbonizing the Electric Sector

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Introduction

The economic growth and well-being of societies across the world are heavily dependent upon the adequacy of their electric systems. Electricity enables light, heat, cooling, the production of goods, communications over long distances, data access and computations, modern healthcare, mass media entertainment, and transportation, all at the flip of a switch or the turn of a key. The development and operation of a robust, reliable, and affordable electric system are as complex as they are important. They require large investments, access to natural resources, technological expertise, and well-crafted public policies and rules.

The electric sector is also central to addressing the world's climate challenge. Power generation accounts for 40 percent of energy-related carbon dioxide (colloquially, "carbon") emissions worldwide, highlighting the importance of making substantial changes to the electric sector to address climate-related issues.[1] (International Energy Administration, 2021) The electric sector can also be leveraged to reduce greenhouse gas emissions from other sectors of the economy. For example, the transportation sector accounts for 23 percent of global energy-related carbon emissions, (International Energy Administration, 2021) and significant emissions reductions could be achieved by a shift to cleaner electricity generation coupled with electrification of parts of the transportation sector. Further, regulators and electric utilities are increasingly developing and implementing plans to improve the resiliency of electric systems, to protect against the greater frequency of hurricanes, extreme heat waves and cold spells, and rising water levels.

These factors contribute to a complicated web of challenges and opportunities for electric sector businesses. The complexity of these challenges and opportunities is amplified by greatly varying regional economic conditions, access to capital, natural resources, government structures and policies, pre-existing electric system structures, and societal needs. The landscape for electric sector businesses therefore varies across countries and, on a more granular basis, across localities within a single country. Despite this regional variation, several similar dynamics and considerations apply across much of the world, albeit certain factors may be more prevalent in one locality versus another.

This chapter and the chapter that follows examine these issues in detail. This chapter discusses the complexity and varying conditions in the electric sector, what we refer to as a "patchwork quilt," focusing on the sector's recent history and current structure, often using the United States (U.S.) as a case study. The following chapter takes a longer view, discussing the prospect of a transition to a fully decarbonized economy-wide energy system that will last several decades, and the unprecedented investment opportunities and challenges that this presents for business.

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[1] In addition to these direct greenhouse gas emissions from the generation of electricity, some processes that support the electric sector, such as the extraction, processing and transport of the natural resources used in today's electric systems, also emit greenhouse gases.

In this chapter, the "Electric Industry Structure and Evolution" section provides a brief overview and history of the electric industry, including structural, technological, and greenhouse gas emission developments. Over the last several decades, the U.S. electric industry has been shaped by several important trends including the restructuring of traditional vertically-integrated utilities in some regions of the country to allow for wholesale and retail competition, the growth of combined-cycle generating technologies and innovations in natural gas production that have driven down the cost of natural gas as a fuel for the generation of electricity, and, most recently, the substantial cost declines and the rapid growth of wind, solar, and battery technologies. At the national level, these developments have led to the significant expansion of natural gas-fired and renewable generation, the decline of coal-fired generation, and reductions in the emissions of carbon dioxide and other air pollutants. Still, as discussed in the next chapter, limiting global warming to a level between 1.5 degrees Celsius and 2.0 degrees Celsius above preindustrial levels will likely require fundamental changes to the electric industry and massive expansion of sector infrastructure.

The subsequent section of this chapter, "Today's Complex Patchwork Quilt," covers the varied policies and market-related factors that define the opportunities and challenges for potential investors and businesses active in the electric sector. This section provides insights about the nature, dynamics, and interplay of the various types of climate and clean energy policies that comprise the patchwork quilt, and the associated considerations for businesses. There is great variation in the electric sector at the regional level across the U.S. and the world. Major contributors to this variation include differing natural endowments of coal, natural gas, hydro, solar and wind resources, and differing state and local priorities for energy and environmental policy. These have led to the patchwork quilt of conditions in the regional electric markets, especially in countries such as the U.S. which lack stable energy and climate policies at the federal level. The quilt has two overarching ramifications for businesses.[2] First, the quilt can contribute to large investment opportunities, but these are highly dependent on regional market and policy conditions, some of which can be local and complex. Second, in many cases, the patchwork quilt is accompanied by increased business risks due to the interplay between different regulators' policies, the uncertainty about future policy changes, and other factors including the emergence of new technologies and changing commodity prices. These can lead to financial risks for investors and unnecessary costs to satisfy climate goals.

Using this chapter as a foundation, the next chapter looks at the energy transition that is widely expected to occur over several decades. This transition will entail decarbonizing today's carbon-emitting fossil-fired generation or replacing it with carbon free electricity, as well as massive electricity system expansion with substantial investment opportunities to electrify and decarbonize portions of the transportation, industry, and space conditioning sectors of the economy. The transition is deeply uncertain in its form and timing due to ongoing uncertainties about federal and state policy, technology pathways, and the pace at which it will be possible to deploy new energy infrastructure. For companies in the electric industry, this points to three broad challenges: how to deploy carbon-free technologies that have already been commercialized, how to demonstrate and commercialize new advanced clean energy technologies, and how to manage the existing fleets, particularly fossil-fired and nuclear generating plants.

[2] Affected businesses include both energy sector investors as well as businesses that consume electricity and therefore are exposed to electricity costs that are affected by electric sector developments.

To succeed in this environment, businesses need strategic foresight, financial resources, and prudent risk management. Companies must be able to understand and manage commercial risks arising from uncertain state regulation, federal policy, technology, supply chain, and project development forces.

Electric Industry Structure and Evolution

The Electric Grid

The electric grid, or electric system, is an interconnected network that produces, transmits and consumes electricity. It is often thought of as being composed of four primary segments: the *generation* of electricity at power plants, long distance *transmission* of electricity across high voltage power lines, *distribution* on local, low voltage power lines, and *customer* use of electricity to power lighting, appliances, commercial processes, industrial machines, and other activities.

The generation and consumption of electricity must be precisely matched on an instantaneous and locational basis to avoid blackouts and shorter service interruptions. To accomplish this, the organizations operating the U.S. electric grids direct the operation of power plants in real time to meet electric demand at the lowest operating cost in an approach known as "security-constrained economic dispatch," which the U.S. Department of Energy defines as "an area-wide optimization process designed to meet electricity demand at the lowest cost, given the operational and reliability limitations of the area's generation fleet and transmission system." (U.S. Department of Energy, 2007)

In the centralized wholesale power markets of the U.S., the system operator holds daily competitive "energy market" auctions to select which power plants generate electricity, offer backup reserve capacity if needed to respond to unanticipated events, and provide ancillary services to the grid, with market prices that settle on an hourly or more granular basis.[3] The operation of the system is quite complex, as demand is constantly changing, different generation resources have different operating constraints, transmission constraints limit power flows across the system, and the availability of generation resources and power lines can change due to factors such as weather and equipment failures. These factors, as well as significant differences between the dispatch costs of various types of generation resources, contribute to market volatility and uncertainty for competitive generation companies and other businesses.

Some system operators also administer "capacity markets" to ensure that there are always adequate quantities of supply resources available. Winning bidders in a capacity auction administered by the system operator must guarantee that specified megawatt quantities of supply will be available in the upcoming year associated with the auction. Supply resources in capacity auctions may include new generation resources, existing generation resources, upgrades to existing generation resources, demand response (guarantees from consumers that they will reduce their electricity use when called upon), energy efficiency, and transmission upgrades.

Industry Restructuring

Bolstered by state regulation and New Deal legislation during the first half of the twentieth century, the U.S. electric industry expanded from a series of largely urbanized and separate electric systems to one with long-distance transmission interties connecting adjoining utilities, electric cooperatives and public

[3] As will be discussed later, the system operators that administer these auctions are often referred to as "Regional Transmission Operators."

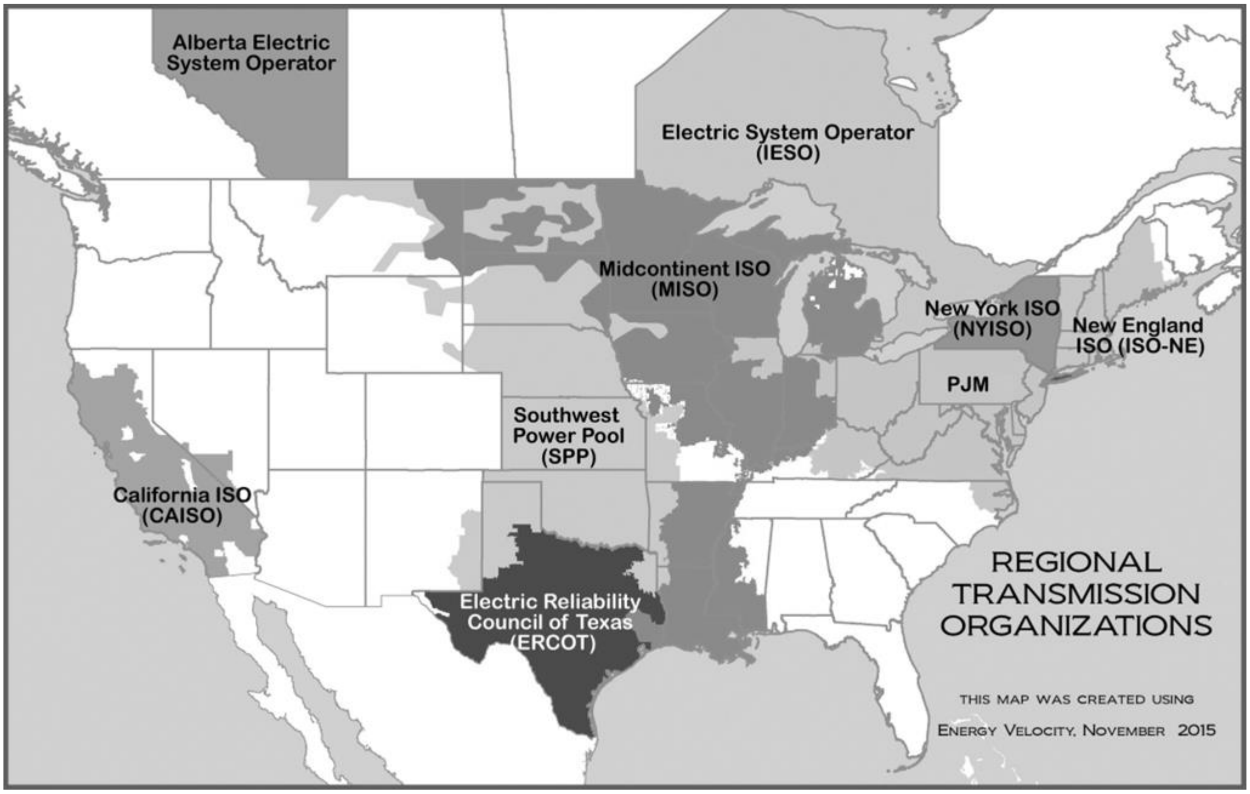
power authorities, and with more extensive service to rural areas. From that era up to the 1980s and 1990s when large portions of the electric industry were restructured, the predominant industry model revolved around vertically integrated generation-transmission-distribution utilities each supplying power to customers in a defined geographic region with retail rates set by a state regulator and interstate transmission overseen by federal regulators.

The industry enjoyed steady growth and remained largely unchanged structurally until the energy crisis and OPEC oil embargo of the 1970s, which resulted in supply shortages of fossil fuels and large swings in their prices. In response to that, the Public Utility Regulatory Policies Act (PURPA) was enacted in 1978. Among other policies intended to promote energy efficiency, solar and wind technologies, and nuclear power, PURPA designated cogeneration facilities[4] and smaller renewable generation projects owned by independent power producers as qualifying facilities (QFs), which allowed them to sell electricity to utilities at preestablished prices based on the utility's "avoided cost," which was basically the incremental cost that the utility would incur if it instead generated the electricity itself or purchased it from another source. While largely unintended, PURPA had the effect of demonstrating that non-utility power suppliers could develop and operate large-scale power plants, thereby encouraging further regulatory reforms in the 1980s and 1990s. In 1992, Congress passed the Energy Policy Act (EPACT) to facilitate competition in wholesale electricity markets by opening transmission lines to non-utility generators and expanding the definition of qualifying facilities. EPACT essentially forced utilities to open their transmission systems, giving non-utility generators more freedom to sell their electricity to buyers located large distances from their plants.

In 1999, the Federal Energy Regulatory Commission (FERC) issued Order 2000, encouraging owners of transmission facilities to pool their transmission assets under the control of a Regional Transmission Operator (RTO). While Order 2000 leaves flexibility as to how the RTOs may be structured, the primary purposes of each RTO are to control and monitor the transmission system. Common practice is for the RTO to administer a wholesale electricity market across its footprint and coordinate system-wide dispatch of electricity generators based on market bids. The intent of establishing these organized electricity markets was to provide stronger incentives to improve the economic efficiency of the electric sector and lower the cost of electricity service for consumers relative to the cost that would be achieved under traditional regulation without these markets. Many regions of the U.S. are now served through RTOs.

[4] Cogeneration facilities are electricity generation facilities that capture the waste heat, usually in the form of steam, and apply it for another purpose such as an industrial process, often through a sale of the steam to another party.

Figure 5.1: Regional Transmission Organizations



Source: U.S. Federal Energy Regulatory Commission.

(U.S. Federal Energy Regulatory Commission, 2015)

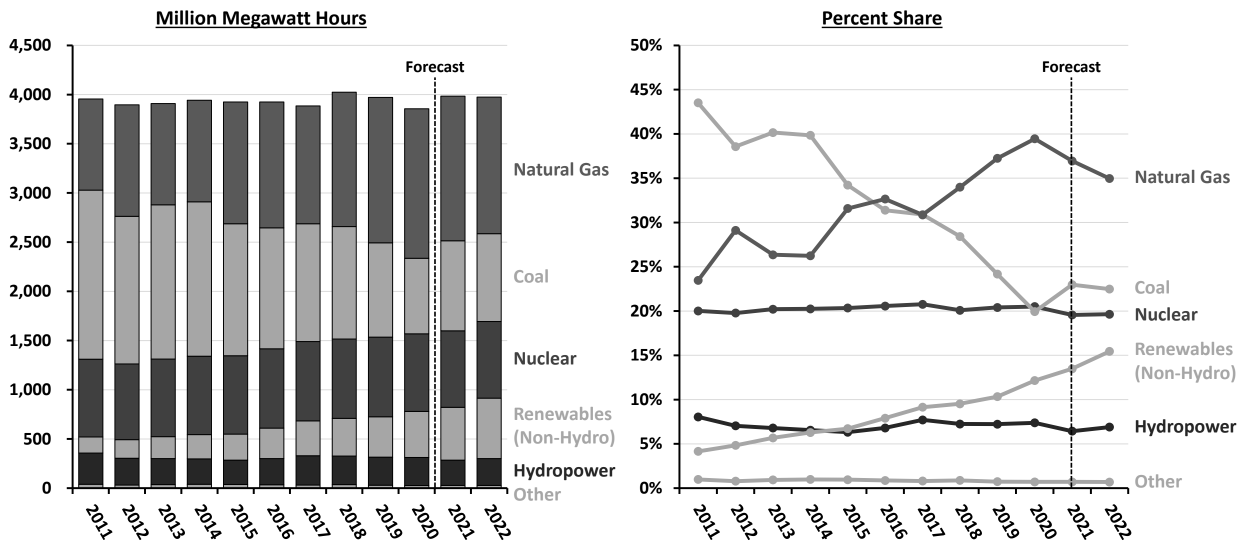
All the RTOs in the U.S. are regulated by the FERC, apart from the Electric Reliability Council of Texas (ERCOT), which as a single-state transmission organization avoids certain aspects of federal regulation. The transmission systems in regions without RTOs, mostly in the western and southeast states, are overseen by vertically integrated electric utilities and public power authorities.

Often driven by state regulations, many utilities in RTOs have sold their power plants to third parties who compete in the wholesale markets. These utilities rely on wholesale market purchases to satisfy their customers' electricity supply needs. While the local utility still is responsible for the distribution of electricity supplied to all customers in the utility's service area, in several states, each customer now may choose among many companies to provide the customer with the electricity supply at the retail level. These competitive retail providers provide an agreed-upon price structure that the customer pays, assume responsibility for the wholesale market cost to supply the customer, and manage the associated risks accordingly. Despite the similar purpose of the different RTOs, the structure and operations of each regional market differs. This contributes to the patchwork quilt theme discussed later in this chapter.

The Changing Generation Mix and Declining Emissions

Most electricity generation in the U.S. is fueled by natural gas, coal, nuclear, and renewable energy technologies including hydropower as well as non-hydropower renewables such as wind and solar.

Figure 5.2: U.S. Electricity Generation by Fuel Type



Source: U.S. Energy Information Administration.

(U.S. Energy Information Administration, 2021g)

From 2011 to 2021, generation from non-hydropower renewables, predominantly wind and solar, grew from less than 5 percent to almost 15 percent of U.S. generation, natural gas-fired generation grew from less than 25 percent to roughly 35 percent, and coal-fired generation declined from approximately 45 percent to less than 25 percent. The drivers of these trends are explained later. Not surprisingly, U.S. electric sector carbon emissions have declined, due to the growth in zero-carbon generation such as wind and solar, the growth in natural gas-fired generation which has lower carbon emission rates than coal-fired generation, and the decline in coal-fired generation with its high carbon emission rates. U.S. electric sector carbon emission levels in 2019 were 33 percent below 2005 levels, dropping the sector to be the second largest source of carbon emissions behind the transportation sector. (U.S. Energy Information Administration, 2020b) While this represents meaningful progress, it falls short of the pace of reductions needed to achieve many stated climate goals, as discussed in the next chapter.

Natural gas and coal-fired power plants have the capability to provide reliable power around-the-clock, and many natural gas-fired plants can quickly increase their output to meet rapidly increasing demand in peak hours. This capability makes these plants valuable electric generation resources. But without controls to capture and sequester their carbon emissions, natural gas and coal will remain the dominant sources of electric sector carbon emissions. Since natural gas has a lower carbon content than coal, and because natural gas combined cycle generating technology is more efficient than conventional coal-fired technology, natural gas generation typically emits 40 percent to 50 percent of the carbon on a per unit of electric energy basis relative to conventional coal.

Nuclear, hydropower, wind, and solar generation are the main sources of electricity in the U.S. that do not directly emit carbon.[5] As of 2021, nuclear generation supplies the largest share of electricity among these generation types. However, most of the country's nuclear fleet is aging. Many nuclear plants have reached or are approaching their original plant licensing lives. Some, especially those without long-term contracts

5 The electricity generation processes for these technologies do not directly produce carbon emissions, but carbon may be emitted in the manufacturing and development of these generation plants.

or government guarantees of cost recovery, struggle to earn enough revenue to continue operation. Hydropower also provides a significant share of electricity. Many hydroelectric plants can be operated to provide around-the-clock electricity or be dispatched in response to changing demand (a.k.a. “load”) and market conditions. But opportunities to develop new hydroelectric generation plants are limited due to the difficulty of permitting new reservoirs. Solar and wind facilities are increasingly used to produce energy whenever they can because of their low variable operating costs, their lack of carbon emissions, and the availability of financial credits for electricity generated from wind. But the variability of their output, and the possibility of low or zero output during extended periods of relatively calm winds and cloud cover, create significant challenges for these technologies alone to reliably serve peak electric loads.

Growth of Natural Gas-Fired Electric Generation

Two developments drove natural gas generation to become the U.S.’s most widely relied upon fuel source for power generation, allowing natural gas generation to displace coal generation and reduce electric sector carbon emissions. The first was the commercialization of combined cycle technology, and the second was the “fracking revolution.”

The natural gas-fired combined cycle generating technology was widely commercialized in the last quarter of the twentieth century. With this generating technology, the hot gas exhausted from a gas turbine, itself driving a generator to produce electricity, flows into a heat recovery steam generator, which boils water to produce steam that drives a steam turbine to generate additional electricity, increasing total system efficiency. This allows more power to be produced with less fuel, resulting in lower fuel costs and less carbon emissions than older generation natural gas plant technologies and coal-fired alternatives.

In the first decade of the twenty-first century, natural gas generation received another boost as the fracking revolution unfolded. Specifically, advances in certain technologies that extract natural gas from underground shale rock formations substantially changed the economics of natural gas production in the U.S., where shale rock formations are plentiful. The most prominent of these extraction technologies is a production procedure that is known as hydraulic fracturing (a.k.a. “fracking”), which involves drilling underground to the shale rock formation and injecting a fracturing fluid mixture of sand, water, and chemicals into the rock to fracture it, thereby releasing natural gas and other hydrocarbons. While fracking technology had existed for decades, it had not been commercially viable on a widespread basis. However, advances in another technology, horizontal drilling, combined with the development of more effective mixtures for fracturing fluids, suddenly changed the economics of fracking. As its name implies, horizontal drilling is the process of drilling horizontally after reaching the depth at which the shale rock formation lies, and horizontal drilling provides access to larger sections of geologic formations. These advances led to an increase in U.S. natural gas production of more than 50 percent from 2008 to 2018, (U.S. Energy Information Administration, 2021h) and a decline in U.S. natural gas prices of more than 50 percent over that period. (U.S. Energy Information Administration, 2021i)

These developments have greatly contributed to a reduced cost of natural gas-fired generation relative to coal-fired generation, allowing natural gas generation to displace coal generation and reduce electric sector carbon emissions. The availability of low-cost natural gas supplies has also enabled the U.S. to become a net exporter of energy with implications for global energy trade and diplomacy.

Commercialization of Wind, Solar and Batteries

While the deployment of natural gas-fired generation substantially increased in recent decades, more recent cost reductions in wind, solar, and batteries indicate a major surge in the deployment of these technologies going forward. In part because of these cost reductions, wind and solar technologies are expected to have a key role in achieving climate goals, as discussed in the next chapter.

Significant declines in the costs of wind and solar generation technologies have helped spur increasingly rapid deployment of these technologies. The U.S. average levelized cost[6] of onshore wind projects has declined by over 60 percent, from $90/MWh in 2010 to $33/MWh in 2020. (Wiser, et al., 2021) The cost of utility-scale solar photovoltaic (PV) generation has declined even more. The U.S. average levelized cost of this type of generation declined from about $220/MWh in 2010 to $34/MWh in 2020, a cost reduction of 85 percent. (Bolinger, Seel, Warner, & Robson, 2021) These cost declines, coupled with state renewable procurement mandates and voluntary purchases by large technology and consumer products corporations, have driven rapid increases in the construction of wind and solar generation. In aggregate in 2020, wind and solar generation represented 80 percent of the total U.S. generation capacity additions, as compared to about 30 percent in 2010. (Bolinger, Seel, Warner, & Robson, 2021) Along with the development of natural gas-fired power plants and their increasing utilization rates displacing coal-fired generation, solar and wind deployment have been significant contributors to U.S. electric sector carbon emission reductions.

Similarly, the U.S. is undergoing a substantial increase in battery capacity on the electric grid. By the end of 2010, large-scale battery storage systems[7] installed in the U.S. totaled about 50 megawatts of power capacity.[8] By the end of 2019, this value had increased by a factor of 20, to over 1,000 megawatts. Furthermore, the U.S. Energy Information Administration projects the amount of installed large-scale storage battery to be over 12,000 megawatts by the end of 2023, an amount roughly 12 times that installed as of the end of 2019. (U.S. Energy Information Administration, 2021b) These increases are driven by both significant battery cost reductions and the adoption of policies at the state and federal levels to promote battery development for the services that batteries can provide. With the capability to store and release electricity over a four-hour period or somewhat longer, batteries can address short-term supply deficits and serve particularly high peak demands. Batteries also can increase the amount of electricity that is sourced from environmentally friendly generation resources such as wind and solar generation by charging batteries from these generation resources during hours when electricity demand levels are low compared to the availability of these resources and discharging the batteries during hours when demand levels are high. They are also adept at providing "ancillary services" that stabilize grid operations. However, battery technology performance and costs will need to further improve substantially from today's levels for batteries to be suitable to address longer-term seasonal variations in solar and wind output or multi-day periods of calm winds and cloudy skies.

Another related trend is the adoption of distributed energy resources (DERs). DERs are generation resources or controllable loads that are directly connected to a local distribution system or connected to a host facility that is directly connected to the local distribution system. DERs include rooftop solar generation, small-scale wind generation, backup generators, and batteries connected to the distribution

[6] The "levelized cost" of a generating plant is a measure of the average price of electricity, in real dollars, which would be required to recover the costs of building and operating the plant during its life, and to achieve a fair return on the investment. The levelized cost reflects the plant's capital costs (often including the cost of any required transmission system upgrades), operations and maintenance costs, fuel costs, financing costs, and an assumed technology-specific capacity factor, but it generally does not include the costs associated with the use of the electricity transmission and distribution system to deliver the electricity to consumers. The quoted levelized cost values are expressed in 2020 dollars.

[7] Large-scale battery storage systems are defined as those that are connected to the grid and have a nameplate power capacity greater than 1 MW.

[8] Power capacity refers to the maximum amount of power output a battery can provide in any instant.

system or installed on the customer's side of the utility electric meter. In certain circumstances, DERs can defer or avoid the need for expensive grid investments, and they can improve the reliability of customer service by avoiding or mitigating service interruptions from distribution-level power outages. Depending on the fuel type used, DERs may also displace the need for more emissions-intensive centralized power plants that are powered by fossil fuels.

Climate and Energy Policies

The technical advances, cost reductions, and increased deployment of natural gas, solar, wind, battery, DER, and other technologies are the result of private sector investments and government policy both overseas and in the U.S. at the federal and state levels. The next section, "Today's Complex Patchwork Quilt," identifies and addresses the types of climate and clean energy policies that are often applied in the electric sector, it presents specific examples, and provides insights regarding policy dynamics and the associated ramifications for businesses. The patchwork quilt of energy and climate policies that exists today has helped to reduce harmful emissions. However, as discussed in the next chapter, the pace of overall reductions to date falls short of that needed to achieve many stated climate goals, and varying policy priorities and unnecessary costs due to the lack of coordination and alignment may undermine the prospects of satisfying these goals.

In the U.S., this lack of coordination and alignment is partially driven by the failures of federal efforts in recent decades to establish uniform national emission or clean energy requirements. These include the U.S. government not adopting the Kyoto Protocol treaty negotiated in 1997, the Senate's rejection of the American Clean Energy and Security Act of 2009 (also known as the Waxman-Markey Bill), the holdup in the court system of President Obama's Clean Power Plan, President Trump's withdrawal of the U.S. from the Paris Agreement in 2017, and Congress's failure to enact the Clean Electricity Performance Program proposed in the House in 2021. While the U.S. rejoined the Paris Agreement under President Biden, strong government programs and coordination will be required over several decades for the U.S. to achieve the goals of the Paris Agreement or other ambitious climate goals.

Today's Complex Patchwork Quilt

Today's global and U.S. electric sector landscape is a "patchwork quilt" of regional market conditions and climate and energy policies. The patchwork quilt has supported various levels of clean energy resource deployment and electric sector greenhouse gas emission reduction, and it often complicates business opportunities.

The quilt is partially defined by regional differences in the abundance of natural resources, the topography of the electricity grid, and the structure of the electricity markets, all of which shape the opportunities and risks in each region. In addition, the government policies intended to support clean energy and address the changing climate have also become a major part of the quilt and the business opportunities that it presents. Regional and political differences regarding climate concerns and the preferred approaches to address these concerns lead to policies that vary locationally and across different levels of government.

The patchwork quilt has two overarching ramifications for businesses.[9] First, while the quilt can contribute to large investment opportunities, these are highly dependent on regional market and policy

[9] Affected businesses include both energy sector investors as well as businesses that consume electricity and therefore are exposed to electricity costs that are affected by electric sector developments.

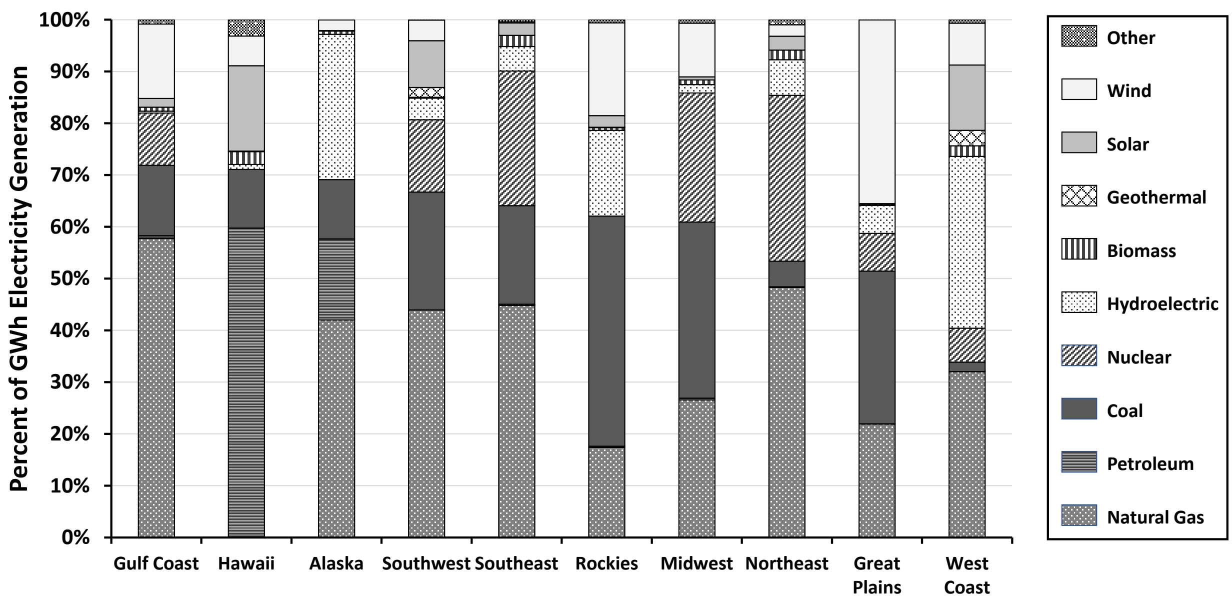
conditions, some of which can be quite local and complex. Second, in many cases, the patchwork quilt is accompanied by increased business risks due to the interplay between different regulators' policies, the uncertainty about future policy changes, and other factors including the emergence of new technologies and changing commodity prices. The nature of many of the policy approaches and the inconsistencies between policies also can lead to unnecessary costs associated with satisfying climate goals.

The U.S. provides an exemplary case study of the patchwork quilt, given the size of its economy and carbon footprint, its geographic variation in natural resources, and its frequently polarized political environment.

Case Study: The Patchwork Quilt in the United States

The mix of electricity generation in operation in each region of the U.S., and the mix that is being constructed in each region, provide a starting point to understand the patchwork quilt that characterizes the U.S. electricity landscape. The following figure depicts the aggregate regional sources of grid-connected electricity generated across the U.S. as of 2020.[10]

Figure 5.3: Regional Electricity Generation Mix Across the U.S. (2020)



Based on data from the U.S. Energy Information Administration.

(U.S. Energy Information Administration, 2021c) (U.S. Energy Information Administration, 2021f)

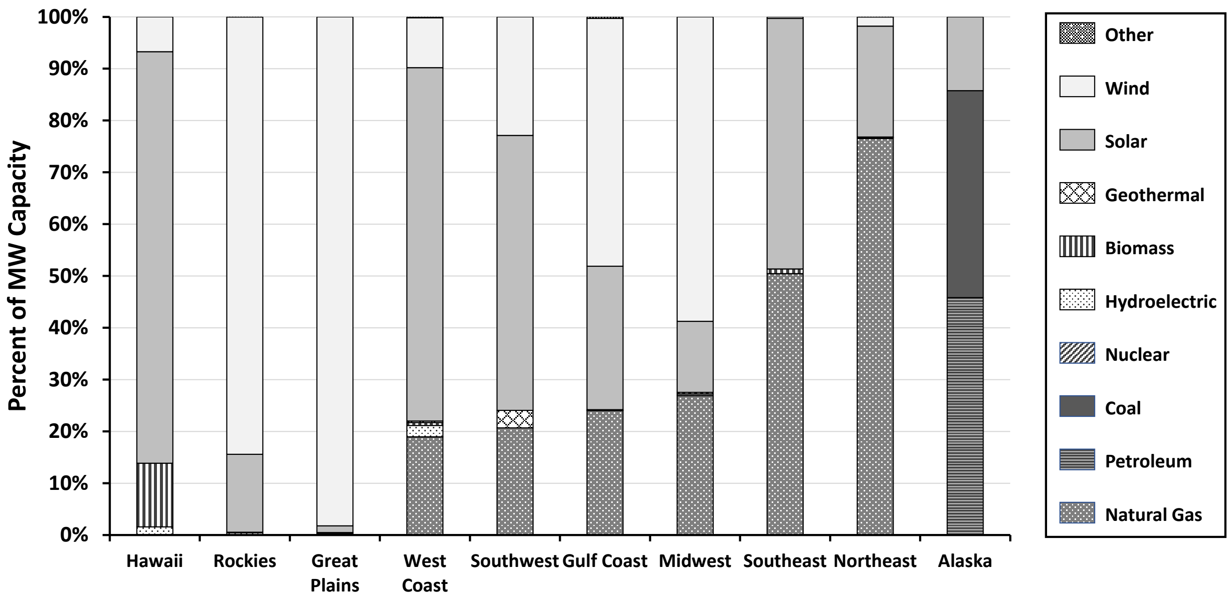
As the figure shows, as of 2020, most of the power generated in almost every region of the U.S. was generated by fossil fuels, predominantly natural gas and coal, with petroleum being the dominant fuel for electricity generation in Hawaii. Despite the national expansion of natural gas-fired generation in recent years as described previously, coal-fired generation still held a significant share as of 2020, especially in

10 Northeast: CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT; Southeast: AL, FL, GA, KY, NC, SC, TN, VA, WV; Midwest: AR, IL, IN, IA, MI, MN, MO, OH, WI; Gulf Coast: LA, MS, TX; Great Plains: KS, NE, ND, OK, SD; Rockies: CO, ID, MT, WY; Southwest: AZ, NV, NM, UT; West Coast: CA, OR, WA. Values are calculated by summing EIA's reported net generation values (EIA-906, EIA-920, and EIA-923) and EIA's small scale PV estimates.

the coal-rich Rockies, Midwest and Great Plains regions. Among the clean sources of generation, nuclear power is the largest generation source, especially in the Northeast, Southeast and Midwest regions. Substantial amounts of power are also generated by hydroelectric sources in the Northwest (part of "West Coast") and Alaska where rivers and waterways are plentiful. Wind power has become a significant source of electricity in the Great Plains states where winds are especially strong and project sites are more abundant due to relatively low population densities.

The picture is quite different when trends in new construction are studied instead of looking at a snapshot of existing generation. The following figure shows the compositions of the aggregate regional capacities of grid-connected electricity generation resources built during 2018-2020.[11]

Figure 5.4: Regional Electricity Generation Builds Across the U.S. (2018-2020)



Based on data from the U.S. Energy Information Administration.

(U.S. Energy Information Administration, 2021e) (U.S. Energy Information Administration, 2021f)

In many regions, renewable power generation such as wind and solar comprised the majority of generating capacity built during this period. Wind power development has represented the largest source of new power on a megawatt capacity basis in the mid-American regions such as the Great Plains, Rockies, Midwest and Gulf Coast, where wind intensities are quite high. Similarly, solar power development has been substantial in areas that experience high levels of insolation such as Hawaii, the Southwest, the Southeast, and California (part of "West Coast"). State policies in these regions are also supportive of solar power. The confluence of strong solar energy policy supports, solar cost reductions, and high levels of insolation can drive solar adoption to levels at which the need for flexible and controllable electricity supply increases quickly and significantly as the sun sets. California and Hawaii have both experienced this dynamic to a relatively significant degree. As discussed in the next chapter,

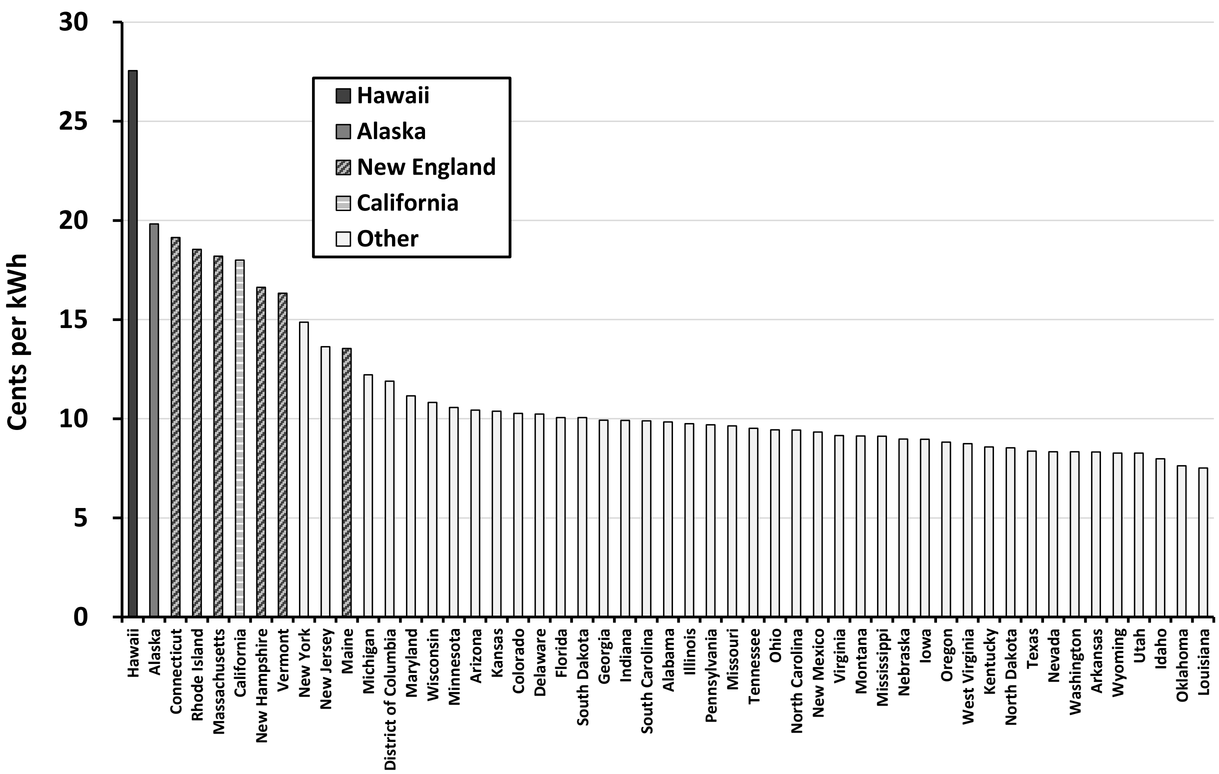
[11] Northeast: CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT; Southeast: AL, FL, GA, KY, NC, SC, TN, VA, WV; Midwest: AR, IL, IN, IA, MI, MN, MO, OH, WI; Gulf Coast: LA, MS, TX; Great Plains: KS, NE, ND, OK, SD; Rockies: CO, ID, MT, WY; Southwest: AZ, NV, NM, UT; West Coast: CA, OR, WA. Values are calculated by summing EIA's reported operable generator values (2020 Form EIA-860 Data - Schedule 3) and increases in EIA's small scale PV estimates.

transforming the electricity grid to handle increasing levels of renewable and distributed generation resources will require substantial investments in the coming decades.

Natural gas was the dominant fuel for new capacity resources in the Northeast during 2018-2020, due largely to substantial natural gas resources unlocked in Pennsylvania by the fracking revolution and the relative lack of other resources in much of the Northeast. The New England states do not have especially productive conditions for solar and wind, except offshore wind, which is beginning to emerge in the U.S. as costs decline and states enact supportive policies. Natural gas-fired generation represented roughly half of the new capacity additions in the Southeast, as natural gas resources are abundant in the nearby Gulf Coast. Alaska's megawatt capacity additions were much smaller than the additions in other regions. While Alaska relied heavily on fossil fuels for its additions, solar power was a part of this mix.

The patchwork quilt of market conditions and climate-related policies also contributes to a variation in the electricity rates that electricity users pay across the U.S., as shown in the following figure.

Figure 5.5: Average Retail Price of Electricity Across the U.S. (2020)



Source: U.S. Energy Information Administration.

(U.S. Energy Information Administration, 2021d)

Hawaii and Alaska have the highest average electricity rates in the U.S. Hawaii's electricity costs are driven by the limitations of the resources on the islands that comprise Hawaii and the costs of importing fuels across the ocean. Due to Alaska's dispersed population, many Alaskan communities are not connected to a larger grid that leverages significant quantities of generation resources. (Institute for Energy Research, 2013) Even the Railbelt, the grid that serves many of Alaska's more urban populations, is isolated from the electric grids in Canada. (U.S. Energy Information Administration, 2021a)

After Hawaii and Alaska, the average rates in the New England states are among the highest in the U.S. These relatively high rates are driven by a dependency on the imports of natural gas to fuel many of New England's power plants, coupled with limited pipeline capacity into the region. (ISO New England, 2021) Some parties also attribute New England's relatively high electricity rates to the costs of policies adopted in the region to support the growth of renewable generation resources and implement energy efficiency programs, (Brown, 2017) as well as policymakers' reluctance to expand natural gas pipeline infrastructure. (Consumer Energy Alliance, 2017) Furthermore, while some parties have argued that electricity rates in New England could be lowered by proposed electric transmission projects that would import larger amounts of power from Canada to New England, such as the Northern Pass project and the New England Clean Energy Connect, these proposals have been controversial and rejected for a variety of reasons, including their cut through wildlife habitats, their impacts on landscapes, their disproportionate benefits across the states they traverse, general attitudes toward their project sponsors, and concerns about associated hydroelectric generation resources being located on unceded First Nations lands. (Iaconangelo, 2021)

California's electricity rates are also among the highest in the U.S. Drivers of California's relatively high rates include above-market generation contracts and utility-owned generation that in part support the state's clean energy goals, costs associated with wildfire risk mitigation and damages, the costs of the state's energy efficiency and other public purpose programs, and authorized utility rates of return on equity that are higher than in other parts of the U.S. (Energy Institute at Haas, UC Berkeley, 2021) (California Public Utilities Commission, 2021) While California's electricity rates are among the highest in the U.S., the upward effect on overall electricity bills is mitigated by the fact that California's electricity use per capita is among the lowest in the U.S., driven by the state's mild climate and its aggressive energy efficiency programs. (California Public Utilities Commission, 2021)

Electricity rates for California utility customers without solar generation systems on their premises have been further increased by California's utility rate structures. California's utility rate structures incorporate electricity bill reductions for customers who generate solar power on their premises, and these bill reductions have been adequately large to support the substantial growth of customer-sited solar generation systems in the state. However, as explained in a 2021 independent study prepared for the California Public Utilities Commission, under California's current rate structures, the electricity bill reductions that California utility customers are provided by generating solar power on their premises are in part funded by increases in other customers' rates. (Verdant Associates, LLC, 2021) This has been a contentious issue in California, and similar rate design issues have been contentious in other states where the growth of customer-sited solar generation systems has been relatively high or where such systems are disproportionately adopted by utility customers with higher incomes, leaving disproportionately lower-income utility customers to bear additional cost burdens. This is further discussed in the later section, "Retail Ratemaking and Net Metering." The variation in rate designs between utility service areas, as well as uncertainty about how rate designs may be changed in a particular jurisdiction, adds to the patchwork quilt of business opportunities and risks.

Patchwork Quilt Policies Affecting Business

As the regional study of the U.S. electricity generation mix and retail rates indicates, government policies play a significant role in defining the business opportunities in the electric sector. The influence, heterogeneity, and complexity of policymaking has increased with climate concerns, as policymakers at various levels of government respond to concerns about climate change and clean energy deployment with widely varying priority levels and preferred approaches. Investors in electricity generation projects and related technologies must understand the landscape of existing and potential climate-related policies applicable to a given location before committing to projects. The unique combination of policies that exists in a particular region, or that may be implemented in the region in the future, can be the key to whether an electric sector business venture or a business that uses large quantities of electricity is a money-maker or is destined for losses. Some relevant climate-related policy supports are federal but many of the supports are state or regional. The most prominent types of policies which electricity businesses and major electricity consumers must monitor and consider are discussed below.

Mandated Portfolio Standards

Government-mandated portfolio standards typically require that a specified percentage of the overall electricity generation be produced by a certain type of generation. In the U.S., these portfolio standards are typically established at the state level and support renewable forms of generation, and they are commonly referred to as Renewable Portfolio Standards (RPS).[12] A given state's RPS may specify different percentage requirements for different generation types (e.g., solar, wind, etc.), with requirements as to where qualifying generation resources must be located (e.g., in the respective state, in the respective RTO, etc.). Each retail supplier in the state (e.g., the regulated electric utilities and competitive retail suppliers) must show regulators that it is supplying electricity from the required generation types in amounts at least equal to the respective required percentages of its overall supply. Most RPSs incorporate a Renewable Energy Credit (REC) system in which qualifying generators are granted a certificate for each megawatt-hour that they generate. They can sell these certificates to retail suppliers, thereby allowing the retail suppliers to verify satisfaction of their requirements with regulators. Market prices for RECs can vary significantly from one state to another, based on the cost to build and operate the specified generation types, as well as supply and demand factors such as the percentage requirements and whether generation resources located in a region larger than the state may qualify for the state's RECs. With over half of the U.S. states adopting RPS programs, a 2021 Lawrence Berkeley National Laboratory report cited RPS policies as a "key driver" of renewable energy growth, noting, "Roughly half of all growth in U.S. renewable electricity (RE) generation and capacity since 2000 is associated with state RPS requirements, though that percentage has declined in recent years, representing 23% of all U.S. RE capacity additions in 2019. However, within particular regions – namely, the Northeast and Mid-Atlantic – RPS policies have remained a dominant driver for RE growth." (Barbose, 2021)

A benefit to mandated portfolio standards is that they help to directly ensure the development of specified quantities of certain types of generation that are deemed favorable for climate or other policy reasons. However, as explained in the later section, "Preferential Technology Deployment Policies," one of the downsides of RPS programs is their cost inefficiencies in meeting climate goals. To mitigate this issue, some states have built upon their RPS programs by adopting a Clean Energy Standard (CES). While there is no universally accepted definition of a CES, the term frequently refers to a standard that is generally technology-agnostic, and that includes clean or low-emission generation resources that would not be qualifying resources in an RPS, such as nuclear, or coal or natural gas coupled with carbon capture infrastructure, as well as generation resources that typically would qualify in an RPS.

Feed-In Tariffs

A feed-in tariff is a policy mechanism that pays owners of qualifying generation technologies a pre-established price for each unit of electricity. Where feed-in tariffs are used, they are generally offered for renewable generation resources. Prices under feed-in tariffs are typically structured as fixed prices per megawatt-hour, or they may be structured to pay the difference between a fixed benchmark price and the

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[12] Alternatively, these types of programs are sometimes called, "Alternative Energy Portfolio Standards."

prevailing wholesale market price while allowing the resource receiving the feed-in tariff price to sell its output into the local electricity market. The prices are often locked in over a contract period of 10 to 25 years. Costs are typically recovered from retail electricity customers through grid charges or other surcharges. Feed-in tariffs are currently quite rare in the U.S., but they were widely used in the 1980s to procure output from generators qualifying under PURPA. Feed-in tariffs are used more frequently outside of the U.S. Worldwide, feed-in tariffs were in place in 83 jurisdictions at the national, state or provincial levels as of the end of 2020. (REN21, 2021)

Feed-in tariffs provide benefits to renewable generation investors because they remove energy price risk from the investment equation. However, this risk is effectively shifted to electricity customers, which can result in costly situations if technology costs drop after feed-in tariff contracts are signed. This risk is further compounded by the fact that the feed-in tariff price is determined administratively, rather than directly through competitive market forces. This leads to an increased likelihood that the price paid for the electricity under the feed-in tariff is excessively high, especially because a policy objective of a feed-in tariff is to set price levels high enough to stimulate deployment of the chosen technologies. One of the more controversial examples of electricity feed-in tariffs is that stemming from Germany's Renewable Energy Act, which was first introduced in 2000. Under this Act, a long-term, fixed price was provided for the megawatt-hours generated by each qualifying renewable energy project. (Raikar & Adamson, 2020) These prices were typically set for 20 years, they often were set at levels above market prices, and they are recovered from charges imposed on electricity customers. (Raikar & Adamson, 2020) By 2016, German citizens were paying over six euro cents per kilowatt-hour, or approximately 23 billion euros annually, in support payments under the program. (Thalman, 2015) Some critics claim that the high power costs in Germany, which are at least partially attributable to these support programs, have impaired the ability of German businesses, and especially its smaller businesses, to compete. (Wilkes & Parkin, 2018)

In addition to the risk of paying an unnecessarily high price for the targeted type of generation, feed-in tariffs can increase society's overall electricity costs as investors may choose to ignore opportunities to develop lower cost generation projects, even if they provide similar or greater environmental benefits, and instead develop the specific types of projects that are eligible for the tariffs. This may also disrupt the competitive wholesale electricity markets, especially if the feed-in tariffs support excess supplier entry, disadvantaging competitive generation projects that are not supported by the tariffs. Consequently, policymakers must be careful about the design of feed-in tariffs, as they involve tradeoffs from a societal perspective.

Competitive Solicitations for Long-Term Contracts

New investments in generating plants that are made on a "merchant" basis, which is without regulatory or contractual assurance of full cost recovery, face the risk that revenues will be adversely affected by decreases in future electricity market prices without commensurate decreases in the project's fuel costs. As will be explained later, this is an especially significant risk for climate-friendly resources such as solar or wind generation, which have no fuel costs. Lower electricity market prices could be caused by many factors including decreases in the prices of fuels such as natural gas which power the generation units that often determine wholesale market prices, by low load growth, or by policies or cost reductions that support or increase the market's supply of new generation resources, including other climate-friendly resources such as solar, wind, hydroelectric, or nuclear generation.

As a result of these factors, most investors in renewable generation projects have especially large appetites to mitigate the risks associated with ongoing market exposure. For example, according to the

American Wind Energy Association, 73 percent of the new wind capacity installed in the U.S. in 2019 was either contracted with a long-term contract (a.k.a. “power purchase agreement,” or “PPA”) or was built by a utility that has regulated cost recovery mechanisms. (American Wind Energy Association, 2020) Furthermore, of the remaining 27 percent, only 3 to 4 percent did not have some form of financial hedge in place. (American Wind Energy Association, 2020)

Competitive solicitations for long-term PPAs can address this issue and provide the same level of financial certainty to generation investors as feed-in tariffs while harnessing the forces of competition to better ensure that the buyer receives the lowest price for the electricity. As of 2020, approximately 50 countries throughout the world use these types of solicitations to procure renewable energy, and the use of this approach continues to grow. (Raikar & Adamson, 2020)

Many U.S. states also have established solicitations for long-term PPAs for renewable energy. For example, to meet its mandate of supplying 70 percent of its electricity consumption from renewable generation, the State of New York relies heavily on annual solicitations administered by the New York State Energy Research and Development Authority (NYSERDA) and the New York Power Authority (NYPA) for contracts with durations of up to 20 years. (New York State Energy Research and Development Authority, 2020c) New York’s solicitations result in the procurement of contracts for solar, solar, hydroelectric, land-based wind, offshore wind generation, as well as contracts for utility-scale storage. (New York State Energy Research and Development Authority, 2020b) By 2020, New York’s annual solicitation in aggregate constituted the largest competitive procurement of renewable energy in U.S. history to date, (Sylvia, 2020) garnering contracts for over 4,600 megawatts of renewable capacity. (New York State Energy Research and Development Authority, 2020a) Massachusetts has also utilized solicitations for long-term contracts as a significant step toward meeting its climate goals, including a solicitation that resulted in a 20-year contract for almost ten million annual megawatt-hours of hydroelectric generation from Hydro-Québec, which was approved by the Massachusetts Department of Public Utilities in 2019. (Walton, 2019) The development of the U.S. offshore wind generation market is also being driven by competitive solicitations for long-term contracts. For example, Massachusetts, Rhode Island, Connecticut, New Jersey, Maryland, and New York have conducted or plan to conduct such solicitations. (Beiter, Heeter, Spitsen, & Riley, 2020) (Kuffner, 2020) States or regulated utilities that administer long-term PPA solicitations for renewable energy may include the associated RECs (from the state’s RPS) in the purchase under the contract. The RECs may then be resold into the market, or they may be used by the regulated utility to satisfy its share of the RPS requirement.

Competitive solicitations for long-term contracts entail tradeoffs. Long-term contracts mitigate the energy price and policy risks faced by investors in generation projects, reduce the financing costs of the projects, support development of the targeted projects and speed commercialization of clean energy technologies. Furthermore, unlike feed-in tariffs that administratively set a long-term price that may be unnecessarily high, solicitations harness competitive forces to set the price received, thereby reducing the chance of locking into needlessly high prices. Still, retail electricity consumers, who ultimately cover the costs of contracts executed by governments or regulated utilities, assume the risk that the prices in the long-term contracts turn out to be above prevailing market levels in the future. This procurement system may also disadvantage competitive generation projects that are not provided the same long-term cost recovery guarantees, making it more costly to finance projects that are not supported by the long-term contracts. Policymakers must consider these tradeoffs when deciding whether and how to use this procurement and contracting method.

Carbon Pricing

The idea behind carbon pricing mechanisms is simple: since the world's climate challenge is largely driven by carbon dioxide (a.k.a. "carbon") emissions, parties that emit carbon should be charged an amount equal to the damages that their carbon emissions impose on society. As of 2021, 64 carbon pricing mechanisms were in operation around the world, covering over 20 percent of global greenhouse gas emissions and generating $53 billion in revenue. (The World Bank, 2021)

Carbon pricing mechanisms generally come in one of two forms: a carbon tax and a carbon cap-and-trade program (a.k.a. "emissions trading system," or "ETS"). A carbon tax is self-explanatory, as it is a predetermined price that is imposed by a government per ton of carbon dioxide emitted. If this price reflects the true cost to society of the emitted ton of carbon dioxide, the tax is imposed on all sources of carbon emission, and the tax can be administered cost-effectively, then it will reduce emissions in a cost-effective fashion.

In contrast to a carbon tax, which directly mandates the price of carbon, a carbon cap-and-trade program directly mandates the maximum quantity (a.k.a. "cap") of carbon that can be emitted in a given period such as a year, and it allows a market system to determine the price of an emitted ton, given the mandated quantity. On a periodic basis, emission "allowances," which in aggregate match the carbon cap, are sold or allocated by the government entity administering the cap-and-trade program. Parties can then buy and sell the allowances, so that parties can purchase the necessary allowances to legally emit a commensurate amount of carbon as part of their operations. Typically, the carbon cap is programmed to decrease over time so that carbon reduction goals can be achieved. Under some cap-and-trade programs, parties can bank unused allowances for emissions in future periods. By allowing for trading of the allowances, the resources with the lowest costs to reduce emissions are the most likely to operate, resulting in a greater likelihood that the targeted carbon reductions are achieved in a cost-effective manner. Some cap-and-trade programs also incorporate offset credits, which credit carbon emitters for emission reductions achieved through other activities. In the U.S., a group of Mid-Atlantic and Northeastern states jointly formed a cap-and-trade program known as the Regional Greenhouse Gas Initiative (RGGI) in 2009, and California adopted a cap-and-trade program that connected with Québec's cap-and-trade program in 2014.

Tax Credits

Tax credits can provide significant support for the development of clean generation resources. In the U.S., tax credits are offered at the federal, state, and local levels. The U.S. federal government offers income tax credits in the form of Production Tax Credits (PTCs) and Investment Tax Credits (ITCs). The PTC, which provides tax credits based on the quantity of electricity produced, was first enacted by the 1992 Energy Policy Act. This Act established a ten-year PTC of $0.015 per kWh with an inflation-adjustment mechanism for wind and closed-loop biomass generation resources brought online before July 1, 1999. The PTC has been extended multiple times, its value has changed over time, and the list of qualifying technologies has expanded to include open-loop biomass, small irrigation power, municipal solid waste, qualified hydropower, marine, and hydrokinetic generation. In past years, the PTC has been a key deciding factor in determining how rapidly wind generation is deployed. For example, uncertainty about whether the government would extend the PTC resulted in a 92 percent reduction in U.S. wind power capacity installations in 2013 versus the previous year. (American Wind Energy Association, 2014)

The ITC was first established by the Energy Policy Act of 2005 (P.L. 109-58), providing for a 30 percent tax credit on the eligible property of residential and larger solar energy systems placed in service in 2006 and 2007. (Raikar & Adamson, 2020) As with the PTC, the ITC has been extended several times and its value has changed over time. Solar, fuel cell, small wind, offshore wind, and geothermal projects all qualify for varying levels of ITC.

One of the complicating factors with tax credits is that they generally can be monetized only if the entity claiming the credit is subject to federal income taxes and has sufficient profitability to produce a tax liability to absorb the credits. Consequently, developers often must seek partners to engage in complex tax equity agreements to realize the value of the credits. This adds to the cost of project development and acts as a barrier to enter the clean energy development space. Developers face legal and accounting fees to engage in and administer such agreements, and the tax equity partners require returns for their participation. A 2017 study by Woodlawn Associates found that tax equity investors require between 7.5 percent and 9.5 percent in after-tax returns for unleveraged projects, net of their tax benefits, (Lutton & You, 2017) and most tax equity investors will only join in funds intended to finance at least $75 to $100 million of investments within one year, which is more capital than most developers can deploy. (Lutton & You, 2017)

Since tax credits are typically offered to only certain types of resources, they may entail cost inefficiencies in meeting climate goals, and they can disadvantage other types of resources that may be able to reduce emissions more cost effectively. This basic dynamic is further explained in the later section, “Preferential Technology Deployment Policies.” In the U.S., the PTC has received criticism from some parties along these lines, due in part to the fact that it is credited based on the megawatt-hours generated. With this structure, the PTC provides an economic incentive for certain types of qualifying generation resources to offer negative prices into the daily wholesale electricity markets because they will receive the tax credit if they generate. For example, a wind generator’s marginal cost to generate is very close to zero because it incurs no fuel costs. With the PTC available to the wind generator, the generator has an incentive to offer a negative price into the market, of a magnitude that is up to the pre-tax value of the PTC that it receives for generating.[13] During hours in which wind generation is the marginal type of resource, this can reduce market clearing electricity prices to these negative values. As more wind generation is built, increasing the number of hours in which wind generation sets a negative market price supported by the PTC, the opportunities to profitably deploy other types of clean energy resources could be significantly diminished, and existing clean energy resources may retire prematurely without additional financial supports. Furthermore, these negative market clearing prices could encourage excessive consumption of electricity and lead to additional costs incurred to expand the electric system to accommodate this incremental demand. These issues are likely to be more significant as resources that qualify for the PTC, such as wind generation, increase their market share. Consequently, while tax credits such as the PTC can be useful measures, they must be applied carefully, and they should be periodically reassessed for their range of impacts.

Accelerated Tax Depreciation Benefits

Accelerating the tax depreciation schedules of investments is another policy mechanism employed by governments to support the development of certain types of projects over time. Value from accelerated depreciation is reaped by the project owner due to the time value of money. If an asset with an expected 25-year life is assumed to depreciate for tax purposes over only five years instead of 25 years, then the

[13] The PTC is quoted in after-tax dollars because it is a tax credit. Therefore, the pre-tax value of the PTC is the quoted PTC value divided by one minus the tax rate.

aggregate tax deduction associated with the depreciation of the asset over its life occurs earlier in time, providing a higher present value to develop the project.

In the U.S., at the federal level, renewable energy projects qualify for Modified Accelerated Cost Recovery System (MACRS) treatment. Qualifying assets with long expected useful asset lives may depreciate for tax purposes over much shorter periods, sometimes 5-6 years. In addition, certain projects may qualify for "bonus depreciation," in which a certain percentage of the capital cost is depreciated for tax purposes in the first year of the project's life.

Other Direct Subsidies, Taxes and Low-Cost Financing Arrangements

Governments at federal or local levels may provide other direct financial subsidies or low-cost financing programs for selected energy technologies. Some such programs have creative structures, such as PSE&G's Solar Loan Program, which offers loans to help qualified entities finance a portion of their solar generation investment. PSE&G administers solicitations for parties seeking loans and it grants loans based on the lowest Solar REC (SREC) prices bid. The loans can be repaid with cash or SRECs, in which the SRECs are valued at the higher of the bid price or the market SREC price. (PSE&G, 2016) This allows the most competitive bidders to finance their solar investments in a way that provides them a guaranteed minimum SREC price for the life of the loan, while retaining upside SREC pricing potential.

Government levies on certain technologies can also materially change investment opportunities and patterns on a locational basis. Wyoming's tax on wind power provides an excellent example. As of 2009, Wyoming led its peers in terms of wind power development. However, the 2012 imposition of a $1 per megawatt-hour state tax on wind-energy output effectively stymied wind development in the state. From 2009 to 2018, the cumulative installed wind capacity in three nearby states with similar wind development costs, Montana, Colorado, and New Mexico, increased 415 percent, 205 percent, and 204 percent, respectively. In comparison, Wyoming's cumulative installed wind capacity in the same period increased only 28 percent. (Cotting & Horwath, 2019)

Wholesale Market Design

Policies pertaining to the structure of the wholesale electricity markets also influence the opportunities and risks for generation investors and other businesses. Investors in merchant or partially merchant generating projects rely upon wholesale market prices for their project revenues, so they must consider both the opportunities for market compensation under the existing market designs and the possibility of changes in the market designs over time. For example, a developer of an intermittent renewable generation resource such as a wind or solar resource must consider whether a given electricity market of interest includes a "capacity" product and, if so, then to what requirements would the generation resource owner be subjected, and to what extent would the project's compensation for providing capacity be limited due to the intermittent nature of the resource.

Similarly, the economic viability of grid-scale batteries, which can facilitate the integration of intermittent generation resources into the grid, may hinge on the pricing structures for the services that batteries can provide to the grid. Policy changes in the frequency regulation market administered by the PJM Interconnection (PJM)[14] provide a notable case in point. In 2012, to help maintain the stability of its transmission system, PJM introduced a fast-responding frequency regulation product designed to

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[14] PJM is a regional transmission organization that operates an electric transmission system serving all or parts of Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia.

compensate generation resources that can quickly adjust power output but are limited by the time they can sustain that output. Between 2012 and 2016, utility-scale battery capacity in PJM increased from 38 MW to 274 MW, which at the time was almost half of the entire utility-scale battery capacity in the U.S. (Fletcher & Marcy, 2018) More than 90 percent of this PJM battery capacity was providing frequency regulation service. (Fletcher & Marcy, 2018) The market collapsed, however, when PJM subsequently changed its policy by placing a cap on fast responding frequency regulation, imperiling the income streams for many of the utility-scale battery projects. (Maloney, 2018) This led to subsequent protracted litigation and market design uncertainty.

Another example of how market design influences business opportunities and risks is related to the anticipated significant growth of solar and wind generation. Since solar and wind generators incur no fuel costs, their marginal costs to generate are very close to zero, and the prices they bid into the daily wholesale electricity markets, which are used to develop hourly market prices, are based on these very low marginal costs. Furthermore, growth of solar and wind generation is expected to increase the frequency in which these resources are the marginal resources in the wholesale electricity markets, and therefore increase the hours in which the bids submitted by owners of these resources set the market prices. Consequently, substantial growth of solar and wind generation could create significant downside market price and revenue risks for generation developers and existing generation resources. This raises questions about potential changes in today's market designs to accommodate the growth of these clean energy resources, and how such changes may affect the profitability and opportunities for generation developers and other businesses affected by electricity market prices.

Indeed, the design of the wholesale market in a region, and the uncertainty about design changes over time as the grid transitions to a more climate-friendly system, can make or break the profitability of new and existing projects. Wholesale market designs are continually evolving, with significant changes possible over the coming decade as emerging climate-friendly technologies become increasingly cost competitive and regulators grapple with changes in market design to accommodate and compensate these emerging technologies. For example, in the U.S., FERC Order 2222, issued in September 2020, is intended to remove barriers preventing distributed energy resources from competing on a level playing field in the organized capacity, energy, and ancillary services markets. (Participation of Distributed Energy Resource Aggregations in Markets Operated by Regional Transmission Organizations and Independent System Operators, 2020) (U.S. Federal Energy Regulatory Commission, 2020) The market designs that are adopted in response to the need identified in this order are likely to vary across regional markets, to evolve over time, and to impact the opportunities afforded to distributed energy resource projects while affecting the market landscape for all market participants.

Retail Ratemaking and Net Metering

Policies regarding retail ratemaking and net metering can determine the financial viability of distributed generation projects, such as solar generation located on a customer's premises. Before the turn of the twenty-first century, customer meters that could read both a customer's peak demand during a monthly period as well as the total kilowatt-hour usage over that period were typically only installed at larger customers' premises, as these types of meters were considered too expensive to install at residential customers' premises given their lower loads. Consequently, larger customers' rates often included a significant charge based on peak demand, because these customers had the meters to accommodate such charges and it was generally accepted that this type of charge is aligned with drivers of several of the electric system's costs, especially because distribution capacity must be built to accommodate peak power flows. In contrast to the rate structures for larger customers, the rate structures for residential customers generally did not include a peak demand charge due to the limitations of these customers' meters. Instead, residential rate structures generally included charges based on the customer's kilowatt-hour usage over a month.

This conventional rate structure was not very controversial until the costs of distributed solar generation systems dropped significantly in the first 20 years of the twenty-first century, accelerating the adoption of residential solar systems in many regions. These systems are often interconnected "behind the meter," and for ratemaking purposes they are often treated as reductions in customer usage. The amount of the electrical output of these solar systems, over some periods of time, can be similar in magnitude to the overall electric usage of the customer itself. As a result, residential customers with solar generation systems and with large portions of their bill based on their metered kilowatt-hour usage can avoid paying a substantial portion of what they would otherwise be charged for use of the distribution system. Net metering policies in certain jurisdictions also allow these customers to receive credits for any net positive amounts of electricity that they export onto the grid, credits that are often similar in magnitude to the customer's overall kilowatt-hour-based rate.

Proponents of maintaining this form of residential rate structure (and net metering treatment) argue that these bill reductions and credits help to compensate the residential solar generation owner for the climate benefits that its solar generation provides. Critics argue that since residential solar generation owners still use the distribution system to receive and export electricity, this approach to ratemaking allows them to avoid paying their fair share of distribution system costs, causing other customers who do not have or are unable to site solar generation on their premises to pay more for their electricity. Critics also argue that lower-income customers are less likely to have the financial or physical means to install solar generation systems on their property, so the burden of the cost shift is disproportionately shouldered by lower-income customers. The advent of "virtual net metering" and community solar programs, which treat shares of electricity generated from independently developed solar generation facilities located elsewhere as if they were located behind the meter of residential customers who subscribe to a share of the facility's output, have provided customers without viable solar generation sites on their premises the opportunity to receive the benefits of the rate structure and net metering treatment. However, critics argue that this exacerbates the problem of customers allegedly not paying their fair share of distribution system costs, leaving even more costs for others to pay. Controversy surrounding these issues has caused some jurisdictions to adopt alternative approaches.

To the businesses investing in residential solar generation, profitability can be highly dependent upon a given jurisdiction's residential rate structure, how the net metering of the excess electricity exported to the grid is credited, and how these policies may change in the future. Furthermore, these issues are relevant to all power plant owners and developers because the design of these policies can affect the amount of residential solar generation in the market and therefore it can affect the wholesale market prices that generating plant owners receive for their plants' outputs.

Siting, Permitting and Interconnection Policies

Policies regarding the siting, permitting and interconnection of new generation resources of all types also can affect business opportunities and carbon reductions. For example, the use of coastal waters by offshore wind projects can involve significant permitting requirements, onshore wind projects can face permitting challenges due to their relatively large geographic footprints and their visibility, natural gas-fired generation and pipelines increasingly face siting and permitting challenges, and long-distance transmission lines have been difficult to site and permit for many years.

Regulators also must decide how to allocate the costs to interconnect generation resources between the resource owner and other customers making use of the transmission and distribution system. Policymakers in different jurisdictions may allocate these costs differently. With clean energy resources becoming an increasing share of new interconnections, some policymakers with aggressive climate goals may modulate the allocation to lower the direct cost to developers, while other policymakers may not. Policy decisions along these lines can affect the financial viability of a project.

Generation project developers also benefit from clear and reliable estimates of the interconnection costs they will incur, and from timely completion of interconnection. Uncertain estimates of the interconnection fees for a given project, especially if changes to estimates can occur after the interconnection agreements are signed, can pose significant financial risks for developers. Similarly, development risks arise if there is a notable chance that projects will be stalled indefinitely in an interconnection queue.

Thematic Challenges for Businesses and the Achievement of Climate Goals

The patchwork quilt presents several thematic challenges for businesses and the achievement of climate goals. These include preferential technology deployment policies, emissions leakage due to uneven climate policy, competing federal and state policies, magnified investment risks for capital-intensive technologies, and policy and market uncertainty.

Preferential Technology Deployment Policies

Policies advancing a limited set of preferred technologies constrain development opportunities for other technologies that are not provided preferred treatment, as compared to adopting a broader technology-agnostic policy approach to decarbonization. For example, while RPS programs typically mandate new wind and solar, they often omit or include much less aggressive mandates for other clean energy generation technologies such as preserving conventional nuclear generation, expanding hydroelectric plants, or developing fossil carbon capture and sequestration (CCS) facilities. Similarly, such preferential policies do not support the development of earlier-stage, emerging, climate-friendly technologies such as small modular nuclear reactors and low-carbon oxy-combustion processes.

When one type of clean generation is financially supported, it is provided an economic advantage over other, unsupported types of clean generation, some of which otherwise may be more cost effective than the supported type. This penalizes the unsupported clean generation types in two ways. First, the unsupported types of clean generation are less likely to be viable investments due to their ineligibility to receive financial support. Second, the financial supports may result in additional market entry from the supported generation type, increasing the overall supply in the market and lowering regional energy market prices for some time. The lower market prices may further reduce the likelihood of deploying unsupported clean generation types, and they may increase the likelihood that existing resources of the unsupported clean generation types retire earlier. In addition to potential overall cost inefficiencies, this leads to other types of generation filling the resultant gaps, types which could be higher emitting resources.

The U.S. nuclear industry provides a prime example of this dynamic. Excluding nuclear generation from policies, such as the RPS programs in many states which provide financial supports to other climate-friendly generation resources, can undermine the decarbonization of the electric sector. As of the beginning of 2013, the U.S. had 105 nuclear power reactors. (Scott & Comstock, 2019) However, seven reactors retired between the beginning of 2013 and the beginning of 2019, with 12 more expected to retire by 2025 and only two new reactors expected to be built. (Scott & Comstock, 2019) Generation from greenhouse gas emitting resources often, if not always, replaces a part of the retired nuclear generation.

For example, according to the Edison Electric Institute (EEI), the 2018 retirement of the Oyster Creek Nuclear Generating Station resulted in annual additional carbon emissions of 3.1 million tons, as natural gas and coal generation replaced the lost generation. (Fisher, 2021) Similarly, EEI reported that the 2014 retirement of the Vermont Yankee Nuclear Power Plant was accompanied by a 2.9 percent increase in New England's carbon emissions the following year. (Fisher, 2021) In response to impending nuclear retirements, some states, such as New York, New Jersey, and Illinois, have responded with compensation programs for nuclear plants that were on the brink of closure. (Magill, 2019) But proactive adoption of policies that are broader in scope both geographically and technologically, to include nuclear as well as other types of clean generation technologies, could provide greater certainty to electricity generation investors and facilitate the achievement of climate goals.

Similarly, generation resources that employ carbon capture and sequestration have not been deployed at least in part due to policies that have favored other climate-friendly technologies over this type of system. For example, the failure to complete the Hydrogen Energy of California project, an integrated gasification combined cycle power plant with carbon capture and sequestration, was due at least in part because it could not obtain a long-term PPA approved by the California Public Utilities Commission. (Reicher, Brown, & Fedor, 2017)

Emissions Leakage Due to Uneven Climate Policy

Climate policies that are adopted in one state or jurisdiction but not adopted in another also present risks for investors and often reduce the efficacy in meeting climate goals.

One such example relates to what is commonly known as carbon "leakage." Suppose that one state adopts a policy, such as a carbon tax or a tradable emissions allowances system. These policies are generally designed to favor clean or low-carbon emitting resources, as the costs faced by the carbon-emitting resources in the state are increased, encouraging carbon-emitting resources to be displaced by carbon free or lower carbon emitting resources. This displacement reduces overall carbon emissions. However, if a neighboring state does not adopt a similar policy, and electricity generators in the neighboring state are part of the same wholesale electricity market without transmission constraints between them, then carbon-emitting generation resources in the neighboring state will also be advantaged by the policy. These resources will not face the higher costs of the carbon policy while their competitors in the state that adopted the policy will, and they will have a financial incentive to increase their generating output and sell it into the state that adopted the carbon policy. Consequently, the policy creates unintended incentives for carbon-emitting resources to be built in the neighboring state, reducing the clean energy supports and overall emission reductions intended from the carbon policy. In this way, the efficacy in meeting climate goals can be notably diminished.

The magnitude of these effects can be substantial. For example, a 2020 study issued by the Pennsylvania Department of Environmental Protection estimated the carbon reductions associated with the implementation of an Executive Order by the Governor of Pennsylvania to participate in RGGI. (Pennsylvania Department of Environmental Protection; ICF Incorporated, L.L.C., 2020) Despite the fact that four of the six states that border Pennsylvania also participated in RGGI,[15] the study estimated that 54 percent of the reductions in Pennsylvania emissions from 2022 to 2030 would be offset by higher emissions elsewhere in PJM. (Pennsylvania Department of Environmental Protection; ICF Incorporated, L.L.C., 2020) Similarly, a 2015 study published in *The Energy Journal* estimated that, if cross-border mechanisms to minimize leakage are not effectively enforced, California's cap-and-trade program could

[15] New York, New Jersey, Delaware, and Maryland were a part of RGGI, while West Virginia and Ohio were not.

increase out-of-state emissions by 45 percent of the domestic reduction. (Caron, Rausch, & Winchester, 2015) Cross-border mechanisms can mitigate these types of leakage levels, but development and enforcement of effective mechanisms can be complicated in practice. Regional cap-and-trade programs are helpful to mitigate the effects of climate change, but the achieved climate benefits are often notably reduced by the absence of a more broadly applied program.

Competing Federal and State Policies

Unsynchronized or competing federal and state policies, which may arise when parties with differing policy viewpoints are in power at the federal and state levels, can diminish or nullify the efficacy of policies intended to achieve climate goals, add to the costs to satisfy climate goals, impair or add risk to climate-friendly investment opportunities, and threaten the financial viability of existing climate-friendly resources. The magnitude of this problem has been emphasized by business leaders in the electric sector, including Exelon CEO Chris Crane:

> *[The United States] for too long has separated environmental policy from an energy policy, and competing at federal levels with state levels has made it very difficult for markets to be formed efficiently and made it very difficult for predictability of investments going forward…[L]eadership at the federal level should either come up with a common policy or get out of the way, have the states be allowed to work with the RTOs and design the markets [that] the state desires.* (Christian, 2017)

One high-profile example of the issues that can arise from lack of alignment at the federal and state levels is the incongruity between a December 2019 U.S. FERC order regarding capacity resources serving loads in the PJM region, (Order Establishing Just and Reasonable Rate, 2019) and the intent of state policies designed to support clean energy resources. PJM's original Minimum Offer Price Rule (MOPR) placed floors on the prices that certain generation resources could offer into PJM's capacity market, to prevent bidders who are net buyers of capacity in the market, such as load-serving utilities, from exercising buyer-side, or "monopsony," market power. This safeguard was designed to prevent net buyers of capacity from artificially suppressing overall capacity market prices by offering their generation capacity into the capacity market at prices below their costs, and to prevent the net buyers from having their contracted electricity suppliers do the same. FERC's 2019 MOPR Order modified the rules of the original MOPR. Specifically, the 2019 MOPR Order required PJM to expand the application of the offer price floor to all new and existing capacity resources that receive or are eligible to receive state subsidies, subject to certain exemptions.[16]

Per the 2019 MOPR Order, the minimum offer price of any capacity resource subject to the MOPR is based on an estimate of the resource's costs going forward, without reductions to account for the state subsidies that the resource receives. Many states in the PJM region have established policies that effectively provide subsidies designed to compensate low-emitting or clean generation resources for the positive value that they provide for the earth's climate due to their low greenhouse gas emissions. These include renewable portfolio standards, clean energy standards, mandates to conduct competitive solicitations for clean energy resources, and other policies. By setting a minimum offer price that reflects a resource's costs without a reduction to account for the state subsidies that the resource receives, the 2019 MOPR Order threatened to offset the climate-based compensation from such state policies because it jeopardized the ability of clean energy resources to offer a sufficiently low price for the resource to be a

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[16] Exemptions applied to most existing renewable generation resources, demand response, energy efficiency, and energy storage resources, but not to new renewable or existing nuclear generation resources.

winning bidder in the capacity market and receive the associated capacity market revenues. All else equal, this reduced the profit opportunities for new clean energy investments, and it increased the possibility of early retirements of existing nuclear plants that are major contributors to greenhouse gas reductions. Furthermore, requirements on these clean energy resources to bid higher prices would likely cause capacity market clearing prices to be higher than they otherwise would be, thereby providing additional financial support to resources that emit greater quantities of greenhouse gases and increasing capacity costs for consumers.

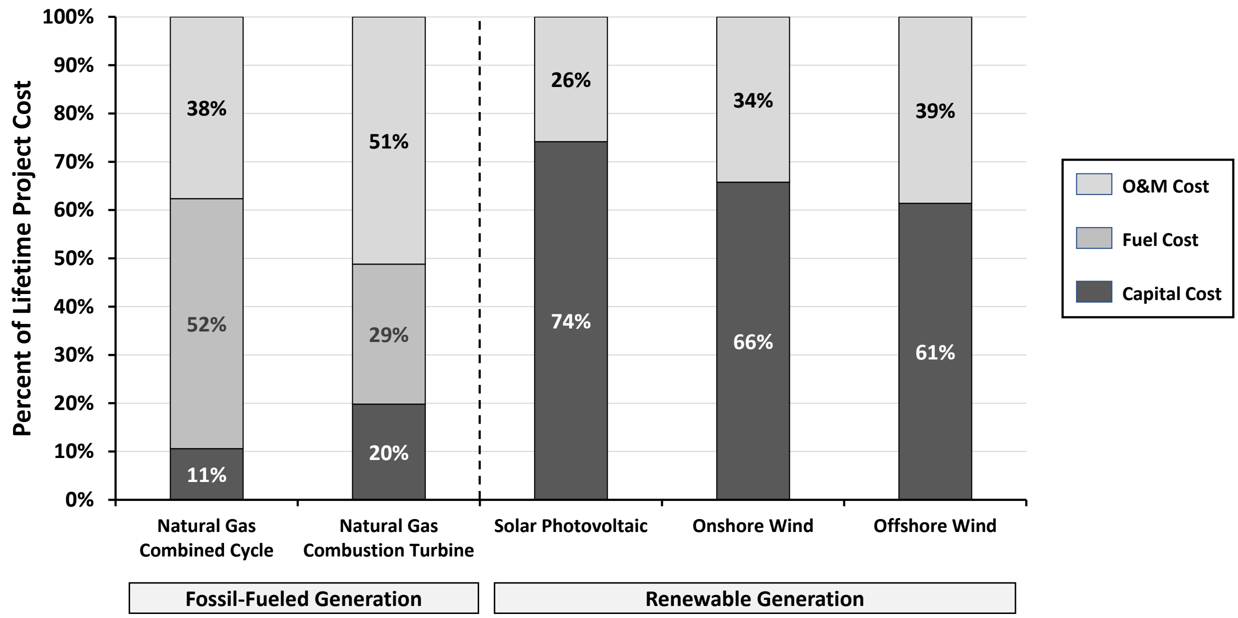
The FERC subsequently took measures to mitigate and nullify the relevant provisions in the 2019 MOPR Order, after the composition of the FERC had changed once President Biden took office. After taking action in 2021 to reverse changes enacted by the 2019 MOPR Order, two FERC commissioners stated, "[The 2019 MOPR Order] was really an effort to strip away any the [sic] influence of disfavored state policies on capacity prices…" (Statement of Chairman Glick and Commissioner Clements, 2021) While the FERC policy has changed since the time of the 2019 FERC MOPR Order, this presents a prime example of how lack of coordination or alignment at the federal and state levels can jeopardize climate-friendly business opportunities and the achievement of climate policy goals.

Magnified Investment Risks for Capital-Intensive Technologies

Without regulatory or financial hedges against revenue uncertainty, clean generation projects with high upfront capital requirements relative to their total lifetime project costs, such as solar and wind generation, can face magnified risks. As shown in the following figure,[17] solar and wind generation generally entail higher capital costs than natural gas generation, as a percent of total lifetime project costs.

[17] This figure depicts the costs of the electricity generation only, and not the fully delivered costs of electricity. Percentages are calculated based on estimated costs expressed in real dollars.

Figure 5.6: Illustrative Cost Breakdown of Various Generation Technologies



Based on data from the U.S. Energy Information Administration and the National Renewable Energy Laboratory.

(U.S. Energy Information Administration, 2020a) (National Renewable Energy Laboratory, n.d.) (Murphy, et al., 2021)

The relatively high capital costs of solar and wind generation are counterbalanced by relatively low operating costs over the project's lifetime, largely because these technologies do not incur fuel costs. However, since investors in solar and wind generation must make proportionally large upfront financial commitments to cover the capital costs associated with project construction, they are likely to be more exposed to the uncertainty of future market revenues than some other technologies with higher emissions, absent means to mitigate the revenue risk.

Furthermore, without reasonable opportunities for clean energy investors to mitigate their revenue risks, the ability to achieve decarbonization goals may be jeopardized. The 2017 Stanford University study, *Derisking Decarbonization: Making Green Energy Investments Blue Chip*, indicates that the world's institutional funds will need to be tapped to a greater extent to make the estimated multi-trillion-dollar annual investments needed globally to keep global warming below 2 degrees Celsius, but the conservative risk profile of the vast proportion of these funds does not match the higher-risk nature of most unhedged clean energy projects. (Reicher, Brown, & Fedor, 2017)

Policy and Market Uncertainty

Another key business challenge with the patchwork quilt stems from its lack of stability. Individuals and political parties can change quickly at both the local and federal government levels. This turnover is often accompanied by different views about clean energy and climate change. This can lead to new policies or the rollback of old policies, which in turn affects the market landscape and business opportunities. When this policy uncertainty is added to the other market and business risks that an electricity project investor faces, the overall risk to the entity can be substantial. Abigail Ross Hopper, President and CEO of the Solar Energy Industries Association, identifies uncertainty, especially about policy change, as a "key" to the development of solar generation in the electric sector:

> *[SEIA member companies] want to know what the rules of the road are, and then they will go out and innovate and adapt and build businesses based on that…Long-term certainty in terms of either tax policy, carbon policy – whatever kind of policy you want to call it – but long-term certainty is really key to that rapid deployment of solar and solar-plus-storage.* (Wagman, 2021)

Uncertainty affects both the prospects for new projects and the economics of existing projects. The economics of a project can be affected by a policy change even if the policy does not directly address that specific type of project. For example, policy changes that alleviate emission requirements on fossil-fired generation resources lower the costs incurred by such resources, reducing the opportunities for more climate-friendly generation projects. The lower costs of the fossil-fired generation, resulting from the less stringent emission requirements, could provide a competitive edge to fossil-fired resources to meet a region's electricity demands. In addition, the lower costs of the fossil-fired generation could lower wholesale electricity market prices that may drive the revenues for a clean generation project.

Takeaways for Businesses: Selective Opportunities and the Need for Risk Management

The patchwork quilt of regional market conditions and climate and clean energy policies that characterizes much of the electricity landscape has two overarching ramifications for businesses in the electric sector.

First, the patchwork quilt can contribute to large investment opportunities for businesses, but these are highly dependent on regional market and policy conditions, some of which can be quite local and complex. Opportunities are shaped by regional market structures and natural resource endowments. They are also dependent upon the potential for technology cost reductions, especially in the technologies that are the most conducive to a given region, which may include emerging technologies such as solar and wind power, batteries, electric vehicles, and other technologies on the horizon such as small modular nuclear reactors and hydrogen. Some of these technologies have already been discussed, while others will be discussed in the next chapter.

Importantly, the business opportunities in any location are also highly dependent upon the policies that apply to that location and the policies in neighboring locations that can affect the overall system. Such policies may include mandated portfolio standards, feed-in tariffs, centralized contracting, carbon pricing, tax and subsidization policies, wholesale market design, retail rate design, and siting, permitting and interconnection policies. Business challenges and economic inefficiencies are especially likely when policies favor certain technologies over other potentially more promising technologies, the unevenness of policies across a geographic region creates distorted incentives, or federal and state policies compete with one another. As policymakers at various levels of government respond to concerns about climate change, with widely varying priority levels and preferred approaches, policy considerations can be the deciding factor between a profitable investment and one that is destined to lose money.

The second overarching ramification for businesses in the electric sector relates to the complexity of the risks that businesses face, and the resultant need to assess and manage these risks. Projects in the electric sector face risks associated with obtaining the necessary siting and permitting approvals, acquiring satisfactory financing arrangements, future market conditions, and changes in government policies. Fossil-fired projects face risks associated with increasing public sentiment to implement new policies that are detrimental to generation resources that emit harmful pollutants, while investors in more climate-friendly technologies face the risk that supportive policies will be rolled back as federal or local government priorities change. Projects without regulatory or financial hedges against market uncertainty face magnified risks. This is especially true for clean generation technologies such as solar and wind, given their high upfront capital costs relative to their total lifetime project costs, which require solar and wind developers to make proportionally large upfront financial commitments. Furthermore, the low variable costs of solar and wind generation could result in significant electricity market price declines as the deployment of these technologies expands, adding downside market risk for generation resources without revenue hedges. While regional variations in economic conditions, natural resource endowments, and societal needs mean the patchwork quilt is to some extent inevitable, policy approaches that are better coordinated and more uniform would reduce today's investor risks and help reduce carbon emissions in a more cost-effective manner.

With this current state of the electric sector as a foundation, the next chapter takes a longer view, discussing the prospect of a transition to a fully decarbonized economy-wide energy system that will last several decades, the linchpin role of the electric sector including massive expansion to help decarbonize other sectors of the economy, the deep uncertainties associated with technology pathways, policy development, scaling deployment and consumer acceptance, and three broad challenges for businesses in the electric sector.

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