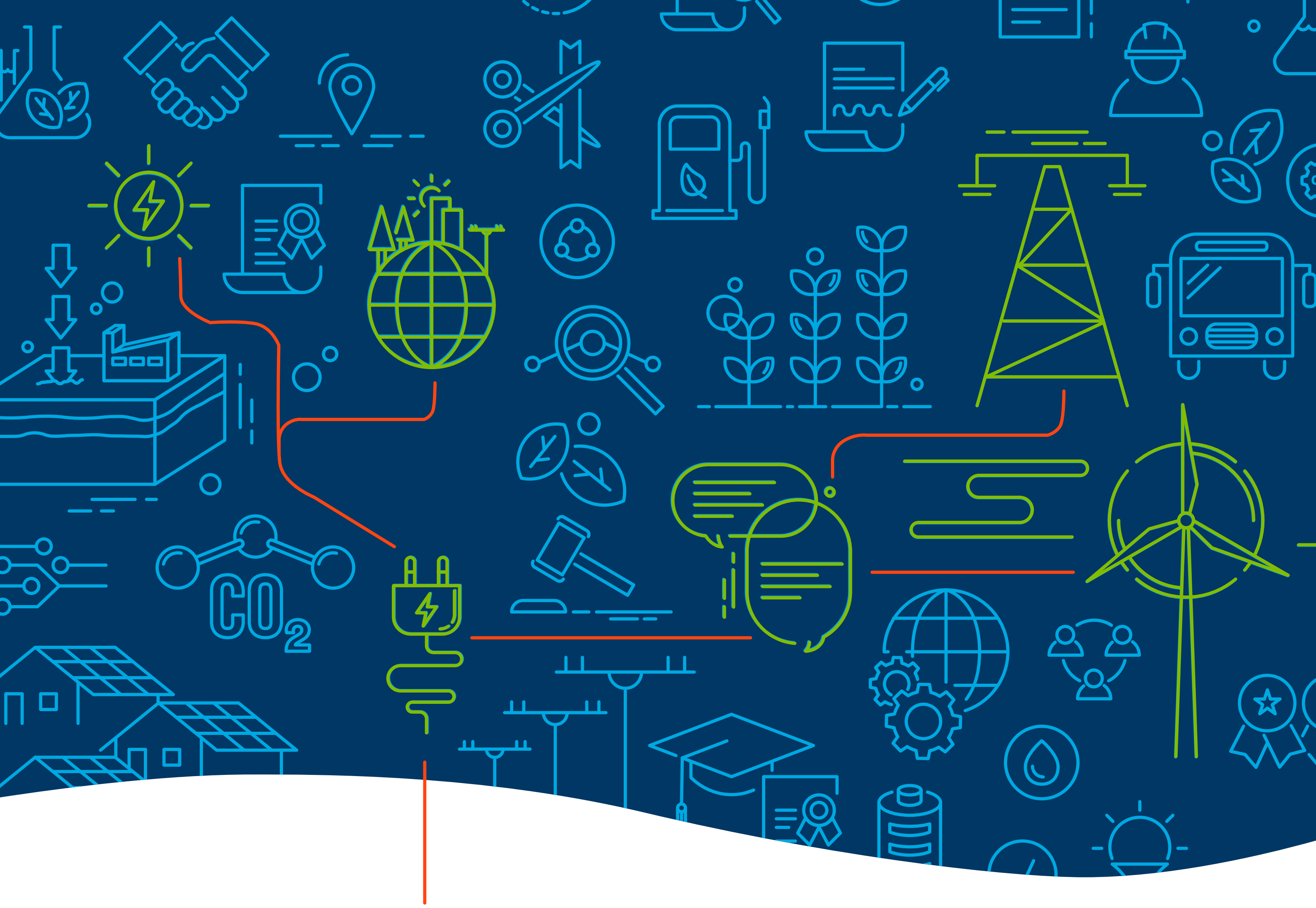

A Road Map to Decarbonization in the Midcontinent

ELECTRICITY SECTOR

MIDCONTINENT POWER
SECTOR COLLABORATIVE

GREAT PLAINS INSTITUTE
Better Energy.
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Midcontinent Power Sector Collaborative

Participants

Center for Energy and Environment

Clean Air Task Force

Clean Wisconsin

Dane County Office of Energy and Climate Change

DTE Energy

Ecology Center

EDP Renewables

Environmental Defense Fund

Iowa Environmental Council

WEC Energy Group

Madison Gas and Electric

MidAmerican Energy

Natural Resources Defense Council

Union of Concerned Scientists

Xcel Energy

Wolverine Power Cooperative

WPPI Energy

State Agency Observers

Minnesota Pollution Control Agency

Michigan Department of Environmental Quality

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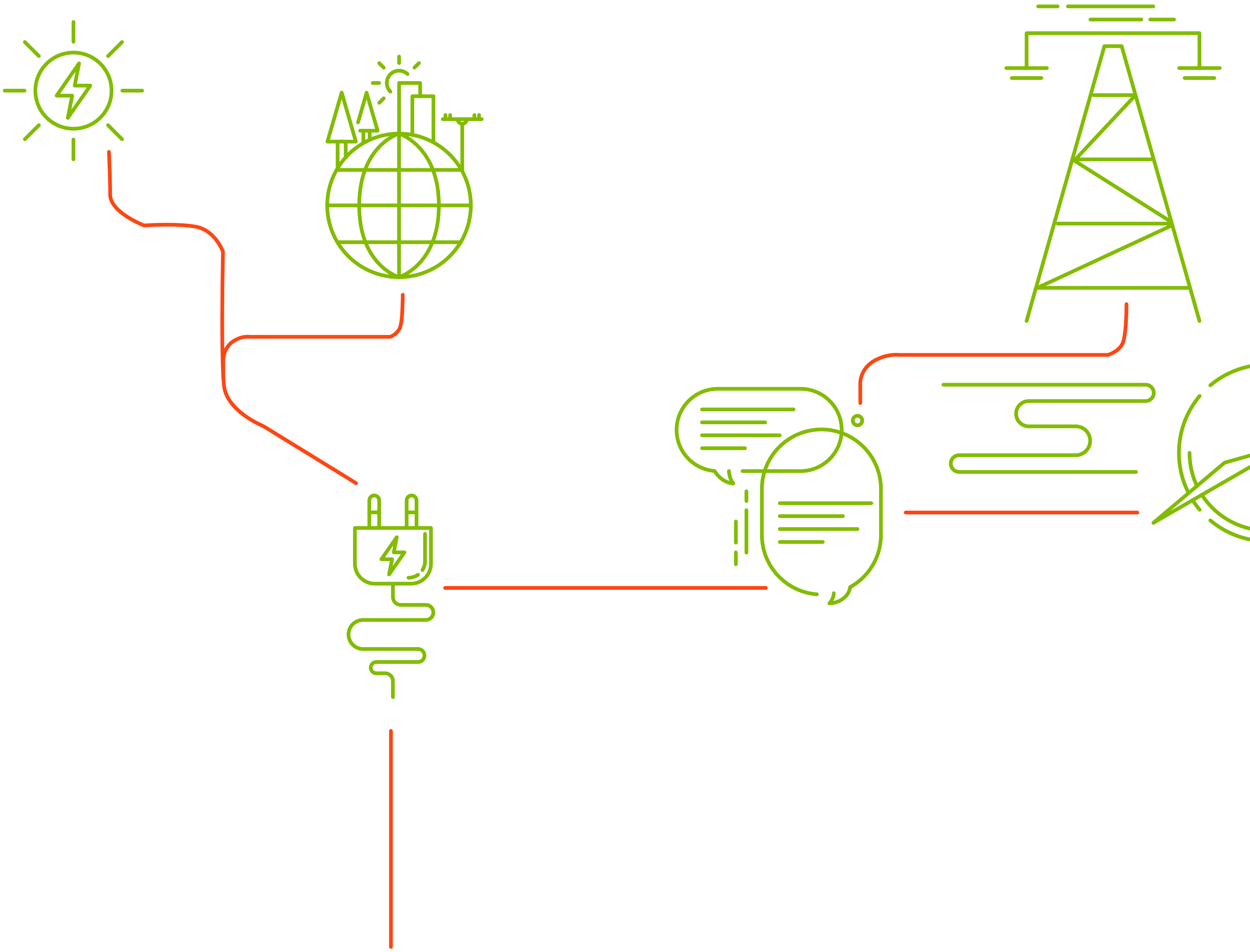
July 2018



About This Road Map Effort

This Road Map to Decarbonization in the Midcontinent: Electricity Sector, and the modeling analysis that informs it, are the work products of the Midcontinent Power Sector Collaborative (MPSC), convened and staffed by the Great Plains Institute. MPSC participants have a diversity of viewpoints and priorities on the most optimal pathways for achieving substantial and cost-effective decarbonization of the electric sector. The road map seeks to identify a range of potential futures and options for policymakers to consider on the road to a lower carbon future. The modeling that informs this initial electricity sector road map is focused on supply-side options in the Midcontinent region. The effect of deeper energy efficiency and deployment of a variety of distributed energy resources will be explored in the next phases of the effort and this road map should be read with this in mind. This road map does not recommend a specific policy or set of policies, nor a specific technology or mix of technologies and nothing in the road map authorizes any participant to speak on behalf of other participants. Ultimately, the goal of the MPSC is to inform better public policy.

Contents

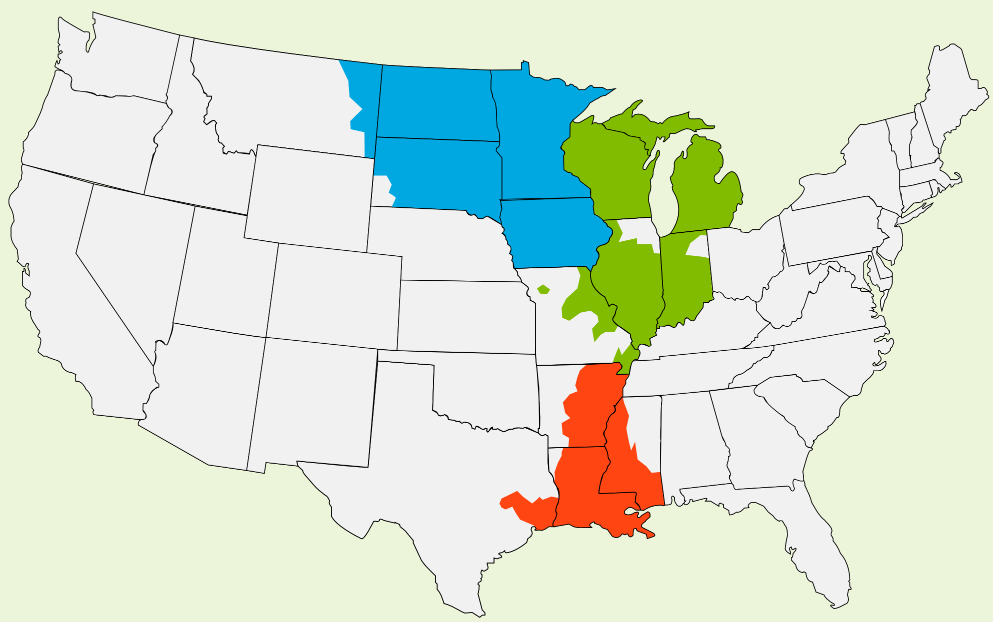
Midcontinent Power Sector Collaborative

The Midcontinent Power Sector Collaborative brings together a diverse set of stakeholders from across the Midcontinent region to develop a road map to decarbonization by mid-century.[1] The goal of the road map is to provide policy makers and stakeholders with a better sense of what may be needed to achieve deep carbon reductions in the region so as to inform better near-term decisions and position the region to meet the challenges ahead.

Because the electricity sector is expected to play the central role in the long-term decarbonization of the region, the Collaborative's initial focus is this electricity sector road map. The road map contemplates numerous possible pathways to reach substantial decarbonization in the electricity sector, which we define for purposes of this road map as reductions of 80 to 95 percent below 2005 levels by 2050.[2]

A substantially decarbonized electricity sector is expected to grow to enable the decarbonization of other sectors through efficiency and electrification. In the transportation and buildings sectors, the road map will examine deep efficiency and electrification. Working closely with additional stakeholders from other sectors, the Collaborative will next tackle the electrification of an efficient transportation sector, followed by buildings.

FIGURE 1: The Midcontinent Region



1 Participants in the Collaborative are listed at the front of this road map document, and include investor-owned utilities, cooperatives, merchant power producers, public power, environmental groups, and observing state officials. The Collaborative is facilitated and staffed by the Great Plains Institute. The Midcontinent region is defined as the area served by the Midcontinent Independent System Operator, which covers all or parts of the following states: Arkansas, Illinois, Indiana, Iowa, Kentucky, Louisiana, Michigan, Minnesota, Mississippi, Missouri, Montana, North Dakota, South Dakota, Texas, and Wisconsin. The region is shown in Figure 1.

2 For purposes of the road map, the Collaborative explored several different decarbonization goals in the range of 80 to 95 percent by 2050. References to "substantial decarbonization" throughout this road map report should be interpreted with this range in mind.

Introduction

PARTICIPANTS IN THE COLLABORATIVE BELIEVE it is likely the electricity sector will substantially decarbonize by mid-century. Utilities are increasingly factoring into their resource planning decisions the risk that substantial decarbonization will ultimately be required of the sector. Some utility investors are calling for sustainability planning and disclosures of climate risks and opportunities. At the same time, public health and clean energy policies, along with market forces and technological change, have led many utilities to invest in energy efficiency, renewables and new natural gas, and retire older higher-carbon resources. In light of these external drivers, many utilities have adopted voluntary long-term carbon reduction goals to guide their actions in this area.

> "The electricity sector is expected to play a central role in the long-term decarbonization of the region.

Because new investments in energy infrastructure can last for decades, choices made today will affect the sector's medium- and long-term pathways. The Collaborative has undertaken rigorous analysis of possible future pathways to better understand the near-term options given the long-term carbon risk and other factors driving decarbonization.

This electricity Road Map is set out in five parts:

1. The market, policy and technology contexts are described.
2. A snapshot of the region's electricity sector is presented.
3. Numerous possible pathways to substantial decarbonization are explored with reference to the modeling analysis.
4. The Collaborative's key findings and questions are outlined.
5. The Collaborative recommends consensus principles for policies aimed at decarbonizing the region's electricity sector.

Background

BEFORE EXPLORING PATHWAYS ON THE ROAD map to substantial decarbonization, the market, policy, and technological contexts are examined below along with a current snapshot of the sector's generation mix, fleet makeup and emissions profile. The context sections are not meant to be exhaustive treatments of each issue. Rather, each brief section is meant to orient the reader to the subsequent discussion of the various pathways to substantial decarbonization.

The Market Context

The electricity sector is undergoing significant change due to several market factors. Natural gas prices have been at historic lows and are expected to remain low. The costs of new solar and wind capacity have also continued to decline. Consumers—including many large business and government customers—are requesting low- or zero-carbon electricity. Investors are increasingly seeing financial and regulatory risk in burning fossil fuels without carbon capture,[3] and opportunities in a shift toward low- and zero-carbon resources. At the same time, aging infrastructure in the sector must be replaced. Lastly, decarbonization through increased electrification in other

3 Throughout this report the terms "carbon capture" are used to mean carbon capture and storage, or carbon capture and utilization that results in the equivalent of storage.

sectors is expected to increase demand from low- and zero-carbon electricity over time.

Key aspects of the market context include:

- **Natural gas prices.** The supply of natural gas has dramatically increased because of an increase in shale gas production, and the new supply has put downward pressure on natural gas prices. Most projections expect natural gas prices to stay low through mid-century.[4] Over the fifteen years ending in 2016, 228 gigawatts of natural gas capacity have been added nationally, and the federal government projects that natural gas will remain the primary fossil fuel used in electricity generation into the future.[5]
- **Renewable energy costs.** The cost of adding wind and solar capacity has decreased in recent years and is expected to continue to decrease.[6] To the extent renewable energy is cost-competitive with or is lower cost than conventional generation, the market will continue to drive renewables penetration and zero-carbon electricity generation.
- **Consumer and stakeholder demands for energy efficiency and renewable energy.** As utilities plan their systems into the future, stakeholders have supported investments in energy efficiency and renewable energy. Many large consumers have also requested access to the zero-carbon electricity to help meet their corporate sustainability goals and lock in stable electricity prices over time.
- **Investor demands.** Certain utility investors have been actively engaged in encouraging a move toward investment that responsibly incorporates carbon risk and moves toward decarbonization. Many utilities have responded to that encouragement in their planning and environmental disclosures.
- **Aging Infrastructure.** Part of the current fleet of power generators is growing old, raising concerns about plant retirements that may need to be replaced. In considering decarbonization pathways, the possible retirements of aging power plants may have implications for the challenges facing the sector.
- **Changing electricity demand because of electrification.** Market changes in other sectors will also affect the future of the electricity sector. Advances in electric vehicles have yielded mass-market options that are more appealing to customers. Shared and/or autonomous vehicles also raise the potential for rapid adoption of electric vehicles across fleets, particularly in urban areas. Technological innovation of this sort will add demand for electricity.

4 The US Energy Information Administration (EIA) "Annual Energy Outlook 2018" ("AEO 2018") projects that natural gas prices will remain low through mid-century. Available at: https://www.eia.gov/outlooks/aeo/

5 AEO 2018, US EIA, 2018.

6 According to Lazard's Levelized Cost of Energy Analysis, Version 11.0 (2017), new wind generation has the lowest levelized cost of energy (between $30 and $60 per megawatt hour), compared to the next lowest cost generation, which is a natural gas combined cycle power plant (between $42 and $78 per megawatt hour). Available at https://www.lazard.com/perspective/levelized-cost-of-energy-2017/.

> Participants in the Collaborative consider it reasonably likely that substantial decarbonization will ultimately be required.

- **Changing electricity demand because of energy efficiency.** Electricity demand has largely flattened in recent years, partly driven by more efficient energy consumption. At the same time that electric use has become more efficient, the U.S. economy has continued to grow. Energy efficiency will continue to be a critical contributor to decarbonizing multiple economic sectors.

These market factors have implications for the sector's policy, technological and emissions futures.

The Policy Context

At present, no mandatory policy exists that would require the region's electricity sector to substantially decarbonize by mid-century. While a number of legislative and regulatory efforts have sought to put the sector on such a mandatory track, including the U.S. Environmental Protection Agency's Clean Power Plan, none of those efforts have reached final implementation.[7] Despite this regulatory uncertainty, participants in the Collaborative consider it reasonably likely that substantial decarbonization will ultimately be required of the sector. Current state-level resource planning and federal and state policies are playing a role.

- **State-level Resource Planning.** The state-level resource planning process provides an opportunity for state commissions to influence the choices utilities make and consider the long-term consequences of resource planning and acquisition decisions in light of long-term decarbonization. The Midcontinent region consists of states with traditional economic regulation of vertically integrated utilities, with the exception of Illinois. Vertically integrated utilities will plan to meet the expected demand on their system with a combination of existing and new generation resources and energy efficiency, aiming to prudently serve their customers into the future. In this context, utilities and the utility commissions that regulate them plan while taking the market, technological and policy contexts into account. In a market environment where natural gas prices are low and projected to remain low, for example, we see some utilities investing in natural gas generating facilities. Similarly, as the costs of renewable energy like wind and solar have continued to decrease, helped along by federal tax incentives, utilities are building renewables in most areas. Many utilities have retired aging coal plants when prudent planning and the economics of natural gas and renewables make it rational to do so.

- **Federal and State Tax Incentives.** Federal and state tax incentives have also been influential in encouraging deployment of specific types of electricity resources. The federal production tax credit and investment tax credit have spurred the penetration of wind and solar generation and are currently designed to phase out for the most part by 2020 and 2024, respectively.[8] In early 2018, Congress enacted the FUTURE Act, which reformed and extended the tax credits available for carbon capture and storage.[9] This expanded tax credit is intended to spur new carbon capture projects on power plants, among other facilities, and could change the longer-term technological context for decarbonization in the country.

- **State level energy policies and standards.** Energy policies at the state level have also been influential in driving a changing electricity sector. Some states have implemented renewable portfolio standards, energy efficiency resource standards, and other clean energy standards designed to encourage utilities to reduce electricity demand and supply an increasing amount of zero-carbon energy from renewable and in some cases nuclear sources. Numerous states have implemented state-level tax credits and other regulatory policies, such as net-metering, to encourage renewable energy deployment.

7 We note that the ultimate fate of the Clean Power Plan is not settled. Promulgated in final by the U.S. Environmental Protection Agency (EPA) in 2015, the rule was stayed by the U.S. Supreme Court and is the subject of a proposal to repeal and possibly replace the rule by the current U.S. EPA. It is likely that the federal courts will decide whether the Clean Power Plan, or some replacement, will take effect covering the sector.

8 The production tax credits (PTC) and investment tax credits (ITC) have been extended numerous times by Congress, and the analysis completed for this road map suggests that there may be reason to extend the credits once again. As discussed below, without the PTC/ITC, wind penetration slows dramatically. The business investment tax credit does not phase out and remains at 10 percent.

9 In modeling the potential penetration of carbon capture, the model included the economic effects of the federal tax credits and the use of carbon dioxide for enhanced oil recovery (EOR). The emissions reductions calculated for CCS were credited to the power sector and did not account for the emissions from oil extraction using EOR. Emissions results should be read with this in mind.

The Technological Context

While the cost of deploying renewable sources of electricity generation has continued to decrease, the variable nature of wind and solar means there are times when dispatchable resources must be available on the grid to provide "back up" to wind or solar. The current system easily handles this backup function. If the system reached very high levels of renewable penetration, some analysts have suggested it will require lower-cost storage, dispatchable zero-carbon resources or more flexible demand to achieve substantial decarbonization at a lower cost. Balancing variable resources is just one reason technological advances will be helpful, though the analysis suggests that the region can still achieve substantial decarbonization of the electric sector by 2050 with existing technologies under a variety of pathways.

The technological status of energy storage, carbon capture, and flexible demand are discussed briefly below to provide a qualitative context for their inclusion in the pathways explored.

- **Energy storage.** Electricity storage allows renewable electricity to be dispatched when variable renewables are not producing energy. In addition to allowing for greater penetration of renewables, lower cost energy storage would provide other system benefits, such as frequency regulation and response. Storage solutions to address long-duration energy imbalances (days to weeks) may be costly and/or operate at very low utilization levels, creating additional challenges to the economics of these investments.

- **Carbon capture.** Currently, almost all existing fossil fuel generators do not control carbon emissions the way they control emissions of other pollutants. At the same time, these generators are dispatchable. As the electricity sector moves toward deeper levels of decarbonization, carbon capture technologies offer the potential to keep in operation existing fossil generators that otherwise would need to be retired, or build new fossil with carbon capture. Effective carbon capture could complement deeper penetration of renewables in a future with substantial decarbonization.

- **Flexible demand and distributed energy resources.**[10] Wide adoption of smart appliances, such as hot water heaters and air conditioners, smart-charging electric vehicles, demand response programs, and other demand-side technologies, could put utilities in the position of being able to "turn off" chunks of electricity demand when low- or zero-carbon resources are not available to serve the demand. This "flexible demand" could help with the integration of higher levels of variable renewable resources and could make substantial decarbonization less costly. Distributed energy resources, such as rooftop solar, can also play an important role. Electrification provides a unique opportunity for increased adoption of flexible and distributed technologies.

It will also be important to continue technological advances in technologies that are already being deployed more broadly. Improvements in wind technologies are expected to increase wind's capacity factors, and natural gas plants are expected to become more efficient. At the same time, advances in technologies to make end-users more efficient are expected to continue. Advanced nuclear may also play a role in the future.

10 The modeling analysis conducted for this electricity road map did not include in-depth exploration of flexible demand and other distributed energy resources. The transportation electrification and buildings road maps will explore these measures, including their impact on the electricity sector.

Spotlight on Great River Energy: Decarbonization through DryFining and Renewable Energy Goals

A WHOLESALE POWER PROVIDER for 28 member-owner cooperatives that serve approximately 695,000 member-consumers in Minnesota and parts of Wisconsin, Great River Energy (GRE) has worked toward lowering its emissions over the last decade through innovative initiatives and is transitioning its resource portfolio toward a lower-carbon future. These measures have resulted in a 35 percent reduction in the cooperative's carbon dioxide emissions since 2005.

GRE points to two innovative efforts it says have helped it achieve this reduction:

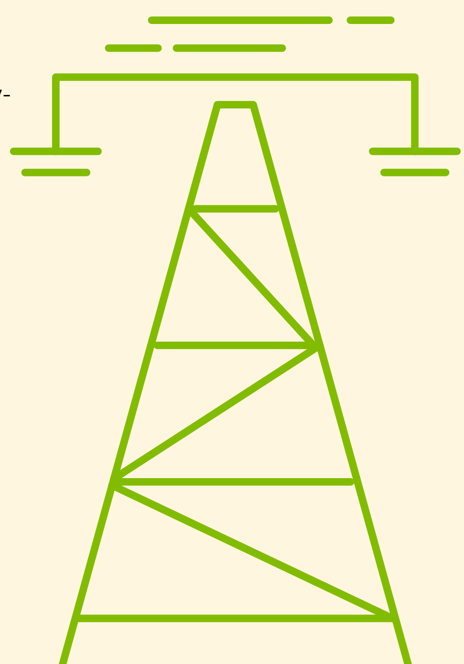
1. **DryFining™ fuel enhancement process.** Great River Energy used to receive power from five coal-based resources. That number is down to two, both of which are fueled by DryFine lignite coal, which has lower emissions due to a patented drying and refining process. Through this process, fuel moisture is reduced from 38 percent to 28 percent; plant efficiency is increased overall by approximately 4 percent; sulfur dioxide, mercury, nitrogen oxide and carbon emissions are reduced; and more than $20 million is saved in annual operations and maintenance.

2. **Ambitious renewable energy goals.** Great River Energy met Minnesota's 25 percent renewable energy standard in 2017 – eight years ahead of the requirement. In June 2018, Great River Energy committed to providing its membership with energy that is 50 percent from renewable resources by 2030. The announcement also established interim renewable energy goals of 30 percent by 2020 and 40 percent by 2025. These goals come at a time when home- and business-owners are increasingly interested in incorporating more renewables in their energy supplies, and when wind energy is currently the lowest-cost option for new generation resources.

In order to accommodate ever-increasing amounts of wind in the Midwest, Great River Energy has found ways for its other generation sources to be more flexible. Its largest plant, Coal Creek Station, has adapted to market forces through operational and engineering modifications for this particular reason. The plant is now able to significantly adjust its output response to market signals – a rare and increasingly valuable trait for a large plant.

Great River Energy's renewable portfolio currently includes 468 megawatts (MW) of wind energy, 200 MW of hydropower, 4 MW of solar and 30 MW of biomass. The cooperative has also announced plans for an additional 300 MW of favorably-priced wind energy by 2020.

> "Great River Energy met Minnesota's 25 percent renewable energy standard in 2017 — eight years ahead of the requirement.



Snapshot of the Region's Electricity Sector

Current Generation Mix, Fleet Makeup and Emissions Profile

THE ELECTRICITY SECTOR IS IN A PERIOD OF significant change. Low natural gas prices, decreasing renewables costs, and flattening electricity demand are leading to changes in the way the region generates its power. This, in turn, has led to changes in the emissions from the region's electricity sector. Figures 2 through 5 depict recent trends in generation, capacity and emissions in the Midcontinent region.

> The Region is moving toward lower- and zero-carbon electricity.

FIGURE 2: The Region is Shifting Toward Gas and Renewables (Generation Mix, TWh)

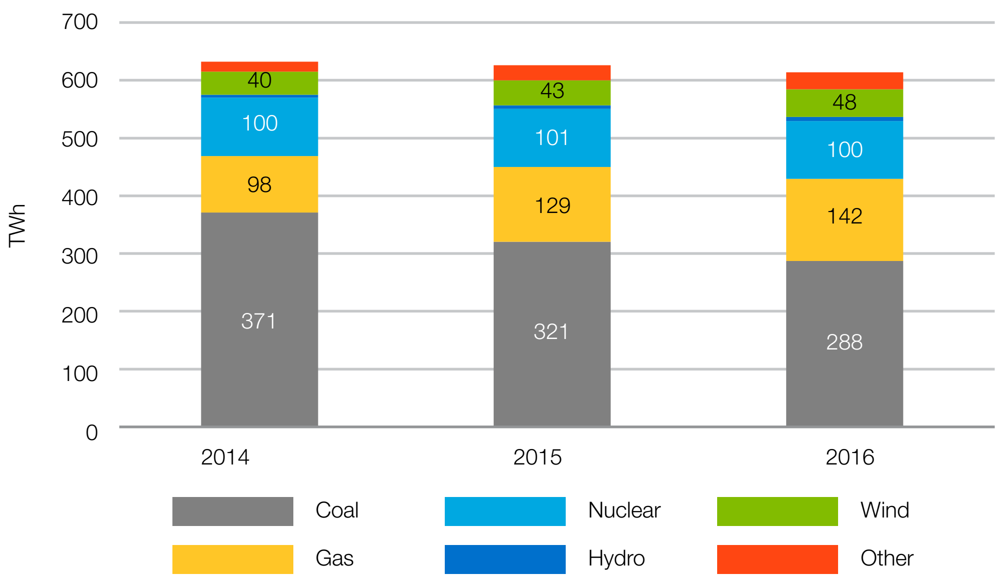


FIGURE 3: Fleet Makeup 2016

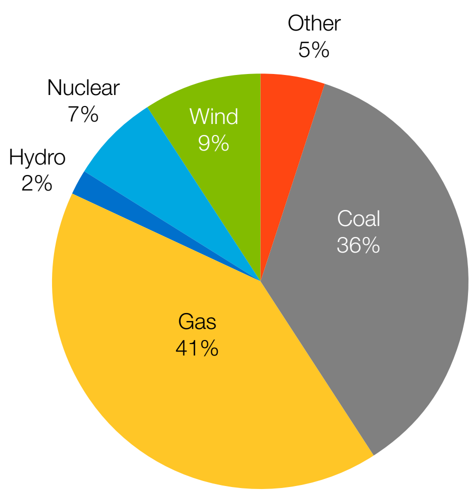


FIGURE 4: MISO Generation 2016

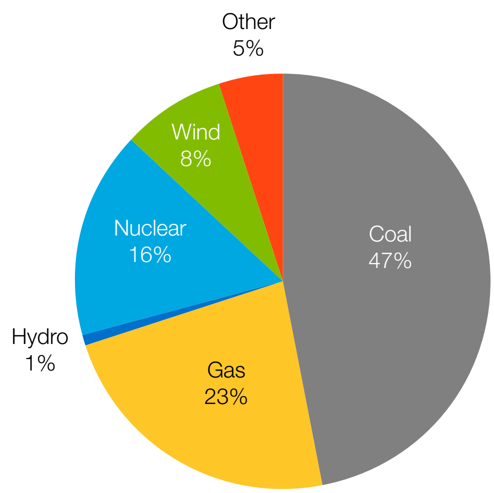
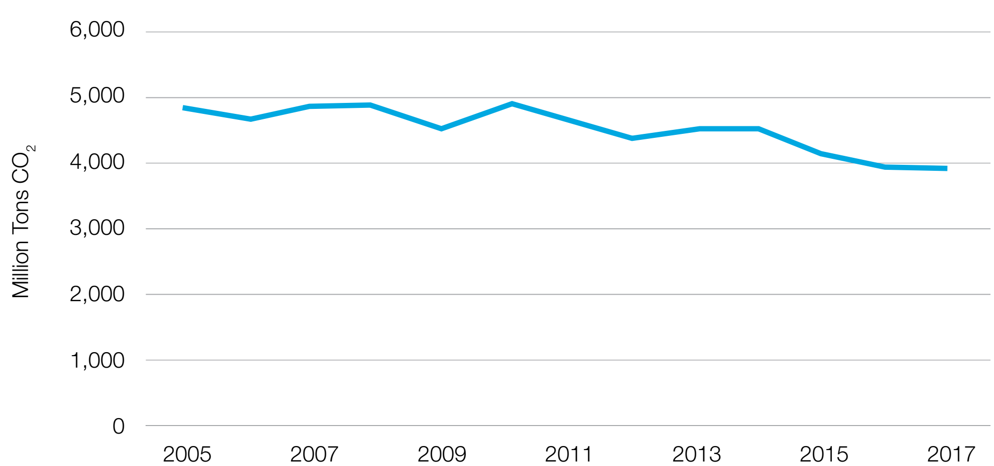


FIGURE 5: The Region's Carbon Emissions Have Declined (2005-2017)



Spotlight

Spotlight on DTE Energy:
Energy Carbon Reduction Initiative

IN MAY 2017, DTE Energy announced a $15 billion broad sustainability initiative to reduce carbon emissions. This plan, among the most aggressive to be announced in the energy industry, includes a 25% reduction in carbon emissions in 2017 from 2005 levels, with plans to cut emissions by 45% by 2030 and by more than 80% by 2050.

The announced plan arose after years of studies by DTE Energy that demonstrated an 80% reduction in emissions was not only achievable by 2050 – a timeframe scientists have broadly identified as necessary to help address climate change – but it was also achievable in a way that keeps Michigan's power affordable and reliable. "There doesn't have to be a choice between the health of the economy and the health of the environment, both can be achieved if climate change is addressed in a smart way," said DTE Chairman and CEO Gerry Anderson.

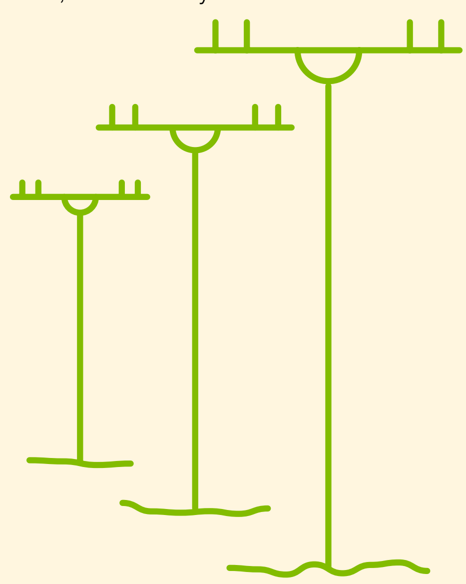
The carbon reduction initiative strategy outlines:

- Construction of an additional 4,000 Megawatts (MW) of zero-emission renewable energy capacity;
- Addition of 3,500 MW of highly efficient natural gas-fired energy capacity;
- Steady retirement of DTE Energy's aging coal-fired plants with the shutdown of three coal plants by the early 2020s and all coal plants by 2040;
- Investment of $5 billion over 5 years to modernize the electric grid and gas infrastructure;
- Engaging customers through cost-effective energy efficiency programs;
- And reducing energy use and water consumption by 25% at DTE facilities.

These plans define a long-term shift by DTE to produce over three-quarters of its power from renewable energy and highly efficient natural gas-fired power plants and about half of its production capacity from zero-emissions resources.

"The transformation of the way we produce power is in full swing," said Anderson. "Like all big transformations, this one won't happen overnight. It needs to be planned carefully and will entail big investments, but that can absolutely be done. We are committed to accomplishing this within the timeframe scientists have laid out, and in a way that works for Michigan's economy, homeowners and businesses."

> "There doesn't have to be a choice between health of the economy and the health of the environment, both can be achieved if climage change is addressed in a smart way," says DTE Energy CEO.

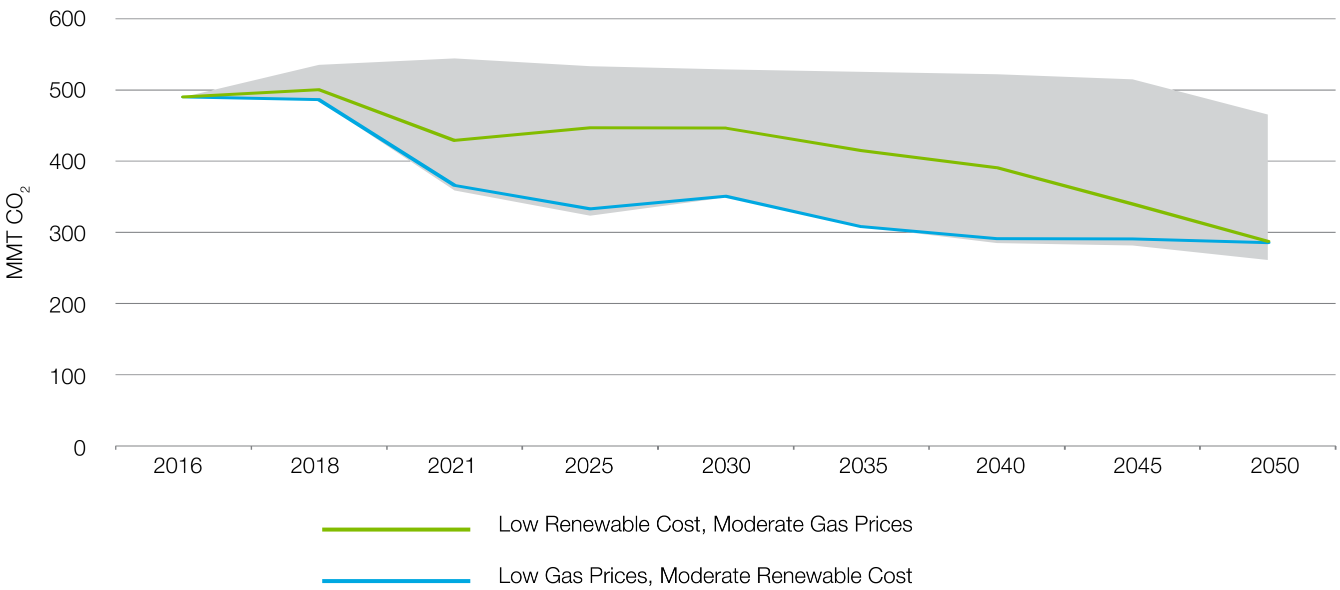


Looking Forward: Business as Usual

DESPITE THE RECENT DOWNWARD TRENDS IN emissions in the electricity sector, the precise future trajectory of emissions in the sector will depend on some key factors and how those factors evolve over time. The Collaborative undertook a modeling analysis aimed at understanding the range of possible emissions futures in the Midcontinent region.[11] While a large number of business-as-usual scenarios were run—yielding projected futures with emissions trajectories spread out in the grey area on Figure 6—the primary focus here is on the two scenarios the Collaborative determined provide the most plausible bounded range. The scenario depicted by the blue line on Figure 6 assumes low gas prices into the future and

11 In the modeling analysis, the Collaborative was able to examine the effects of a large range of electricity sector factors, including natural gas prices, renewables costs, nuclear license extensions, grid expansion, lower storage costs, and a number of other variables. Scenarios analyzing no nuclear license extensions beyond 60 years were compared to scenarios allowing a twenty-year extension and the results were very similar in the region. In this print edition of the road map, we choose to present the results from the modeling scenarios the Collaborative group determined most closely reflect the expected futures. Access to the broader set of modeling results, including the full set of modeling assumptions, is available on the Great Plains Institute website. See roadmap.betterenergy.org.

FIGURE 6: Business as Usual Scenarios: Emission Lower, But Not Low Enough (MMT CO_2)



moderate renewables costs.[12] The line in green assumes low renewables costs and moderate gas prices.[13]

Here are the key findings from the business as usual scenarios, which do not apply any additional carbon constraint beyond current policies or reflect utility carbon reduction targets:

12 The blue line reflects the following assumptions: low natural gas prices, mid-case renewables costs, mid-case oil prices, nuclear license extensions allowed, grid expansion is allowed, and mid-case storage costs. Fuel costs are taken from the Annual Energy Outlook 2017 and renewables and storage costs from NREL 2016. Access to the broader set of modeling results, including the full set of modeling assumptions, is available on the Great Plains Institute website. See roadmap.betterenergy.org

13 The green line reflects the same assumptions as the green line, except natural gas prices are assumed to be the base-case or moderate natural gas prices taken from the AEO 2017 Reference Case and NREL's low renewables cost.

- **Emissions.** As shown on Figure 6, none of the modeled futures—across a wide range of assumptions—results in substantial decarbonization of the electricity sector by 2050 under business as usual conditions. This suggests new policies and utility carbon reduction efforts are needed. Indeed, emissions in the low gas price scenario drop significantly by 2030—by about 29 percent from 2016 levels—and then level off through 2050. Emissions in the low renewables cost scenario drop less significantly—about 9 percent—and then slowly and modestly decrease through 2050.

- **Natural gas.** Low natural gas prices bring a natural gas-dominant future, with natural gas crowding out most other technologies. Moderate natural gas prices and low renewables costs yield a more mixed-technology future.

Modeling Caveat

This road map analysis relies on sophisticated energy-economic modeling performed by Sustainable Energy Economics and KanORS-EMR using the FACETS modeling platform to project what the region's electricity sector might look like under various future conditions. Modeling projections are not predictions of the future, but rather provide a sense of what may happen in the future given a set of assumptions. The assumptions we make today do not take into account technology step changes or other unforeseeable conditions that may occur in the future that will change what the future holds for the region's electricity sector. In this report we note the assumptions that are most important to the outcome of the modeling analysis. More information about the model can be found at: www.facets-model.com.

- **Coal.** Natural gas generation increases at the expense of coal generation.[14] When gas prices stay low and renewables costs are moderate, natural gas generation outcompetes coal, leading to coal retirements. When gas prices are moderate, coal still declines but less dramatically.
- **Nuclear.** Nuclear plants in the region retire in the model for economic reasons because low natural gas prices make it hard for nuclear to compete. Much of the region's nuclear is projected to retire even with moderate natural gas prices.[15]
- **Carbon capture**. The model projects carbon capture retrofits for coal of between 8 and 14 GW of retrofitted capacity. Utilization of the retrofitted plants decreases steadily after federal tax credits expire.[16]
- **Renewables.** The model projects very little utility-scale solar in the region if gas prices remain low. When gas prices are moderate and renewables costs are low, solar capacity increases significantly more. Natural gas combustion turbines are built to support the solar.

Figures 7 and 8 depict the generation mix under the two key business as usual scenarios and Figures 9 and 10 show the fleet makeup.

> "None of the modeled futures — across a wide range of assumptions — results in substantial decarbonization under Business as Usual Conditions

14 None of the scenarios modeled for this road map project new coal plants, with or without a carbon constraint.

15 This modeling does not account for utility commissions in cost of service states that may opt to continue operating nuclear plants over new natural gas plants as part of an effort to decarbonize the system or for other reasons.

16 The expanded tax credits for carbon capture were assumed to expire as specified in current law. There is a possibility those tax credits would be extended.

FIGURE 7: Gas Dominates Generation Under Low Gas Prices and Moderate RE Costs (TWh)

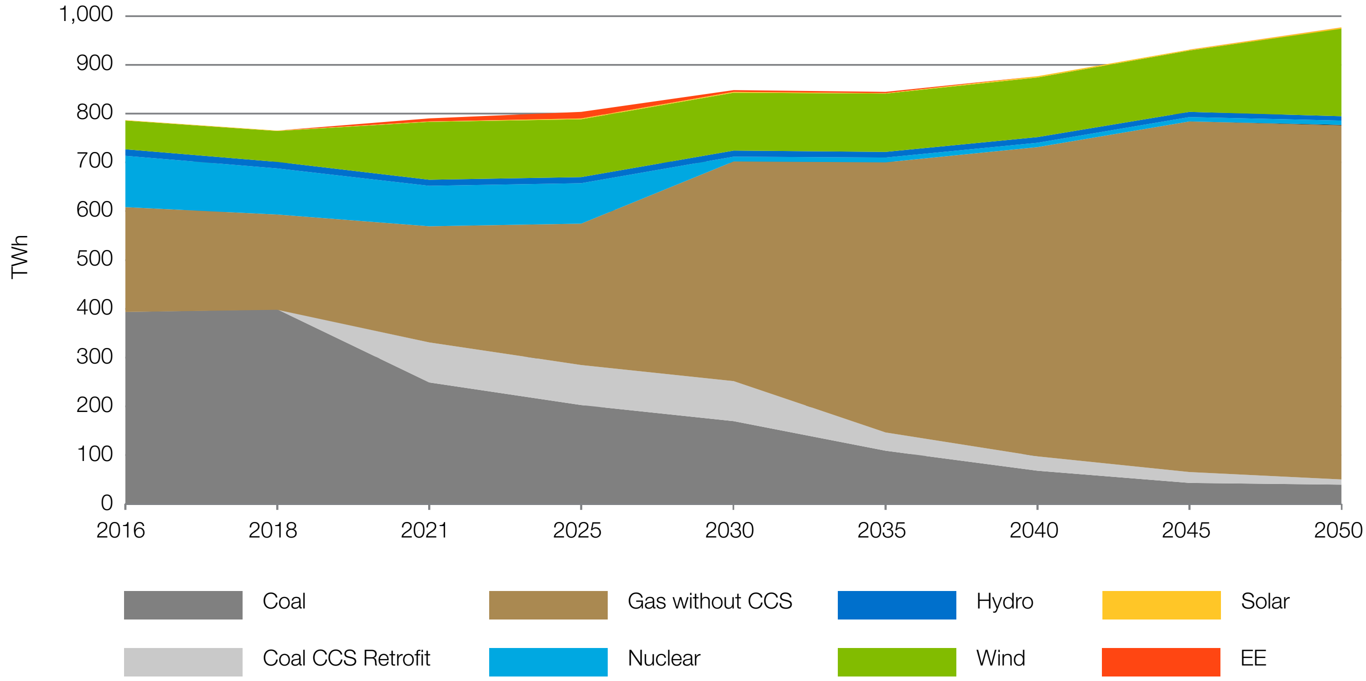


FIGURE 8: More Mixed Generation when Renewables Costs Low, Gas Prices Moderate (TWh)

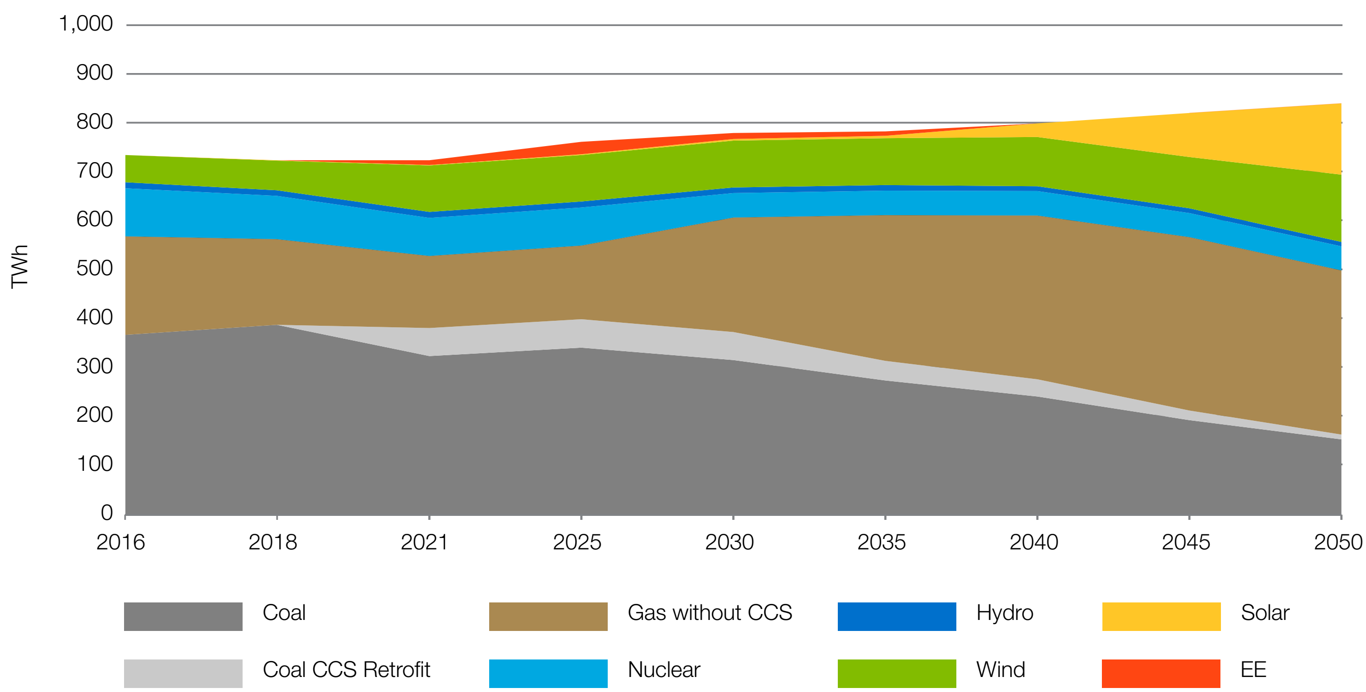


FIGURE 9: Gas Dominates Fleet Makeup with Low Gas Prices, Moderate RE Cost (GW Capacity)

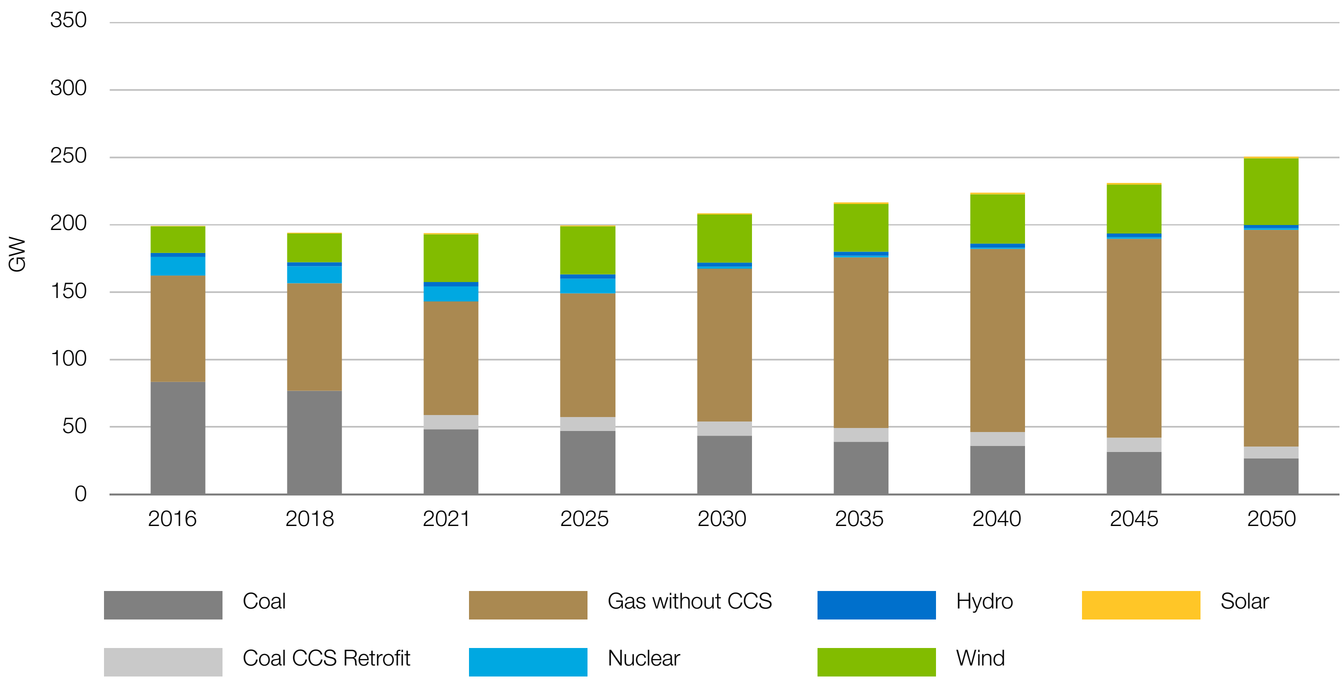
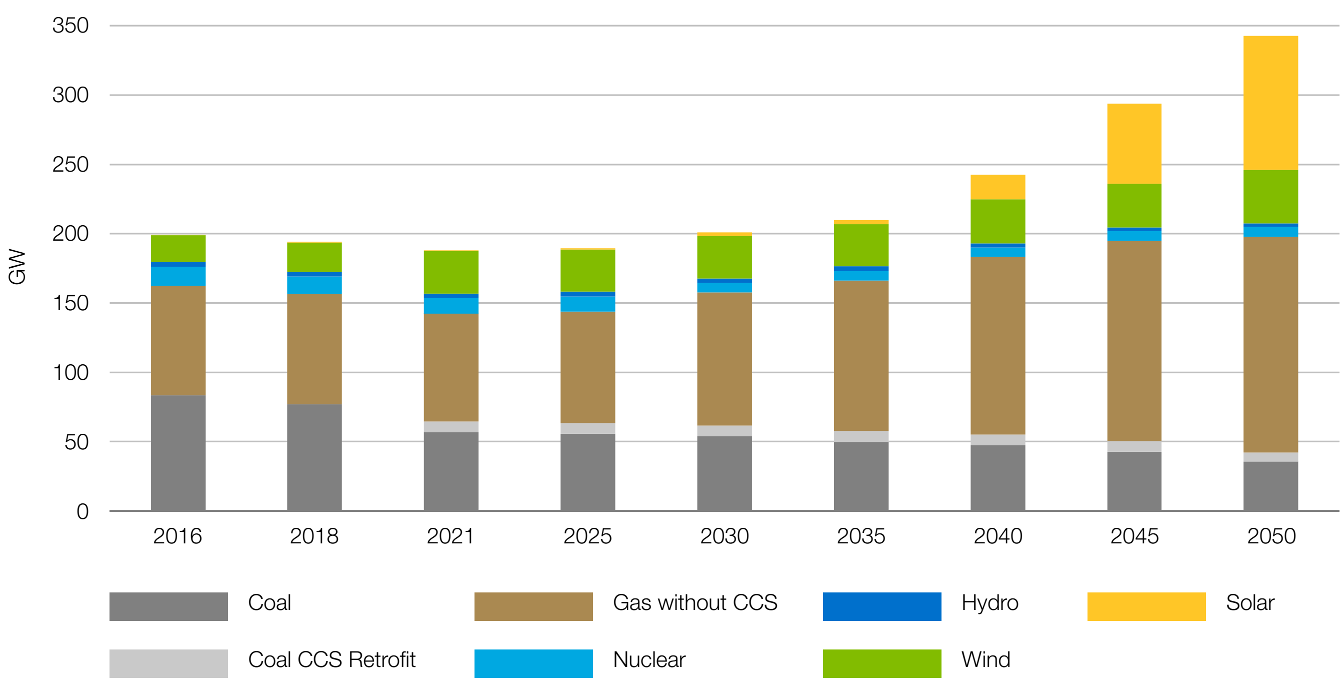


FIGURE 10: Fleet Makeup More Mixed with Low RE Costs, Moderate Gas Prices (GW Capacity)



Spotlight

Spotlight on Madison Gas and Electric: Energy 2030

MADISON GAS AND ELECTRIC (MGE) has created its Energy 2030 framework for the future of energy in its region. This initiative incorporates a greater use of renewable resources, reduces carbon emissions, increases emphasis on energy efficiency and conservation, promotes new products and services and works toward deepening community engagement. Energy 2030 was created to build a community energy company for the future that meets the community's needs while balancing and reflecting their shared values.

Within the framework, a carbon goal has been made to achieve at least a 40% reduction in carbon emissions from 2005 levels by 2030 and at least an 80% reduction in carbon emissions from 2005 levels by 2050. MGE has noted that if the company is able to reduce carbon emissions further and faster than these goals through their work with customers, they will. In conjunction with the goal of reducing emissions, Energy 2030 also includes a goal of 25% renewable energy by 2025 and 30% by 2030.

Some initiatives within 2030 to achieve these emissions reductions and increase renewables include:

- **Building the Saratoga Wind Farm.** Expected online by early 2019, the Saratoga wind farm will be MGE's largest wind farm to date. At 66 megawatts (MW), these 33 turbines are expected to produce enough energy to serve around 47,000 households.
- **Increasing Solar at MGE.** The company recently announced it is seeking regulatory approval for two major solar projects, the Badger Hollow Solar Farm and the Two Creeks solar project. The two projects, in partnership with another utility, total 300 MW and would provide 100 MW of solar energy for MGE customers. If approved, they would come online in 2020.

  In 2017, MGE launched its Shared Solar program in partnership with the City of Middleton. The program's solar array is located on Middleton's Municipal Operations Center, where 1,700 rooftop panels deliver energy to the community grid. An additional array at the Middleton Police Department is expected to provide 25% of the electricity used annually by the building.

  This voluntary program provides subscribing MGE customers with the benefits of solar power without needing to install solar on their own homes. MGE is pursuing an additional Shared Solar project and developing a waiting list of interested customers.
- **Transitioning from Coal.** MGE's trajectory toward deep decarbonization includes growing its use of renewable resources, and advancing energy efficiency and the electrification of transportation. MGE already has taken steps to transition from coal-fired resources. MGE reduced its minority ownership in the coal-fired Columbia Energy Center, a facility co-owned with two other utilities. MGE's megawatts from Columbia are reduced by 14%. The agreement allows MGE to continue its ongoing transition from coal and to forgo capital expenditures in the Columbia power plant. MGE has no controlling interest in coal-fired plants.

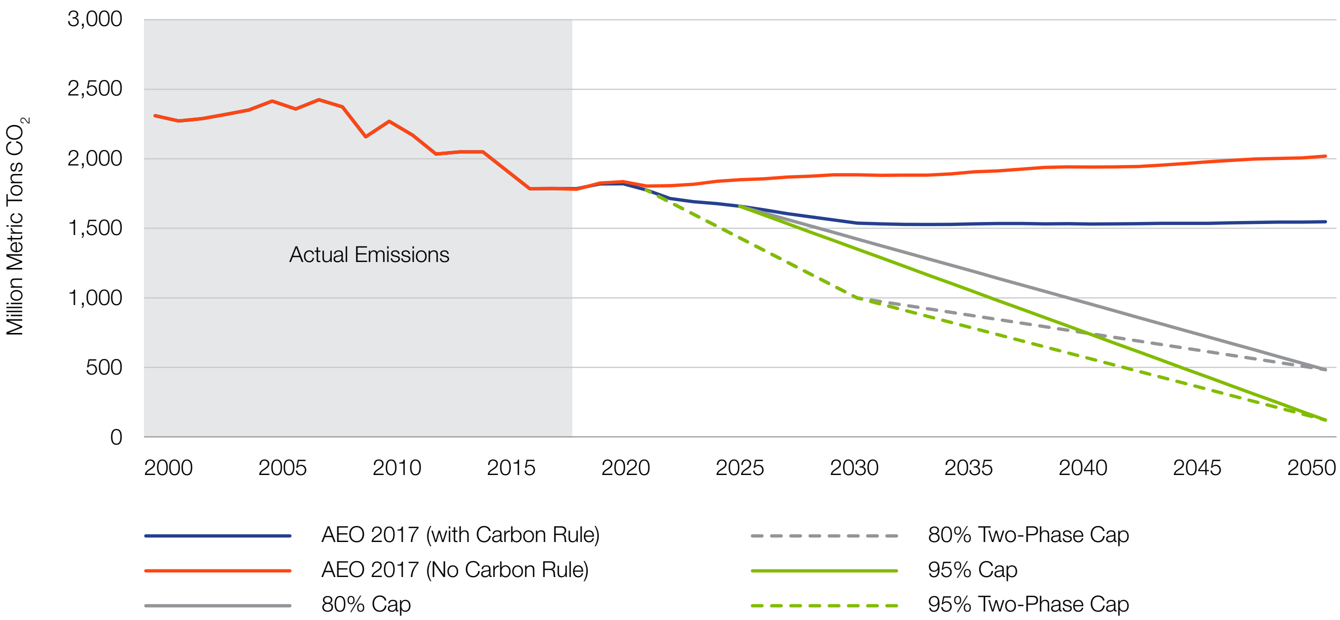
  In 2011, MGE discontinued the use of coal and switched to natural gas at another power plant, Blount Generating Station in downtown Madison, Wisconsin.

Exploring Decarbonization Pathways

TAKING INTO ACCOUNT THE MARKET, EMISSIONS, policy and technological context, as well as the limitations inherent in any exercise that aims to better understand possible futures, the Collaborative set out to understand the various pathways to substantial decarbonization by 2050 for the region.[17] The analyses were conducted by imposing carbon constraints on the electricity sector to identify the least-cost pathways projected by the model for achieving each carbon constraint.

17 The online version of this Road Map includes access to an interactive portal where readers can switch various assumptions on and off to see the effect on projected results. See roadmap.betterenergy.org. In this print version, the Collaborative presents the scenarios it found most important.

FIGURE 11: Modeled Cap Scenarios with Historical Emissions and Federal Projections



If one assumes that substantial decarbonization will be required—somewhere between 80 percent and 95 percent reduction from 2005 levels by 2050—it is reasonable to expect a different set of resource and generation mix decisions over time. The modeling analysis helps us understand how a carbon constraint would change what decisions may potentially be economic compared to the business as usual cases. For example, in the business as usual cases the region's nuclear plants are expected to retire due to competition from natural gas plants. But when one assumes that decarbonization will be required by a state or the federal government, then the analysis suggests it may make sense to keep most of those plants operating under certain circumstances. These and other key results from the modeling analysis are laid out below.

"The Collaborative modeled a range of decarbonization scenarios.

Decarbonization Levels Analyzed

To better understand the optimal makeup of the sector in the presence of a requirement to decarbonize, several cap scenarios were modeled. As shown in Figure 11, straight-line caps beginning in 2025 and taking a linear path to 80 percent and 95 percent below 2005 levels in 2050 were the primary scenarios modeled and analyzed for this road map.

After reviewing the results of these runs, it became clear that reductions in the near-term period through 2030 are very inexpensive—approaching $0 per ton because of the pre-existing trends in the sector that will lead to reductions even absent a carbon cap. To reflect the possibility of deeper reductions in the near term, a two-stage cap was analyzed that imposed a 60 percent reduction from 2005 levels by 2030, and then continued in a straight line to the 2050 targets, as shown by the dotted lines below. The effect of the two-stage caps is to impose a more stringent overall path forward because the two-stage caps require a larger cumulative reduction.

As noted above, this electricity sector analysis focused primarily on supply-side options for reaching substantial decarbonization in the electricity sector. Assumptions

about energy efficiency were simple and conservative.[18] Energy efficiency and other demand-side measures are to be explored more comprehensively in subsequent pieces of the road map focusing on the roles transportation and buildings can play in economy-wide decarbonization. These demand-side measures are expected to have important feedback effects on the electricity system.[19]

We focus primarily on the results from the straight-line scenarios below, noting where appropriate the effect of a steeper near-term decarbonization effort.

Planning for Decarbonization at 80 Percent Below 2005 Levels

If one assumes that the region's electricity system will need to reach a level of decarbonization that is 80 percent below 2005 levels by 2050, the analysis suggests that the optimal makeup of the system depends on natural gas prices and the cost of renewables. When we assume 80 percent decarbonization, the model projects:

- **Reliance on uncontrolled gas decreases.** Natural gas still outcompetes other fuels when gas prices are low. When gas prices are more moderate, natural gas is less dominant. Utilization of natural gas capacity plunges after 2040, even in the low-gas-price scenarios, raising the cost of reductions when that gas can no longer be utilized. Gas with carbon capture becomes a significant part of the mix in the latter part of the modeled time horizon, especially when gas prices are lower.
- **Wind, solar and energy efficiency increase in a carbon-constrained future.**[20] Not surprisingly, renewables are a bigger part of the mix when renewables costs are low and gas prices are moderate. Wind capacity more than doubles in an 80 percent decarbonization scenario compared to the business as usual. Wind and solar combined make up between 38 percent and 57 percent of the generation mix in 2050.
- **Shift away from coal.** A system focused on 80 percent decarbonization will somewhat amplify the shift away from coal predicted by the model in the business as usual cases.

18 The modeling analysis assumed energy efficiency costs based on the LBNL Total Cost of Saved Energy Study (https://emp.lbl.gov/sites/all/files/total-cost-of-saved-energy.pdf). Costs were equally divided between utility and participant costs and discounted the participant portion of costs by approximately 50 percent to account for line losses and differences between wholesale and retail prices. In the buildings sector phase of the modeling analysis, the Collaborative is expected to test more aggressive energy efficiency assumptions. EE potentials were derived from EPRI's State Level Electric Energy Efficiency Potential Estimates study (https://energy.gov/eere/analysis/downloads/state-level-electric-energy-efficiency-potential-estimates-0)

19 As transportation and buildings are added to the road map, the website will be updated. Revised electricity sector results will be available on the website at [insert roadmap web address].

20 The scenarios run for this road map are focused primarily on supply-side options for decarbonization and do not include all possible end-use energy efficiency measures, such as improved building codes and standards. Subsequent phases of this road map will examine demand-side measures more comprehensively in both the transportation and buildings sectors. As a result of this phased approach, energy efficiency plays a more limited role in the scenarios examined in this electricity road map.

- **Nuclear plants preserved.** Nuclear plants continue to operate in a carbon-constrained future. Most plants that would retire in the business as usual scenarios continue operating under a cap.

- **Carbon capture plays a sizeable role.** In the near-term, between 10 and 14 GW of existing coal capacity is retrofitted with carbon capture to take advantage of the federal tax credits, making up between 9 percent and 13 percent of the total energy generation in 2030. Utilization of this retrofitted capacity decreases rapidly once the tax credits expire.[21] In the 80 percent case with the two-stage cap that seeks a deeper reduction in the near term, the model projects an additional 2 GW of carbon capture retrofits, suggesting that greater stringency during the time period when the tax credit applies will yield additional carbon capture deployment. Natural gas with carbon capture becomes a significant part of the mix in the latter part of the modeled time horizon in the scenarios where gas prices are lower.

- **Cost.** The cost of carbon reductions in the near-term timeframe is between $0 and $3 per ton through 2030 because the cap trajectory is modest relative to the business as usual. Modeled carbon prices are between $6 and $12 in 2035, between $10 and $48 in the 2040s, and reach between $68 and $95 in 2050.[22]

- **Transmission.** Allowing new interregional transmission expansion aids in the buildout of wind in the moderate gas price case. Transmission buildout also lowers the cost of reductions in the cap cases by between 1 percent and 3 percent.[23]

Figures 12 through 15 depict the fleet makeup and generation mix for the runs assuming a carbon constraint that achieves 80 percent decarbonization levels by 2050.

21 The carbon capture technology assumed uses an auxiliary gas unit to produce steam at the plant, which lowers the effective capture rate to 79 percent. This, in turn, makes the technology less attractive than gas with carbon capture as the caps tighten. Improvements in the retrofit technology are unlikely to change this outcome for coal plants that will be quite old, especially if low natural gas prices point to new gas as a more economical option. The model does not project any new coal capacity in any scenario.

22 These prices are in 2016 dollars. A more aggressive, two-phase cap that seeks a deeper initial reduction yields a higher carbon price per ton of between $12 and $13 through 2030, between $14 and $40 in 2035, between $17 and $64 in the 2040s, and between $59 and $87 in 2050.

23 The model includes costs for new resource interconnection and intraregional transmission upgrades. The scenarios displayed in this report also allowed interregional grid expansion to accommodate longer distance transmission from new resources. Scenarios that turn interregional grid expansion off are available online at roadmap.betterenergy.org.

FIGURE 12: Fleet Makeup in Region to Achieve 80% Cap by 2050, Low Gas Prices, Moderate RE Costs

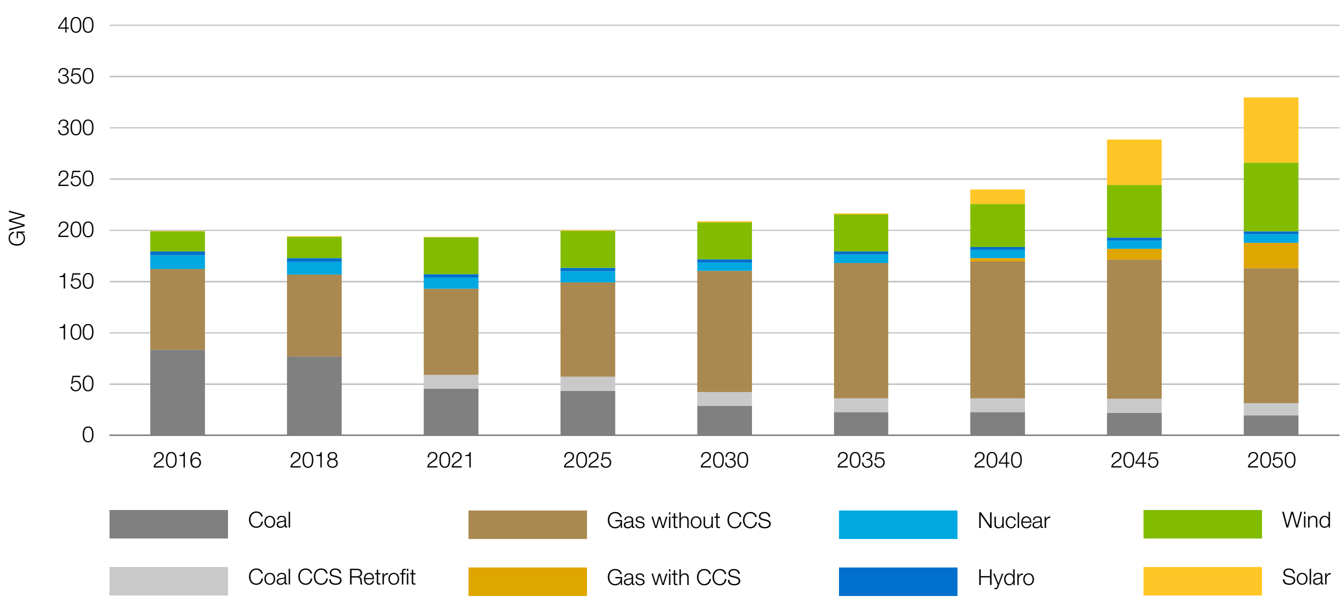


FIGURE 13: Fleet Makeup to Achieve 80% Cap by 2050, Low RE Costs, Moderate Gas Prices

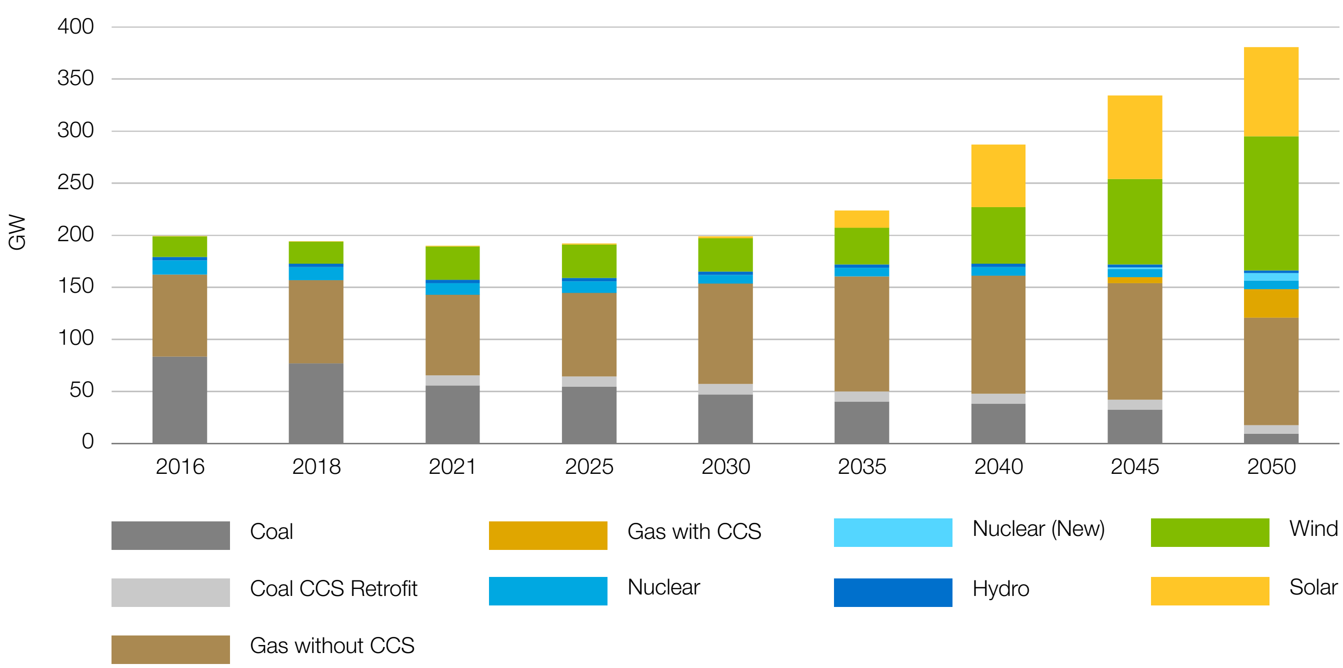


FIGURE 14: Generation Mix Under 80% Cap by 2050 (with Low Gas Prices, Moderate RE Costs)

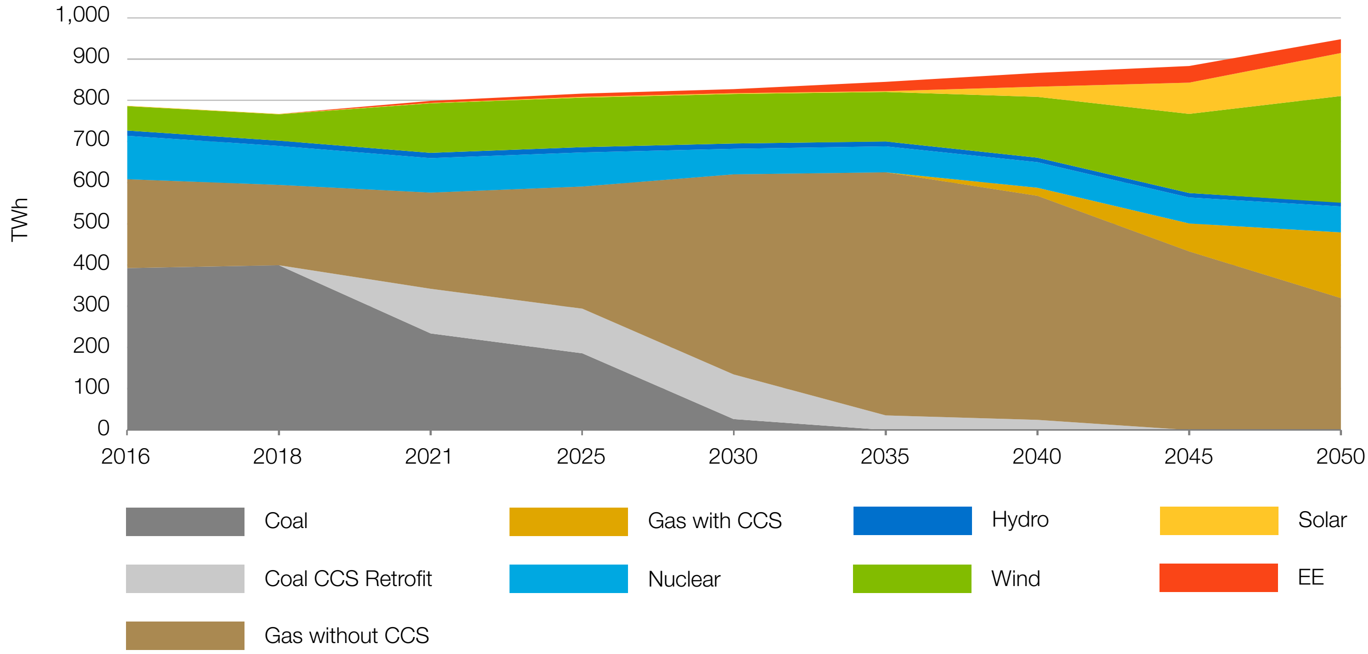
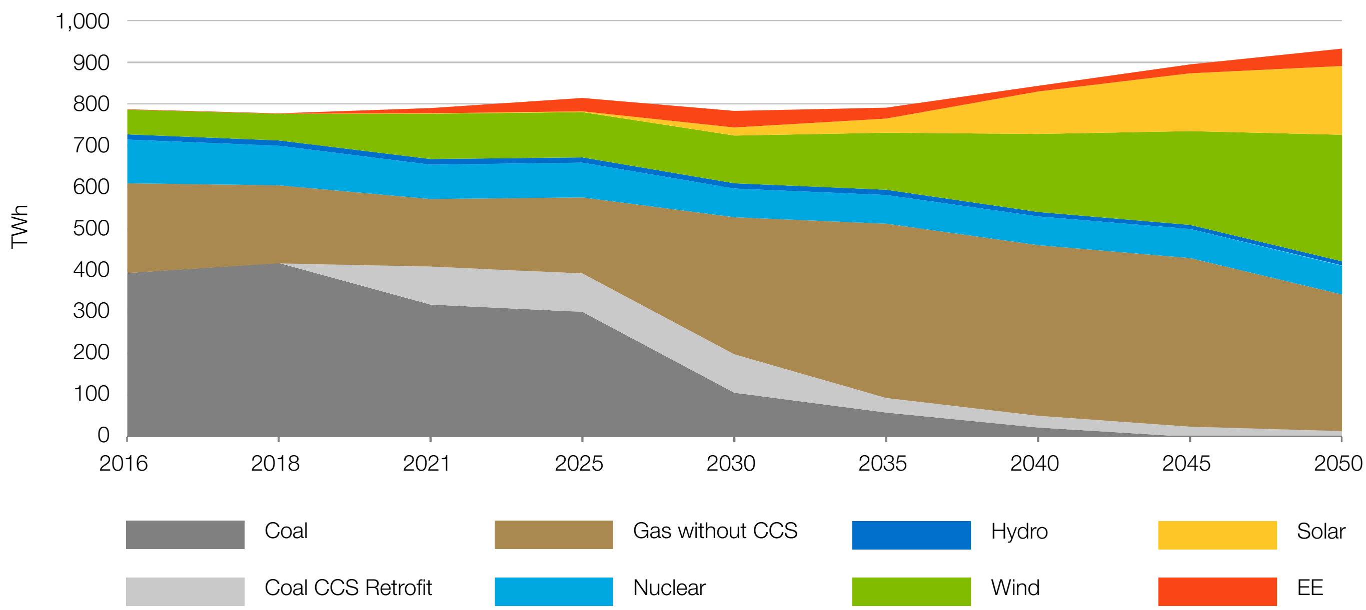


FIGURE 15: Generation Mix Under 80% Cap by 2050 (with Low RE Costs, Moderate Gas Prices)



Planning for Decarbonization at 95 Percent Below 2005 Levels

If one assumes that the region's electricity system will need to reach a deeper level of decarbonization that is 95 percent below 2005 levels by 2050, the analysis suggests that again the optimal makeup of the system depends on natural gas prices and the cost of renewables. In a more tightly carbon-constrained world, the model projects:

- **The Challenge.** Given current technological limitations and cost assumptions, reaching 95 percent decarbonization is significantly more challenging than 80 percent. In an 80 percent decarbonized future, there is more room for uncontrolled natural gas on the system. A 95 percent decarbonization level results in more renewables and natural gas with carbon capture.

- **Wind and Solar.** Wind and solar become dominant in the cases where gas prices are moderate and play a larger role than the 80 percent scenario even in a low gas price future. To reach decarbonization of 95 percent, wind capacity more than triples compared to business as usual, reaching levels in excess of 130 GW of capacity by 2050, when wind and solar combined are between 45 percent and 64 percent of the generation mix.

- **Natural Gas.** Reliance on uncontrolled gas lessens even more. To get to 95 percent decarbonization there is an even steeper drop off in natural gas utilization after 2040, again suggesting that over-reliance on natural gas may increase the cost of carbon reductions when that gas can no longer be utilized. Natural gas with carbon capture is a bigger part of the mix in later years.

- **Nuclear.** Existing nuclear plants continue operating and carbon reduction costs are lower than in the scenarios where nuclear plants are not allowed to extend their licenses. In addition, up to 2 GW of new nuclear capacity is built.

- **Carbon capture.** Carbon capture plays a greater role. In the near term, between 10 and 14 GW of existing coal capacity is retrofitted with carbon capture to take advantage of the federal tax credits, making up between 10 percent and 13 percent of the total generation mix in 2030. Utilization of this retrofitted capacity decreases rapidly once the tax credits expire.[24] Natural gas with carbon capture becomes a significant part of the mix in the latter part of the modeled time horizon in all of the 95 percent scenarios, especially when gas prices are lower.

- **Cost.** In the 95 percent runs, the cost of carbon reductions through 2030 are between \$3 and \$12 per ton, with prices increasing to between \$17 and \$51 in 2035, between \$28 and \$105 in the 2040s, and between \$150 and \$187 in 2050.[25]

- **Transmission.** Allowing new interregional transmission results in a cost savings of between 10 and 15 percent by 2050, because transmission allows access to wind resources that are needed to meet the 95 percent decarbonization level.

Figures 16 through 19 depict the fleet makeup and generation mix for the runs assuming a carbon constraint that achieves 95 percent decarbonization levels by 2050.

24 The carbon capture retrofit technology for existing coal units assumed uses an auxiliary gas unit to produce steam at the plant, which lowers the effective capture rate to 79 percent. This, in turn, makes the technology less attractive than gas with carbon capture as the caps tighten. Improvements in the retrofit technology are unlikely to change this outcome for coal plants that will be quite old. The model does not project any new coal capacity in any scenario.

25 These costs are based on our assumptions today about what costs will be many decades from now, including the anticipated declining costs of many technologies (e.g., natural gas and renewable generating technologies). These assumptions do not take into account unforeseeable step changes in technologies that may occur between now and then. Directionally, however, one can say that decarbonization at a level of 95 percent is likely to be more expensive than 80 percent given what we know now.

FIGURE 16: **Fleet Makeup in Region to Achieve 95% Cap by 2050 (Low Gas Prices, Moderate RE Costs)**

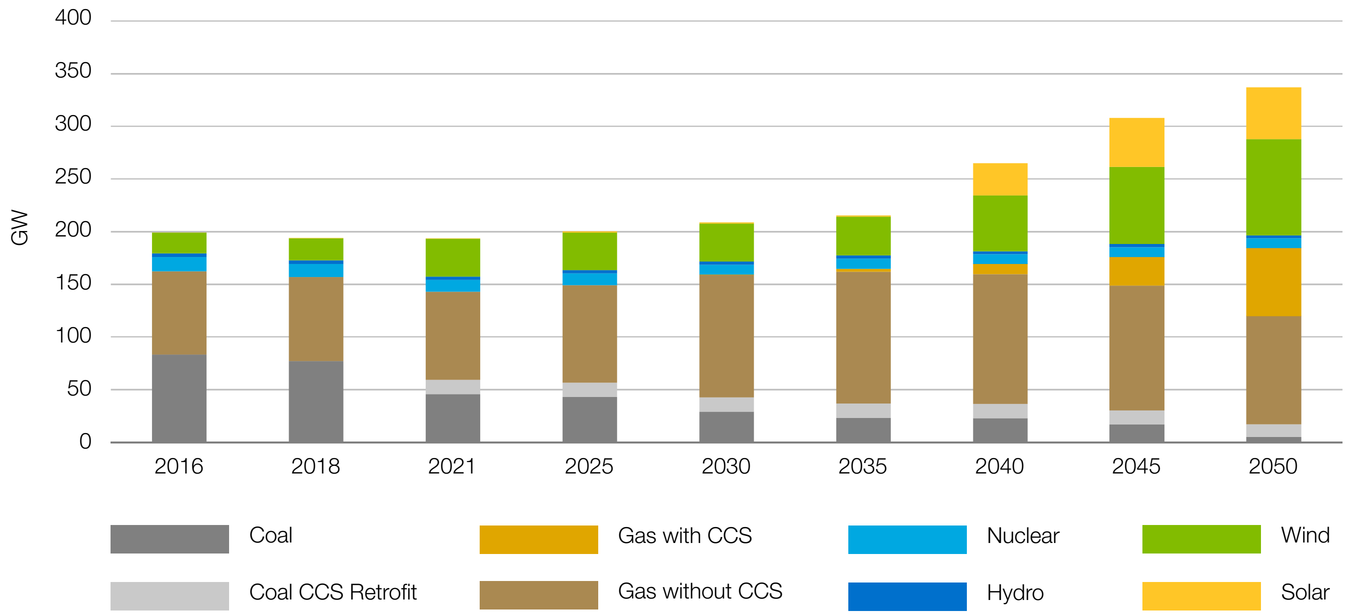


FIGURE 17: **Fleet Makeup to Achieve 95% Cap by 2050 (Low RE Costs, Moderate Gas Prices)**

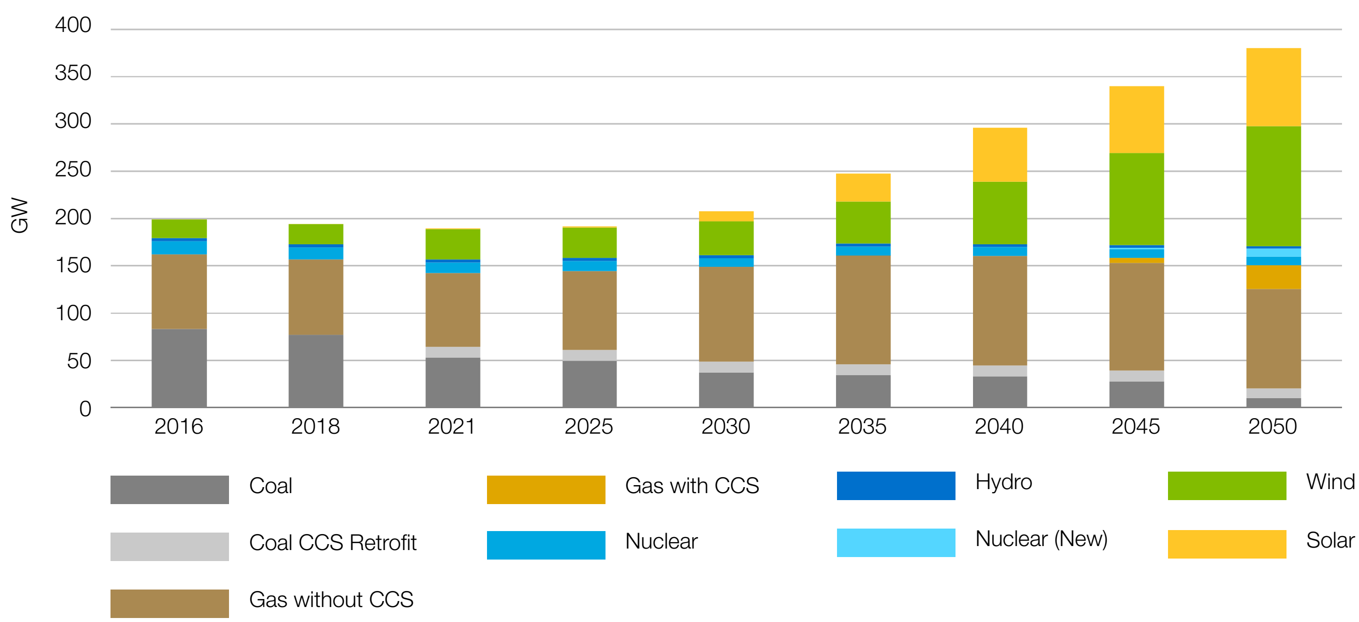


FIGURE 18: Generation Mix Under 95% Cap by 2050 (Low Gas Prices, Moderate RE Costs)

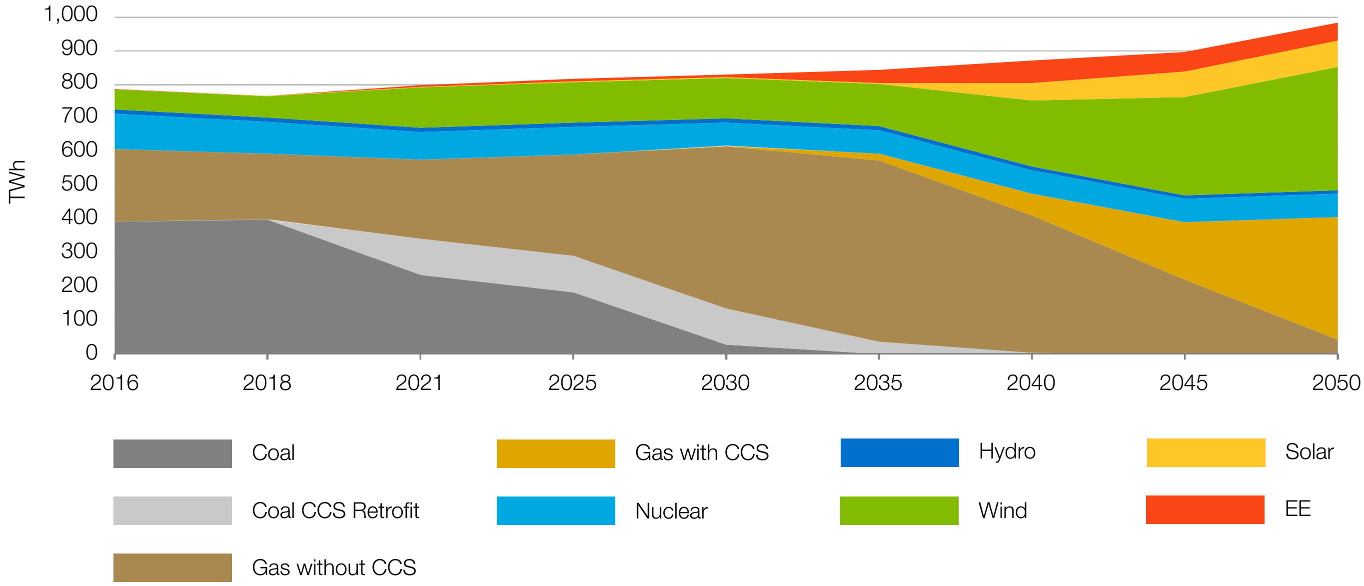
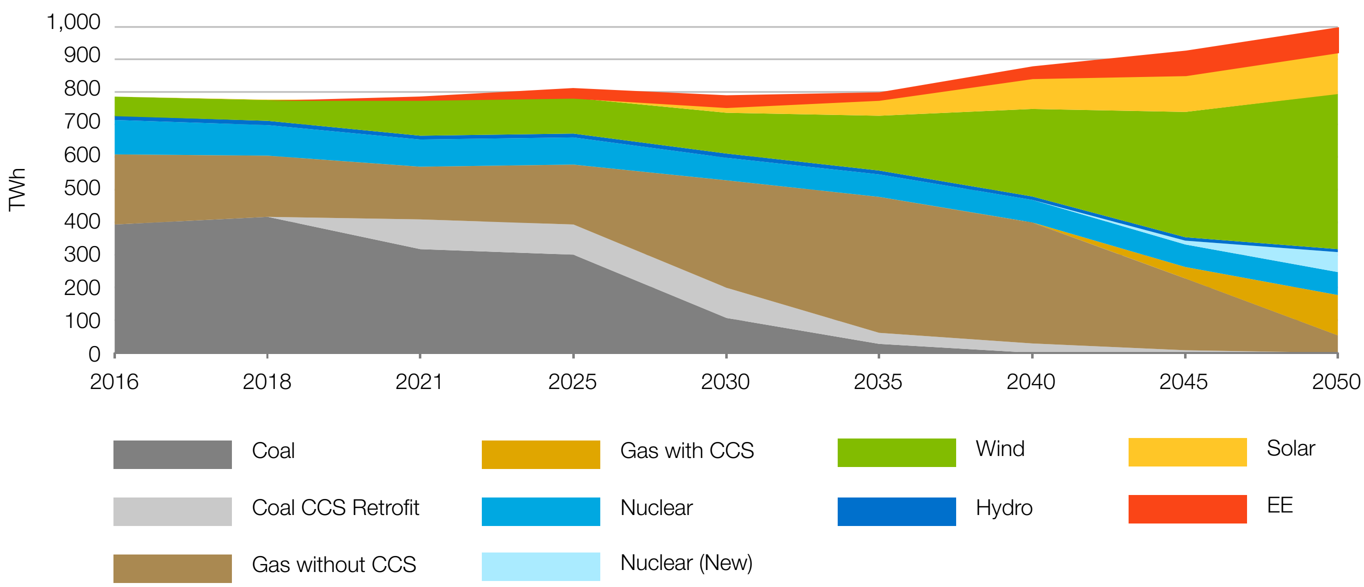


FIGURE 19: Generation Mix Under 95% Cap by 2050 (Low RE Costs, Moderate Gas Prices)



Spotlight

Spotlight on Xcel Energy: Designing the Right Energy Mix for Decarbonization

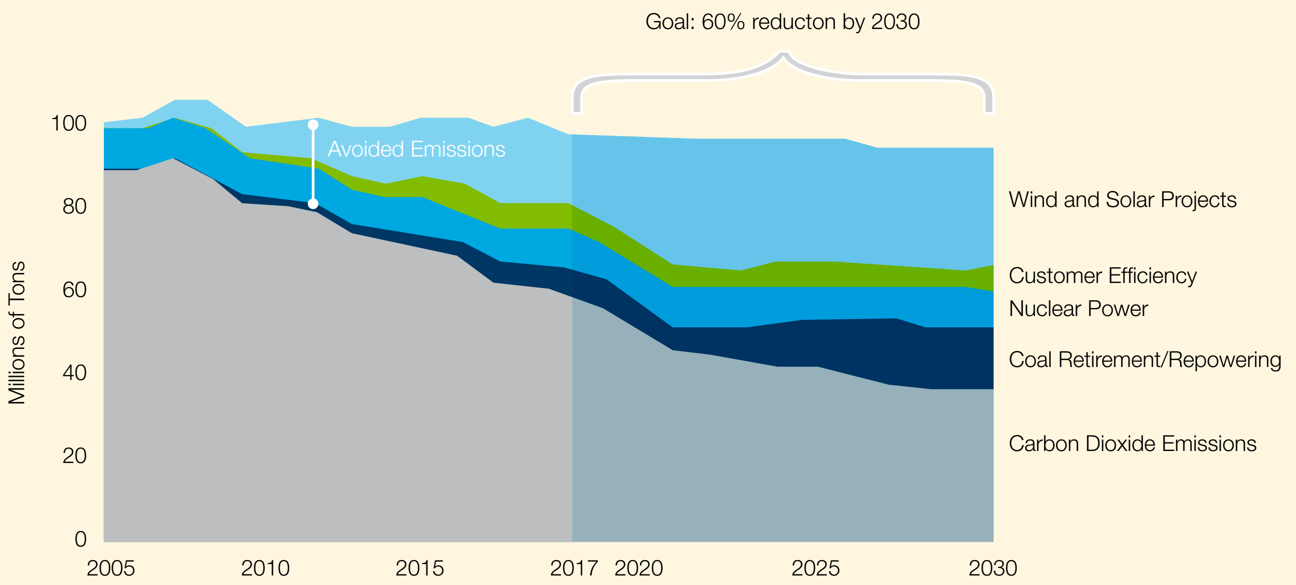
FOR MORE THAN A DECADE, Xcel Energy has pursued a strategy focused on transitioning to a cleaner energy mix while maintaining a reliable, secure grid, keeping bills low, and giving their customers new options. This strategy has four main components as shown in Figure A: retiring aging coal plants; replacing them with cost-effective wind, solar and natural gas; avoiding carbon emissions through energy efficiency; and maintaining their carbon-free nuclear plants. As a result, carbon emissions have been reduced by 35 percent since 2005 and are on track to reduce 60 percent or more by 2030.

In the Upper Midwest, with the right regulatory treatment, Xcel believes it can achieve up to 85 percent carbon-free energy by 2030, while keeping customer rates at or below inflation. Xcel Energy's goals align with the 80% by 2050 economy-wide reductions which are believed to be needed to avoid the worst impacts of climate change. As more customers and cities set their own carbon and clean energy goals, Xcel strives to help achieve these goals alongside them by providing a system mix with lower CO2-intensity, along with competitively priced options for those who want 100 percent renewable energy today.

The Key Role of Nuclear in a Low-Carbon Portfolio

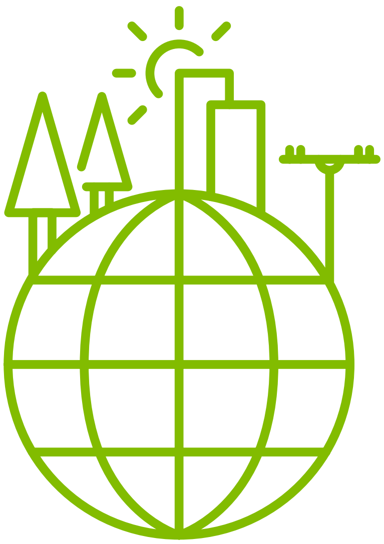
Nuclear plants in Xcel's Upper Midwest system currently provide about half of Xcel's carbon-free energy. Xcel believes it is crucial to maintain those plants at least through current licenses as they are a key backbone of a reliable system and vital in reaching 85% carbon-free energy in 2030. Beyond the end of those licenses, Xcel is exploring a broad range of options and technologies that may be available to maintain their decarbonization trajectory.

FIGURE A: **Visualizing a 60-Percent reduction by 2030**



Key Findings and Questions

THE ANALYSES CARRIED OUT FOR THIS ROAD MAP lead to the following findings and raise the following questions:



- The region could achieve substantial decarbonization of the electric sector by 2050 with existing technologies under a variety of pathways.
- Decarbonization of the electricity sector is an essential contributor to decarbonization of other sectors because of the role electrification can and is likely to play for transportation and buildings.[26]
- Based on what we know today, the region will need a mix of very low or zero-carbon resources to decarbonize the electricity sector. In this mix, energy efficiency and renewables play a very significant role and dispatchable resources such as natural gas with carbon capture also play a role. As in any modeling analysis looking decades into the future, it is not

26 The modeling for the electric sector has thus far not made any special assumptions about electrification in these other sectors. A range of penetration levels is expected to be explored in the next phase of the Collaborative's work.

possible to know what innovations will emerge that favor one part of the mix over another.

- A key question to explore in subsequent phases of the Road Map is the full potential that energy efficiency can play in decarbonization. Energy efficiency assumptions in this electricity sector analysis were simple and conservative. As the Collaborative and its partners examine possible future scenarios in the transportation and buildings sectors, the role energy efficiency can play will become clearer.

- Another key question to explore is the extent to which advances in flexible demand and other distributed energy resources can aid in the substantial decarbonization of the electricity sector. Wide adoption of smart appliances, such as hot water heaters and air conditioners, smart-charging electric vehicles, demand response programs, and other demand-side technologies, could put utilities in the position of being able to "turn off" chunks of electricity demand when low- or zero-carbon resources are not available to serve the demand. This "flexible demand" could help with the integration of higher levels of variable renewable resources and could make substantial decarbonization less costly. Distributed energy resources, such as rooftop solar, can also play an important role.

- There is disagreement across existing decarbonization studies on just how deeply wind and solar can cost-effectively penetrate given alternative pathways that may cost less. What proves "cost-effective" will depend on the cost of renewables—including technologies needed to integrate them at higher levels—compare to the alternatives.

  - The Collaborative's modeling analyses suggest that the region must step up its deployment of renewables penetration to be on a path consistent with the substantial decarbonization scenarios given current technologies and expected costs. Indeed, the modeling analysis suggest lowest cost scenarios that call for renewables penetration in the range of 34 percent to 60 percent. The region as a whole is currently at approximately 11 percent renewables capacity, with 9 percent wind and 2 percent hydro.

  - It will be important to make accommodations to avoid issues that might otherwise arise at higher levels of renewables penetration, such as curtailments that lead to a decline in the capacity and energy value of renewables. Storage technologies and methods could make good use of renewables when they are not needed for immediate electricity demand and would otherwise be curtailed. Flexible demand could also help to target electricity demand so that variable renewables are better utilized. Efficient transmission expansion can also better integrate increases in renewable generation and avoid curtailments.

- Given current technologies, deeper decarbonization—95 percent—will likely be a more expensive proposition than more modest levels of decarbonization without further efficiency and cost advancements. Because deep decarbonization is expected to be necessary, investment in research, development and deployment of new zero- or low-carbon technologies to mitigate costs will be necessary. For example, more economical storage of renewable electricity in various forms will enable the system to capture the energy at times the generation would otherwise be curtailed on the system.

- Given the uncertainty about technological progress, the region should keep its options open and pursue several very low and zero-carbon options for power generation and storage. The analysis suggests:

- Maintaining existing nuclear plants beyond their current licensing periods may make economic sense in a future where decarbonization is a goal.
- Cost-effective carbon capture and/or storage at scale may result in a lower-cost system.

- Waiting to take into account carbon risk may have consequences. Indeed, the modeling results suggest that over-reliance on natural gas could lead to higher costs in later years when utilization of natural gas must drop precipitously.
- There may be surprises in our future. Planning for decarbonization demands that utilities, state regulators, and policy makers make choices that maximize flexibility across the possible futures.
- Differences between the Midcontinent and the rest of the country are important.
  - The Midcontinent has been a source of zero-carbon electricity for export and is likely to continue to play that role. This makes investments in renewables and transmission in the region less risky.
  - The generation profiles of renewable energy vary in different regions. Wind generation and solar generation in parts of the Midcontinent region are complementary, unlike certain other regions of the country. It will be important for resource planners and policy makers to keep local generation profiles in mind when making decisions.
  - There may be opportunities for importing generation to bolster the system in the Midcontinent. For example, access to expanded hydroelectric power in the northern part of the region could enable deeper penetration of variable renewables. Also, the larger the system, the greater the potential for drawing on variable resources where the wind is blowing.
  - Transmission plays an important role to provide access to areas with the best renewable energy resources and lowers overall costs of decarbonization.

Consensus Principles for Policy Makers and Regulators

1. Invest in all cost-effective energy efficiency. Broaden the types of energy efficiency to capture new load—including electric vehicles and other demand-end technologies—and to enable peak shaving and load shifting that may help in integrating higher levels of renewables.

2. Invest in cost-effective renewable energy. The region is far from any possible economic or system constraints that may exist to limit the penetration of renewables.

3. Very low and zero-carbon resources that are dispatchable and flexible to follow load will be essential on the system.[27]

   a. Investing in carbon capture will take advantage of federal tax credits and develop infrastructure that can facilitate natural gas plants with carbon capture in later years.

   b. Investing in energy storage can firm up variable resources so they function as a dispatchable resource up to the limits of the storage technology.

4. Preserve existing nuclear power to the extent it makes technical, economic and environmental sense.

5. Investments in carbon-emitting resources should be evaluated against the genuine risk that substantial decarbonization of the sector will be required by mid-century.

27 The precise mix of technologies, regulatory measures and policies will of course depend on the decisions of state regulators, utilities and other actors in each state, and many factors will come into play beyond the economics.

6. Step changes are not foreseeable, and energy and carbon policies must be flexible enough to accommodate those changes.

7. Flexible, market-based approaches to reducing carbon emissions have advantages because they do not pick “winners” among different technology types and allow the market to find the lowest cost solutions. There are drawbacks to the flexibility of a market-based policy, however. The analysis tended to show a reliance on natural gas plants under a market-based policy that may result in path dependency and a reluctance to abandon natural gas assets when emissions reductions are necessary. To hedge the risk of path dependency, policies that support the development of a broader mix of technologies is prudent.

    a. Planning should incorporate the need for deep reductions. Any policy needs to get the system to a very low emissions rate by 2050.

    b. Early reductions are valuable but it is important to ensure that investments do not present a long-term problem. The decision-making process should recognize that the best choices given current costs and technologies may not be the best choices in 2035 based on advancements in technology and lower costs.

    c. An economy-wide flexible, market-based program could lead to deeper reductions in electricity due to electrification as the chosen abatement method in other sectors.[28]

8. Targeted incentives to spur research, development and deployment of key low- or zero-carbon technologies will be important just as tax incentives for renewables have been effective at lowering the cost of those technologies.

    a. Large-scale energy storage. Research and development in the area of energy storage is necessary and important.

    b. Carbon capture. The recently enacted tax credits for carbon capture are a positive step in this direction. In order to make carbon capture an attractive option for power generators in the future, efforts to scale up the technology and develop pipeline infrastructure are needed in the coming years.

    c. Renewables. Renewables have benefitted from the federal production tax credit and investment tax credit. Those credits are currently scheduled to phase out for the most part in 2020 and 2024, respectively. The Collaborative’s analysis suggests that the phasedown may significantly impact renewables deployment and may warrant reevaluation should deployment slow. Alternatively, the elimination of permanent incentives enjoyed by carbon-emitting fossil fuel technologies would ensure that renewable energy would not be at a competitive disadvantage.

    d. Advanced nuclear. Research and development in the area of advanced nuclear is necessary and important.

9. Wholesale electricity market structures should evolve to value attributes that contribute to a lower-carbon grid.

28 The interactions between the electricity sector and electrification of other sectors will be the subject of inquiry in the next phase of the road map work

Other Resources

IN THE DEVELOPMENT OF THIS ELECTRICITY ROAD MAP, Collaborative participants consulted numerous experts and reviewed other study results. In some cases, participants have undertaken their own decarbonization and other resource planning studies. Below are some references to other studies that readers may find useful in the context of planning.

Becker, S., B.A. Frew, G.B. Andersen, T. Zeyer, S. Schramm, M. Greiner, and M.Z. Jacobson, "Features of a Fully Renewable US Electricity System: Optimized Mixes of Wind and Solar PV and Transmission Grid Extensions." *Energy* 72: 443-58 (2014).

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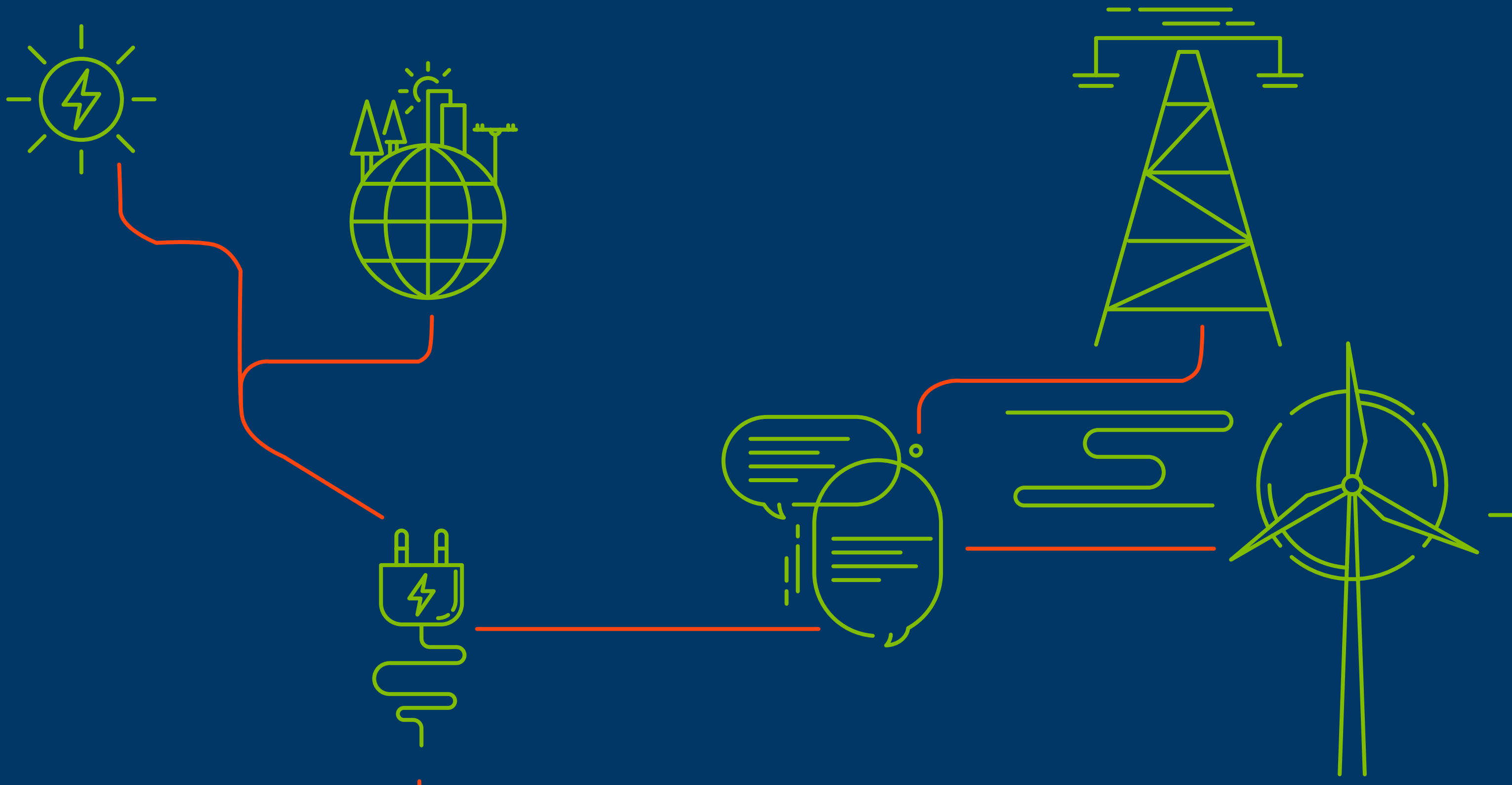
Williams, J.H., B. Haley, F. Kahrl, J. Moore, A.D. Jones, M.S. Torn, H. McJeon. *Pathways to deep decarbonization in the United States*. San Francisco: Sustainable Solutions Network & Institute for Sustainable Development and International Relations, 2014, available at http://unsdsn.org/wp-content/uploads/2014/09/US-Deep-Decarbonization-Report.pdf.

Next Step: Other Sectors

The Collaborative will next explore the electrification of the transportation sector for addition to the road map, followed by buildings. This work is premised on the expectation that a decarbonized electricity sector must grow to serve increasingly efficient and electrified transportation and buildings sectors. The Collaborative and its partners from other sectors will be releasing additional road map reports for the Midcontinent in the coming months.



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