Xcel Energy®

Building a Carbon-free Future | CARBON **REPORT**

To our **Stakeholders:**

Xcel Energy is committed to serving customers, and that includes responding to the concerns of many customers around the risk of climate change. National and international studies paint a sobering picture about this risk and call for nothing less than a transformation of our industry to help address it. While that transformation will be challenging, we see an opportunity for our company and those we serve to significantly reduce greenhouse gas emissions reliably, safely and at a low cost.

In 2018, we reduced carbon emissions from the electricity that serves our customers by 38 percent compared to 2005 levels and plan to do even more. As technologies have improved and costs have fallen, we are making significant changes — more than we imagined possible a decade ago — without compromising the reliability or affordability that our customers expect. We need all three components — clean, reliable and affordable — to make this transition work.

As we carry out Xcel Energy's vision to be a preferred and trusted energy provider, leading the clean energy transition continues to be a strategic priority for us. It's helping to achieve our other two strategic priorities as well — to keep customer bills low and enhance the customer experience.

We're a national leader in wind energy and are harnessing it through our Steel for Fuel strategy, which we expect to reduce costs for customers. We also offer a leading portfolio of energy efficiency and renewable choice programs because an increasing number of customers want to power their homes and businesses with clean energy and take steps to reduce their own carbon footprints.

While our existing efforts are significant, we want to do even more and do it sooner than anticipated. That is why I set an ambitious vision to reduce our carbon emissions 80 percent from 2005 levels by 2030. Longer term, we aspire to serve our customers with carbon-free electricity by 2050. The technology to achieve this aspiration isn't commercially available yet, but I believe it can be available if we make it a priority today.

In this report, we discuss our vision, including the opportunities, risks and challenges we face getting there. We describe how our carbon transition can have an even larger impact in other sectors, such as transportation. We also show how our commitment compares to the targets of international climate agreements.

Xcel Energy is leading the clean energy transition. We know from experience that our goals are ambitious. This change will require collaborative, long-term solutions that are cost effective as well as advanced clean energy technologies. Broad stakeholder support, smart public policy and favorable economics are essential factors in this ongoing transformation.

We can't achieve this transition alone — it will take all of us working together. I look forward to your partnership.

Sincerely,

Ben Fowke
Chairman, President and CEO

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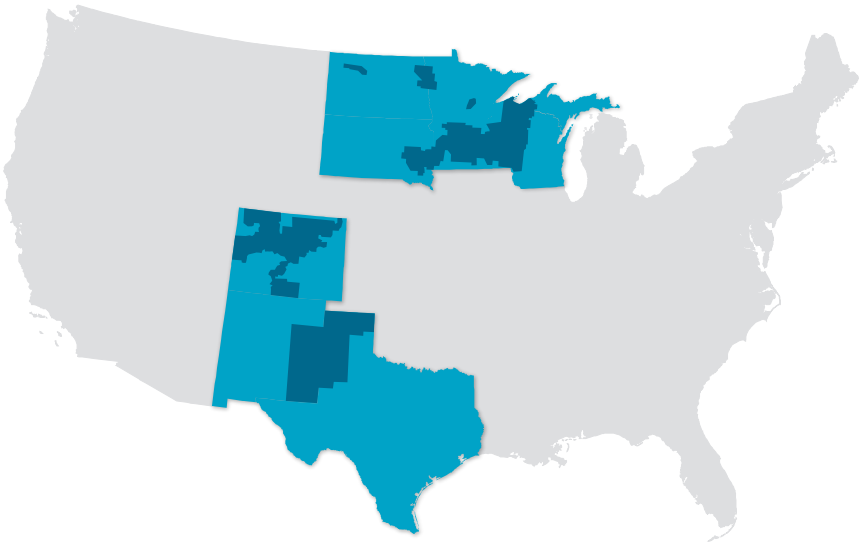
About Us

Xcel Energy is a major U.S. electricity and natural gas company with annual revenues of $11.4 billion. Based in Minneapolis, we operate in eight states and provide a comprehensive portfolio of energy-related products and services to 3.6 million electricity customers and 2 million natural gas customers.

Addressing climate change is a priority for many of our customers, investors and key stakeholders, and is a priority for us as well. In delivering on our strategic focus to lead the clean energy transition, we are successfully reducing carbon emissions and providing clean energy solutions from a variety of renewable sources, reliably and affordably for customers.

More information on our clean energy strategy, corporate governance and risk management is available at **xcelenergy.com** in our corporate reports, including Xcel Energy's Annual Report, Proxy Statement, Corporate Responsibility Report and EEI Environmental, Social, Governance and Sustainability Report.



Forward Looking Statements

The material in this report contains forward-looking statements that are subject to certain risks, uncertainties and assumptions. Such forward-looking statements include projections related to emission reductions, changes in our generation portfolio, planned retirements, and planned capital investments and are identified in this document by the words "aim", "aspire", "assuming", "believe", "could", "expect", "may", and similar expressions. Actual results may vary materially. Factors that could cause actual results to differ materially include, but are not limited to: general economic conditions, including the availability of credit, actions of rating agencies and their impact on capital expenditures; business conditions in the energy industry: competitive factors; unusual weather; effects of geopolitical events; including war and acts of terrorism; changes in federal or state legislation; regulation; actions of regulatory bodies; and other risk factors listed from time to time by Xcel Energy in its Annual Report on Form 10-K for the fiscal year ended Dec. 31, 2018 (including the items described under Factors Affecting Results of Operations) and the other risk factors listed from time to time by Xcel Energy Inc. in reports filed with the SEC.

Aspiration for a **Carbon-free** Energy Future

For more than a decade, Xcel Energy has demonstrated leadership on clean energy — proactively reducing carbon emissions at levels that currently surpass state and federal goals. This environmental commitment is woven into our company's strategy, governance, executive compensation and daily operations.

To respond to growing stakeholder expectations, we have regularly established and achieved increasingly ambitious carbon reduction goals.

Where We Aim to Be

Our vision for the future includes industry-leading goals shown in Figure 1. In this report, we demonstrate how our goals align with an emissions trajectory needed for the electric power sector to meet the goals of the Paris climate agreement.

By 2030, we aim to reduce carbon dioxide emissions 80 percent below 2005 levels company-wide. This means that by 2030, our annual carbon emissions from the electricity that serves our customers will be about 17 million tons, or 80 percent lower than in 2005. We believe these emission reductions can be achieved cost effectively with continued fleet transition and operational changes, and with the renewable, carbon-free generation and energy storage technologies available today.

By 2050, we aspire to provide our customers across all states with 100 percent carbon-free electricity. In the next 30 years, we will transition to serve our customers with electric resources that emit zero carbon dioxide emissions. To fulfill this aspiration, we will continue to increase renewable energy sources on our system, as well as technologies that enable renewable integration. We will need new carbon-free dispatchable technologies — technologies not yet commercially available at the cost and scale needed to achieve our 2050 aspiration. Because of this, there needs to be significant research and development to ensure we have these technologies to deploy in the coming decades.

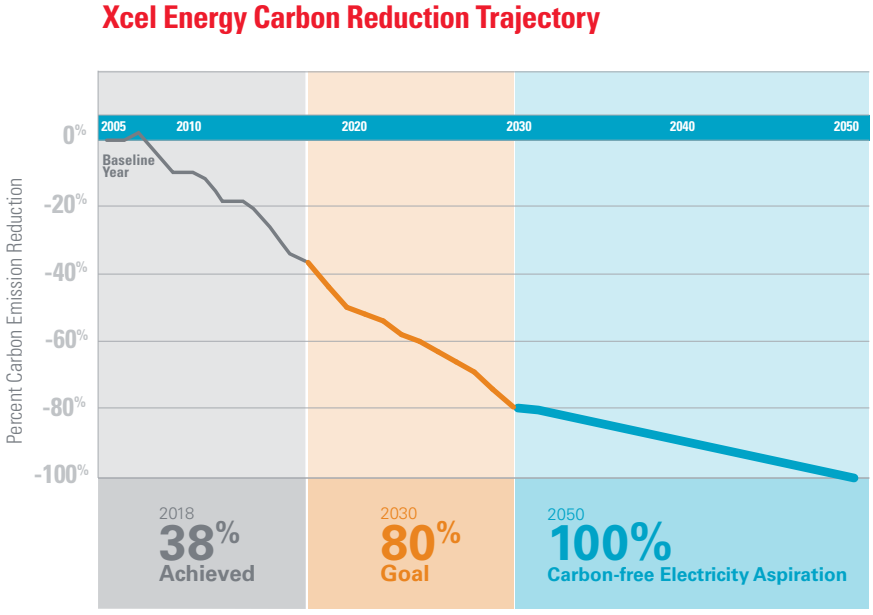


Figure 1: Our vision for the clean energy transition 2030 and 2050

The Path to Get There

We know that climate change is an urgent issue for many of our policy makers and a growing concern of our customers who want to help make a difference. Planning for the transition to a clean energy future today will allow us to deliver the product our customers want and achieve reductions that our policy makers are increasingly demanding. By acting now, we increase our chances to achieve these goals while assuring that our system remains reliable and our prices affordable. These last two points are critical to our success. The electricity we deliver is an essential service that powers the economy and keeps our customers comfortable and safe.

While we move through this transition, we need to make sure that power will be there when our customers need it and that the prices we charge are affordable to all customers , both residential and commercial. To accomplish this, we will build upon four focus areas that are transforming our system and delivering clean, reliable, low-cost power to customers today.

These focus areas include:

- Investing in wind and solar under our Steel for Fuel strategy and offering customers more renewable energy options
- Helping customers manage their energy usage and bills through efficiency and rebate programs and encouraging strategic electrification of other sectors, such as transportation
- Maintaining our carbon-free nuclear plants in the Upper Midwest
- Transforming the energy grid by retiring or reducing the operation of aging coal plants and replacing their energy with low-carbon natural gas, renewables and advanced technologies

Looking ahead to 2030 and 2050, we plan to continue this progress. Our vision is not a single plan or initiative. Instead, it will guide the policies that we support and the resource plans that we expect to file in our states over the coming decades. As we advance these efforts, stakeholders are essential and will help to influence the outcomes. Because of this, we plan to continue working collaboratively with customers, nongovernmental organizations, policy makers and others to identify and implement pragmatic solutions to make our goals possible.

In setting our goals, we did sensitivity analysis to identify key elements and variables that could affect our plans. There are a variety of cost-effective pathways to an 80 percent carbon reduction by 2030, and resource plans in our jurisdictions will determine the exact resource mix. However, through the pathways we explored, we have identified the following common elements that we know will be part of the plans:

- We anticipate adding thousands of megawatts of wind and solar power to our system and incorporating both natural gas and storage resources to help balance high levels of renewables
- Strategic electrification of certain end uses will help create flexible demand
- We will seek to operate our nuclear plants through at least the remainder of their licenses, and we will need to retire additional coal units or change their operations to minimize emissions affordably and reliably
- In addition, we will need to make critical investments in supportive infrastructure, such as transmission

As we transition our system and retire plants, we will need to assure that we do so in a way that our company remains financially healthy and that acknowledges the financial impacts of plant retirements and the replacement investment on our investors. Just as we serve other stakeholders, we must provide our investors with value to encourage them to provide the capital necessary to support these plans. There are many ways to accomplish our carbon vision, but the ability to own these replacement resources is clearly an important consideration, as investors support companies that grow their earnings power. This ownership also helps to reduce risk to customers and is fundamental to ensuring our financial viability and ongoing ability to efficiently invest in day-to-day infrastructure needs as well as clean energy.

To reach our 2050 aspiration, there must be more action around the research, innovation and demonstration of advanced technologies. We need, clean technologies that can be dispatched to balance the peaks when customer use exceeds renewable generation and valleys when renewable generation exceeds customer use. Cost-effective, low-carbon and carbon-free dispatchable resources will be required to remove the remaining carbon from the system to serve customers with carbon-free electricity. Technology advancement is key to the long-term success of our strategy.

Analysis Related to **Our Vision**

In planning our future carbon transition, we have reviewed the research on climate science to confirm the effectiveness of our goals. A trio of climate reports — from the Intergovernmental Panel on Climate Change (IPCC), the U.S. Global Change Research Program and the UN Environment Program — examine potential climate change impacts and the greenhouse gas reductions needed to meet the targets of the Paris climate agreement. While providing broad context for our analysis, none of these reports includes actionable guidance for utility decision making or for individual company greenhouse gas goals.

We also participate in an Electric Power Research Institute (EPRI) project that is analyzing the science around climate scenario analysis and emission goal setting. While providing useful insights about global, regional and electric sector emissions consistent with limiting temperature increases to 2 C, the EPRI project does not provide company-specific comparisons to the Paris climate targets.

To bridge this gap, we hired experienced climate modelers at the University of Denver to compare Xcel Energy's goals to the Paris climate targets. We compared our goals to electric power sector emissions in industrialized countries, in IPCC scenarios consistent with a high probability of achieving the 2 C and 1.5 C temperature goals in the Paris climate agreement.

The Paris Climate Agreement

In December 2015, the international negotiations of the United Nations Framework Convention on Climate Change (UNFCCC) produced the Paris climate agreement, with the goal of "holding the increase in the global average temperature to well below 2 C above preindustrial levels and pursuing efforts to limit the temperature increase to 1.5 C above preindustrial levels, recognizing that this would significantly reduce the risks and impacts of climate change."[1]

The Paris climate agreement does not establish goals, mandates or even guidance for individual economic sectors or companies. This makes it challenging to address the relationship between the agreement's goals and company-level targets. Its temperature goals represent a global ambition, pursued through nationally determined contributions and subsequent national and sub-national (e.g., state) policy decisions about how to allocate the emission reduction burden across sectors, industries and individual companies.

IPCC Special Report

The IPCC in October 2018 published a Special Report on Global Warming of 1.5 °C. The IPCC estimates that warming to date is about 1 C above average preindustrial temperatures and that warming is likely to reach 1.5 C between 2030 and 2052.[2] The report evaluates human and natural impacts of climate change associated with global warming of 1.5 C and compares these to impacts at 2 C or more. The IPCC then explores what global greenhouse gas reductions would be needed, on what timeframe, to limit warming to 1.5 C. It estimates that global net human-caused carbon dioxide emissions would need to peak within the next few years, then fall dramatically, reaching net zero by around 2050 (meaning that after that point, carbon emissions are balanced by carbon removal.) The report indicates that allowing global temperatures to temporarily overshoot 1.5 C, but return below 1.5 C by 2100, would require greater reliance on negative emission technologies after mid-century. To stay below or only temporarily exceed 1.5 C, global emissions in 2050 would have to be between 71 percent and 129 percent below 2010 levels.[3]

US Fourth National Climate Assessment (NCA4)

The U.S. Global Change Research Program in November 2018 released its Fourth National Climate Assessment, summarizing the latest scientific understanding of climate change impacts, risks, mitigation and adaptation, both nationally and by regions of the United States. The report finds that climate change is having significant impacts on U.S. communities, the economy, trade, water, public health, ecosystems, infrastructure, energy systems, agricultural productivity, oceans and coastlines. Potential impacts on the electric sector include reduced generation efficiency at thermal plants, power outages, grid reliability challenges, fuel transport, changing wind patterns, increased electricity demand for cooling and reduced natural gas demand for heating.

Under a high emissions future, NCA4 finds that "climate change is projected to impose substantial damages on the U.S. economy, human health and the environment. Under scenarios with high emissions and limited or no adaptation, annual losses in some sectors are estimated to grow to hundreds of billions of dollars by the end of the century."[4] However, NCA4 also finds that greenhouse gas reductions sufficient to keep the world on a lower warming pathway could still avoid or significantly reduce these damages — and that the earlier the reductions, the greater the chance of avoiding the worst impacts.

UN Emissions Gap Report

The U.N. Environment Programme (UNEP) in November 2018 released its annual Emissions Gap Report, which assesses the status of countries' "nationally determined contributions" under the Paris climate agreement. The report finds that global carbon dioxide emissions increased in 2017 after staying relatively flat for three years, reaching 53.5 billion metric tonnes CO2e (GtCO2e) and show no signs of peaking in the near term. Without additional efforts, UNEP predicts global warming of about 3 C by 2100. UNEP estimates a gap of 13 GtCO2e per year by 2030 between global emissions under the nationally determined contributions and the annual emissions needed to achieve the 2 C target (for the 1.5 C target, a gap of 29 GtCO2e.) UNEP finds it is still possible to bridge the gap and contain warming below 2 C and 1.5 C, but this will require aggressive reductions by 2030, particularly in emission scenarios that are more pessimistic about the potential for negative emissions (i.e., carbon removal technologies) later on.

EPRI Research

Because the reports summarized above do not include guidance specific to electric utilities or other industries, Xcel Energy also participates in a multi-utility project convened by EPRI to examine the current state of the science around climate scenario analysis and company greenhouse gas goals.[5] EPRI released a report in fall 2018 that takes stock of current scientific understanding and provides analytical guidance, titled Grounding Decisions: A Scientific Foundation for Companies Considering Global Climate Scenarios and Greenhouse Gas Goals. We outline here a few key findings from the report.

Figure 2 illustrates the many variables defining the relationship between global temperature goals and company-level greenhouse gas emissions. Uncertainties in the relationships between each variable result in ranges of global, country, sector and individual company emissions consistent with a temperature goal. This means there is no single or uniform target that can be applied to all companies and is appropriate in all plausible futures. Nonetheless, ranges can be identified that are consistent with achieving the temperature goals.

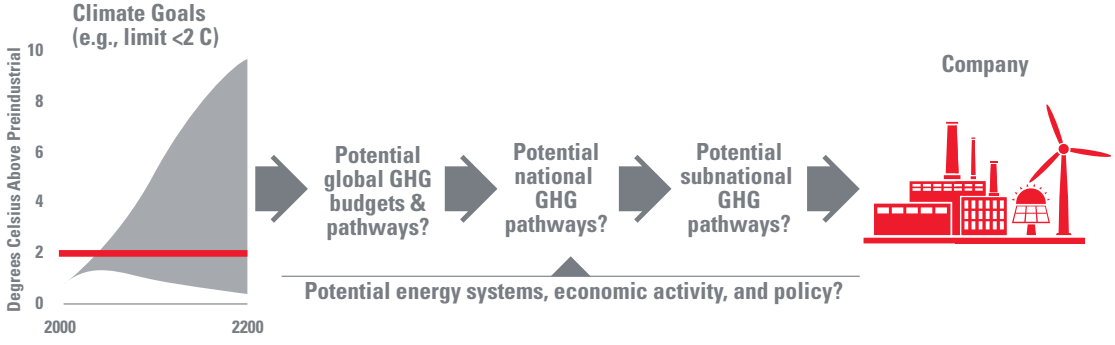


Figure 2: The relationship between global climate goals and company-level targets. Reproduced from EPRI 2018, page 2-1.

EPRI draws on the IPCC Fifth Assessment Report (AR5) emission scenario database and other scenarios to characterize current understanding of these relationships. Among other things, the EPRI study identifies sets of global, regional and electric power sector emission scenarios consistent with different probabilities of limiting global average temperature increase to 2 C.[6]

Figure 3, reproduced from the EPRI report, shows the range of global carbon dioxide scenarios consistent with a 40 percent or greater chance of limiting global warming to 2 C. The left-hand chart shows that a broad range of scenarios, rather than a single scenario, is consistent with this temperature goal. It also shows that scenarios that increase emissions in the near term generally require significant negative emissions after mid-century to offset the near-term increase and achieve the temperature goal.[7] The right-hand chart shows the much smaller range of scenarios that can achieve the temperature goal with the same 40 percent probability, if negative emissions technologies are unavailable.

The EPRI study also presents sets of regional and electric sector emissions pathways consistent with 2 C. However, as discussed by EPRI, these results are dependent upon global assumptions — in particular, global economy-wide policy design and technology availability assumptions that facilitate reducing carbon with electricity. These are important uncertainties for electric power companies to evaluate, and sub-global scenario results should be used with caution and with these uncertainties in mind.

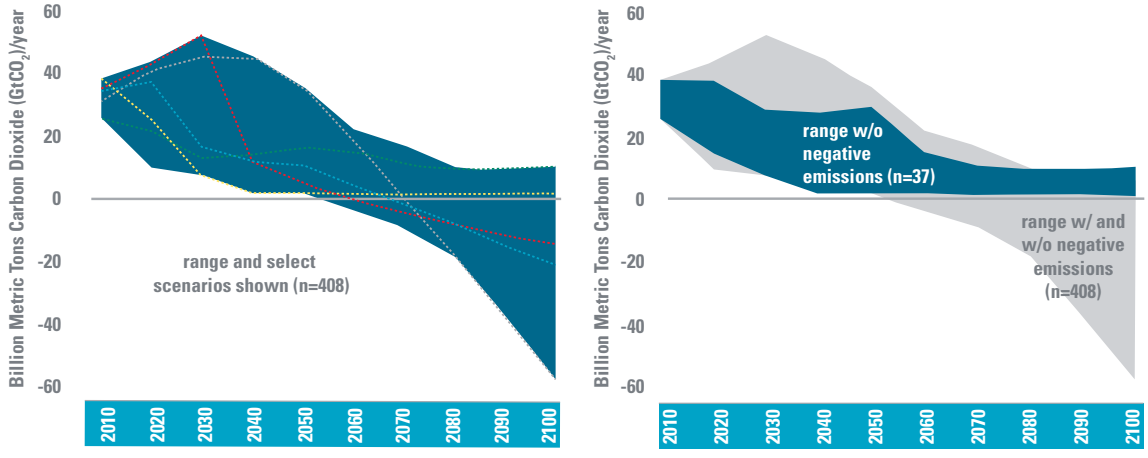


Figure 3: Global net carbon dioxide pathway ranges consistent with a 40 percent or greater chance of limiting warming to less than 2 C. Reproduced from EPRI 2018 and supporting material.

EPRI's report provided key insights for our subsequent work with the University of Denver. First, there is a broad range of emissions pathways consistent with a given probability of achieving a temperature goal. We need to consider our carbon goals relative to this range and the uncertainties it represents, including uncertainties about policy, technology availability and reductions assumed to be achieved in sectors other than electricity. Second, we can choose to compare ourselves to pathways with higher likelihood of achieving temperature goals, as well as compare to Xcel Energy to sub-global pathways such as electric power sector emissions. However, in doing so, it is important to recognize the assumptions, challenges and uncertainties embedded in such an analysis and their implications for our goals.

Finally, many IPCC scenarios assume the availability of significant negative emissions after mid-century, in some cases offsetting emission increases in the near term, to achieve the temperature goal. This is particularly true of the 1.5 C scenarios. Because negative emissions electricity technologies are not commercially available today, to be conservative we compared ourselves only to carbon scenarios that do not include negative emissions technologies within the electric power sector in industrialized countries (but may include negative emissions in other regions and sectors.) If negative emissions electricity technologies become available, we would consider them along with other options for providing customers reliable, affordable clean energy. Because our analysis does not rely on these technologies to reach our goals, we plan to continue to reduce carbon emissions aggressively in the near term, consistent with cost (which is also influenced by need) as well as reliability.

Comparing Xcel Energy to the Paris Climate Agreement Goals

EPRI did not attempt to identify company-specific emission trajectories corresponding to the global temperature goals because of the increasing uncertainty at higher levels of resolution. However, investors and others routinely ask Xcel Energy to compare company-specific emissions to the temperature goals, so we needed to go a step further. We commissioned an analysis by experienced climate modelers at the University of Denver, including a lead author on the IPCC's forthcoming Sixth Assessment Report, to compare our goals to electric sector carbon dioxide emission scenarios consistent with limiting warming to both 2 C and 1.5 C. We provided the modelers our carbon emission forecast and goals, and had them compare these to electric sector carbon emission scenarios consistent with 2 C and 1.5 C. We set three constraints on their analysis:

- Focus on scenarios categorized by the IPCC as having a high probability of achieving the temperature goals
- Compare Xcel Energy to the electric power sector in industrialized countries
- Exclude scenarios that rely on negative emissions technologies within the electric sector

On pages 11 to 13, the University of Denver modelers summarize briefly their approach and findings.

Xcel Energy targets and limiting warming to less than 2 C and 1.5 C

By Dr. Brian O'Neill and Steve Hedden

Climate researchers have carried out a large number of studies of how much and how fast greenhouse gas emissions would have to be reduced in order to achieve the Paris climate targets of limiting warming to less than 2 C, or even to below 1.5 C. We drew on the results of those studies to compare Xcel Energy's emissions reduction goals to emissions pathways consistent with the Paris climate targets. In those pathways, global carbon emissions generally decline to zero (in net terms) by around 2070 or later to stay below 2 C and by around 2050 to stay below 1.5 C.

However, emissions associated with one company in one country are just a fraction of global emissions, so we compared Xcel Energy's goals to a more detailed and more relevant set of results from these studies: net carbon emissions from the electric power sector in industrialized countries. We found that Xcel Energy's goals represent reductions that are consistent with, and in most cases larger than, those that occur in this sector in scenarios that achieve the Paris climate targets.

Approach

The Intergovernmental Panel on Climate Change report from October 2018[8] assessed the scientific literature on emissions scenarios consistent with the Paris climate targets. To support that assessment, researchers created a database of 416 published emissions scenarios.[9] The scenarios were developed using computer models that calculate the greenhouse gas emissions and warming that would result from the production and consumption of energy, food, transportation and other goods in regions around the world over the coming decades. The future is uncertain, so these scenarios investigate a wide range of possibilities about how fast population, incomes and energy demand may grow and what kinds of climate policies may be pursued to achieve the Paris climate targets.

We compared the Xcel Energy goals to a subset of these scenario results. First, we selected two sets of global greenhouse gas emission scenarios from the database: those that would be likely (defined as having a greater than 66 percent chance) to stay below 2 C, and those that would be more likely than not (defined as having a greater than a 50 percent chance) to stay below 1.5 C or to only slightly (and temporarily) exceed that level.[10]

Next, we extracted results from these scenarios for carbon dioxide emissions from the electric power sector in industrialized countries.[11] These outcomes from the scenario database are the best comparison available to Xcel Energy goals. Models that produce emissions scenarios do not represent individual companies, nor even individual countries. Results are reported in the database as totals for groups of countries for different sectors of the economy. By using results for the electric sector in industrialized countries, we can compare Xcel Energy goals to emissions pathways that occur on average across the same sector of countries at similar levels of economic development to the United States.

Finally, we excluded scenarios in which net carbon dioxide emissions from the industrialized country electric sector are negative at any time in the future, through 2100. (Note that these scenarios could still include negative emissions in other sectors and regions.) In the electric sector, net negative emissions could result from technologies like biomass energy with carbon capture and storage (BECCS) that generate electricity while removing carbon from the atmosphere. Scenarios with these technologies often allow for higher global emissions in the first few decades that are compensated for by negative emissions later in the century. However, these technologies are unproven at large scales and involve possible risks to biodiversity and food prices due to the large amount of land that may be required for growing biofuels.

Our selection process left us with 17 scenarios consistent with the 2 C target and five scenarios consistent with the 1.5 C target, a reflection that achieving the lower target without net negative emissions in the electric power sector is relatively uncommon in the scientific literature.

Results

The comparison in Figure 4 shows that Xcel Energy's 2030 and 2050 goals represent emissions reductions that are larger than those that occur in the electric sector of industrialized countries in most of the global emissions scenarios likely to limit warming to below 2 C. Xcel Energy's goals are also within the range of reductions that occur in the limited number of scenarios achieving the 1.5 C target. These figures show scenario results to 2050. Beyond 2050, these scenarios generally indicate low or zero net carbon emissions continuing through the end of the century.

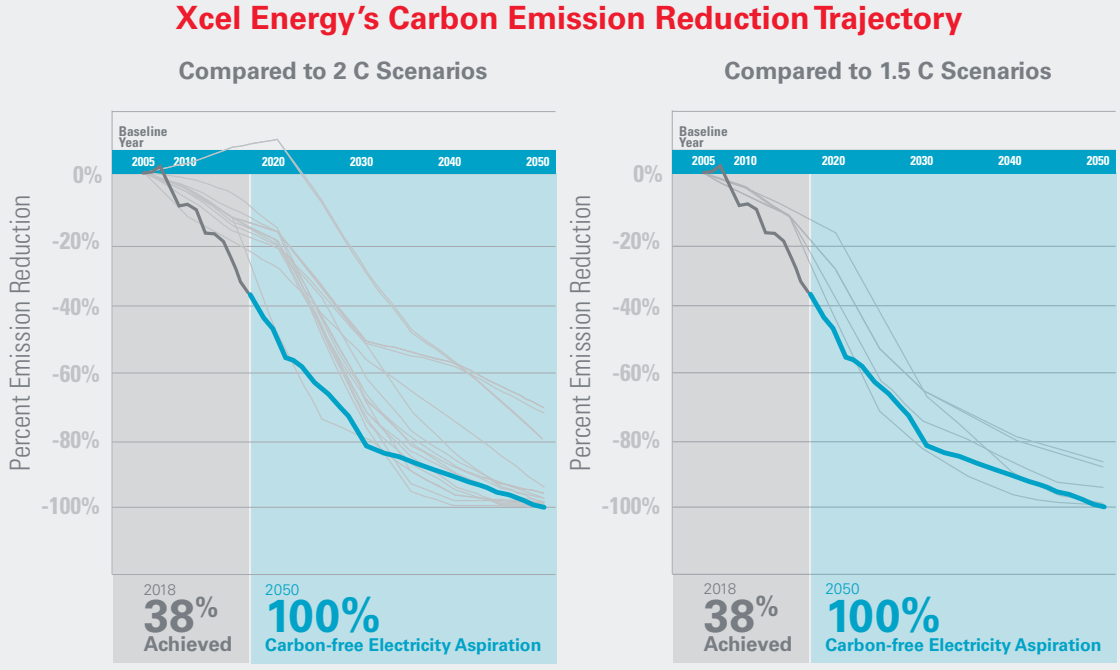


Figure 4: Xcel Energy carbon emissions reduction goals (in blue, with historical emissions in dark gray) compared to scenarios of emissions from the industrialized country electric power sector (in light gray). Emissions scenarios are from global scenarios likely to remain below 2 C warming (left) or more likely than not to avoid 1.5 C warming (right) without significantly exceeding that level. Emissions expressed as a percent reduction relative to levels in 2005.

Caveats to this analysis

To date, most company-level greenhouse gas scenario analysis has focused on 2 C rather than 1.5 C, in part because of the much greater uncertainty about the attainability of limiting warming to 1.5 C. The IPCC notes that limiting warming to 1.5 C may involve unprecedented actions.[12] Without taking a position on the attainability of 1.5 C, in this analysis we have assessed Xcel Energy's goals in relation to both temperature goals. We have chosen to include the 1.5 C scenarios because while that goal is unquestionably harder to attain than 2 C, experience shows that the scale and pace of technological change often outpaces our expectations today. Because of this — and because the IPCC Special Report makes clear that climate risks and damages, while not zero at 1.5 C, are substantively less than at 2 C — we believe it makes sense to include it in our analysis.

Any multi-decade analysis of company- or sector-level carbon dioxide emission trajectories relative to the global temperature goals involves inherently uncertain assumptions about economic growth, technologies, policy and global coordination or lack thereof. If those assumptions are not borne out — e.g., technologies do not develop as expected, economic growth is more carbon intensive than assumed, emission reductions (or negative emissions) assumed to occur in other sectors or regions do not materialize, etc. — then the industrialized country electric sector emissions consistent with a given probability of achieving the temperature goals could change.

We have endeavored to make conservative assumptions in this analysis. For example, we focus only on scenarios with relatively high likelihoods of achieving the temperature goals and exclude scenarios that rely on net negative emissions technologies within the electric sector. Also, we examined our conclusions to ensure that they do not change fundamentally when varying key assumptions, such as allowing net negative emissions in the electric sector, and that they do not rely on unreasonably large assumed reductions in other regions. For a fuller discussion of these issues, see our full report.[13]

Brian O'Neill is professor at the Josef Korbel School of International Studies at the University of Denver and director of Research at the Korbel School's Frederick S. Pardee Center for International Futures, whose mission is to explore, understand and shape alternative futures of global change and human development. He is currently a convening lead author for the IPCC's Sixth Assessment Report and was an author on the United States' Fourth National Climate Assessment.

Steve Hedden is lead system administrator at the Pardee Center and is a coordinating lead author of the United Nations Environmental Programme's (UNEP) sixth Global Environmental Outlook (GEO6.)

Our Conclusions on the Analysis

Participating in the EPRI research, and subsequently engaging University of Denver climate modelers to compare our carbon vision against the Paris climate targets, helped to validate that our goals are consistent with electric sector emissions in scenarios likely to achieve the targets. Our goal to reduce carbon emissions 80 percent by 2030 and aspiration to serve customers with carbon-free electricity by 2050 appear largely consistent with the industrialized country electric sector carbon reductions in scenarios that achieve the Paris climate targets, even acknowledging the many uncertainties and embedded assumptions in any such analysis.

More specifically, Figure 4 shows that our carbon dioxide reductions achieved to date (shown by the dark gray line) fall below all the scenarios corresponding to a high probability of achieving the 2 C and 1.5 C goals. Our trajectory from today to 2030 falls below all but one of the scenarios for both temperature goals. Our aspiration for 2050 lies well within the range of emission scenarios for both temperature goals. In addition, we note that our carbon dioxide emission reduction trajectory from 2030 to 2050 is represented as a simple straight-line projection since we have no resource plans that extend to 2050. Our actual reductions will not likely follow that smooth line and depending on cost and technology developments, and the future of our nuclear plants, could either decline or increase from the line in any given year.

Any climate scenario analysis has embedded assumptions and necessary simplifications. For our analysis, these include:

- Our actual carbon emissions will depend on our resource mix, renewable energy and natural gas prices, total load, degree of electrification of end uses currently reliant on other fuels, and many other factors. We typically run sensitivities for these and many other variables in our resource plans.

- Depending on the amount of electrification assumed, a very low-carbon electric power sector may enable significant greenhouse gas reductions in transportation, buildings and other sectors. Our strategy contemplates significant electrification of the economy. The scenarios shown here virtually remove carbon from the electric sector, but there could be scenarios in which it is cost effective for the electric sector to emit slightly more carbon while reducing carbon in other sectors and still achieving the economy-wide reductions necessary for the temperature goals.
- The cost effectiveness of any greenhouse gas reduction pathway depends to some extent on climate policy, which is not addressed here. If adopted, climate policy frameworks will determine costs to our customers, flexibility in achieving greenhouse reductions, and linkages to or coordination with other emitting sectors. Xcel Energy will continue to advocate for climate strategies that achieve greenhouse gas reductions at the lowest possible cost to customers while maintaining reliability. Since many IPCC scenarios envision significantly increased electricity use in transportation, buildings and industry in order to achieve economy-wide reductions, keeping electricity affordable will be crucial.
- The achievability and cost effectiveness of any greenhouse gas goal will also depend on how technology evolves, which we cannot predict for 2050 or even 2030. Our carbon transition will depend on a mix of renewable energy, energy storage, carbon-free dispatchable technologies and flexible demand that could enable us to achieve deep carbon reductions affordably and reliably.

Reporting and **Measuring Progress**

As an energy provider, we emit greenhouse gases as we provide electricity to our customers. The primary source of these emissions is from the combustion of fossil fuels to generate electricity, which makes up 99 percent of our total greenhouse gas emissions. Nearly all of our generation-related emissions are carbon dioxide. Because of this, it makes sense that we focus our strategy, goals and reporting on reducing carbon emissions.

The carbon emissions discussed in this report and other Xcel Energy reporting are from electric generating plants that we own and from electricity that we purchase from others. Xcel Energy sells a small portion of the electricity we generate into the market, and the carbon emissions from these off-system sales are excluded from our goal and goal reporting because the energy does not serve our customers. Also, it is likely that many companies purchasing the energy account for the emissions in their reporting, so including them in our reporting could result in double counting.

Our goal to reduce carbon emissions 80 percent by 2030 is based on absolute, company-wide emissions from the electricity that serves our retail and wholesale customers, measured from a 2005 baseline. Likewise, our aspiration to serve customers with carbon-free electricity by 2050 is company-wide.

Xcel Energy supports timely, transparent public reporting of carbon dioxide and other greenhouse gas emissions. Our comprehensive greenhouse gas reporting, from all parts of our business, is based on The Climate Registry and its Electric Power Sector Protocol, which aligns with the World Resources Institute and ISO 14000 series standards. Our company joined The Climate Registry as a founding member in 2007 to help establish a consistent and transparent standard for calculating, verifying and reporting greenhouse gases. Through The Climate Registry, we annually third-party verify, register and publicly disclose our greenhouse gas emissions.

Managing the Risks Associated with **Climate Change**

Over the next several decades as we make our carbon transition, we will continue to monitor and take steps to mitigate any risks along the way. Changing weather patterns, extreme weather conditions and other events, such as flooding, droughts, wildfires and snow or ice storms, can all impact our system in terms of system operability, customer demand, revenues, cost recovery and the health of regional economies.

We rely on routine business processes to identify and address these types of risks and emerging challenges. These include our risk management, resource planning and daily operations, as well as our continuous improvement and innovation initiatives.

Integrated Risk Management

Our integrated, multi-disciplinary risk management process creates accountability for managing risk across the company — from employees who are responsible for business compliance and adhering to our Code of Conduct, to senior executives and the board of directors who oversee risk management. Annually, executive leadership conducts a key risk assessment, considering materiality, timing and likelihood and controllability of risks. Management also identifies and analyzes risk through its business planning process and development of goals and key performance indicators, which include risk identification to determine barriers to implementing our strategy. While the assessment is broad, it includes the operational, policy and weather-related risks potentially associated with climate change. Findings are presented to the board of directors, which assigns oversight of critical risks among the board's four standing committees to ensure they are well understood and managed on an ongoing basis. We provide more information on our risk management process, including discussion of climate-related risks, in Xcel Energy's annual form 10-K.

Resource Planning

Our resource planning process is designed to manage capital-intensive investments over decades-long time horizons. Through this regulated process, we evaluate a range of scenarios and stress test our energy portfolio against important variables, including fuel prices, renewable energy and storage costs, transmission constraints and a variety of others. We use load forecasts to account for changing weather patterns, a key variable in explaining actual loads and in forecasting future loads. Load forecast sensitivities can also ensure our portfolio is sufficient to meet different needs created by electrification, which is likely to become more prevalent in a carbon-constrained future. Our resource planning also considers the costs and risks of potential carbon regulation and potential damages from climate change by applying a carbon proxy, allowing regulatory costs, and in some cases, externality damages to be considered in selecting resources.[14]

Operations

Maintaining reliable and resilient operations across generation, transmission and distribution means we constantly prepare for the unexpected. We use a suite of techniques to maintain a resilient system from water management to emergency preparedness. For example, our Monitoring and Diagnostics Center watches the operation of major generating units in real time, identifying potential issues before they occur. We also have predictive analytics and software tools that help avoid plant failures and can even address issues which may result in higher emissions or compromise reliability. Further, we have specific procedures in place to deal with extreme weather, flooding, drought or other conditions that may impact the operability of our plants. To better understand and address climate-related vulnerabilities on our system, we joined the Department of Energy's Partnership for Energy Sector Climate Resilience to work with others in the industry.

A Focus on Grid Resiliency

We continually invest and innovate to maintain and improve the resiliency of our energy grid. The following are several highlights from the many programs we are implementing to address potential system risks.

Under our Advanced Grid Intelligence and Security (Advanced Grid) program, we are upgrading the energy grid to better serve customers and enhance our ability to efficiently restore power and improve reliability. The program builds a platform that provides enhanced visibility and control of the energy grid through the integration of modern information system technology and traditional distribution systems.

In addition to maintaining emergency plans at all of our power plants and planning for extreme weather, we are also focused on successfully managing major storm events, responding quickly and providing information to customers as we restore service. The Edison Electric Institute has recognized Xcel Energy multiple times with its Emergency Recovery Award for outstanding storm response. These efforts extend beyond our service territory, with our crews on standby to help with recovery efforts across the country when hurricanes or other natural disasters strike.

To better integrate high levels of renewable energy, we have deployed sophisticated modeling tools to better dispatch our system. Working with the National Center for Atmospheric Research and its affiliate company Global Weather Corp., we helped develop the Wind WX system that utilities around the globe now use to make better commitment and dispatch decisions. It uses real-time, turbine-level operating data and applies sophisticated algorithms to forecast the amount of wind power that will be produced. Forecasts for a 168-hour period are provided every 15 minutes across Xcel Energy's entire service territory. As we integrate more solar on our system, we are working on similar innovations for solar forecasting.

Our vegetation management program is generally performed on a four- to five-year cycle for our distribution and transmission lines. In Colorado, we have established a Mountain Hazard Tree Program that helps us stay ahead of the tree mortality caused by Mountain Pine Beetles.

Since we provide electricity in drought-prone areas, water is a precious resource that we must carefully manage. A co-benefit of our transition to renewable energy is that we are also lowering our water footprint. Beyond this, we have a comprehensive water management program to minimize the risks of continued water usage, including innovative partnerships to access water during extreme drought periods. For example, we use treated effluent to cool power plants in Texas and New Mexico. This effluent is water that would otherwise not be used and is available during drought.

Opportunities to Lead the **Carbon Transition**

Utilities can play a key role in helping solve the challenges of climate change. According to the Energy Information Administration, the electric power industry collectively reduced carbon emissions 28 percent from 2005 to 2017.[15] This includes Xcel Energy's progress — having reduced emissions 38 percent already, we have plans underway to achieve more, as explained in this report.

As an industry leader in renewable energy and reducing carbon emissions, we have a strategic advantage in continuing to lead this transition. We have been able to provide scalable solutions to reduce the carbon footprint of the energy we provide, while continuing to deliver energy in a manner that is safe, reliable and affordable. As we continue to implement solutions to address emissions across our system, we can also provide customers with options to reduce their carbon emissions and help other sectors reduce carbon through strategic electrification.

Investing for the Future to Reduce Emissions

We must achieve our carbon transition while maintaining a modern, viable electric system, which is dependent on our ability to attract capital and investors. Transitioning to cleaner sources of energy to achieve our carbon reduction goals should consider utility ownership of replacement resources, as we need our investors to support this transition. Our capital plans also envision the need for additional transmission and advanced grid technology. By investing in these assets, we can improve service to our customers, introduce new options and support greater reliability and flexibility in the way energy is delivered. This financial component is important to our plans.

Xcel Energy operates in regions with some of the best wind and solar resources in the United States, and we are capitalizing on this. Our Steel for Fuel strategy calls for adding renewable resources at a net savings because the capital costs of projects are more than offset by future avoided fuel costs. Customers benefit from the clean energy that also helps to keep their electricity bills low.

These renewable projects are just one component of the resource plans that determine new investments. Through the resource planning process with state regulators, we develop comprehensive, cost-effective plans to transform our system, serve customers and advance our transition to clean energy.

Empowering Customers to Reduce Carbon Emissions

We know customers want cleaner energy and more renewable options, but also expect electricity that is affordable and reliable. The great advantage of our system-wide clean energy transition is that all customers are receiving lower-carbon electricity over time — our reductions are their reductions — at an affordable cost.

Some of our customers — from residential customers to corporations and cities — desire to go further faster, accelerating the system transition by setting goals to meet up to 100 percent of their own demand with renewable electricity or to reduce their overall emissions. To meet this demand from customers, we provide an increasing array of voluntary renewable choice products, including cost-effective options to procure up to 100 percent renewable electricity and a comprehensive portfolio of industry-leading energy efficiency programs.

Through our 2030 and 2050 carbon reduction vision, we can further help customers achieve their goals. They will continue to reduce the portion of emissions from their electricity consumption, while we transition our overall system to a diverse mix of cost-effective, low-carbon and carbon-free generation resources.

In addition, we expect that our planned investments in technologies to modernize the energy grid will enable us to deliver new solutions for customers and create a flexible energy grid that allows for two-way power flows from customer-connected devices or distributed energy resources.

Electrification of our Economy

As the nation's electricity supply becomes cleaner, attention has increasingly turned to other sectors of the economy to address climate change.

The transportation sector is now the nation's leading source of greenhouse gas emissions according to the Energy Information Administration.[16] This also applies to the states Xcel Energy serves. For example, data from Minnesota indicates transportation has surpassed electricity as the leading carbon emitter, and that carbon emissions from transportation are declining far slower than electricity — a clear indicator of the opportunity for transportation electrification.[17]

We believe that strategic electrification of certain end uses will be a key component — though not the only solution — for achieving economy-wide greenhouse gas reduction goals. If we continue to electrify transportation and power vehicles with carbon-free electricity by 2050, we can help address the climate challenge for that sector.

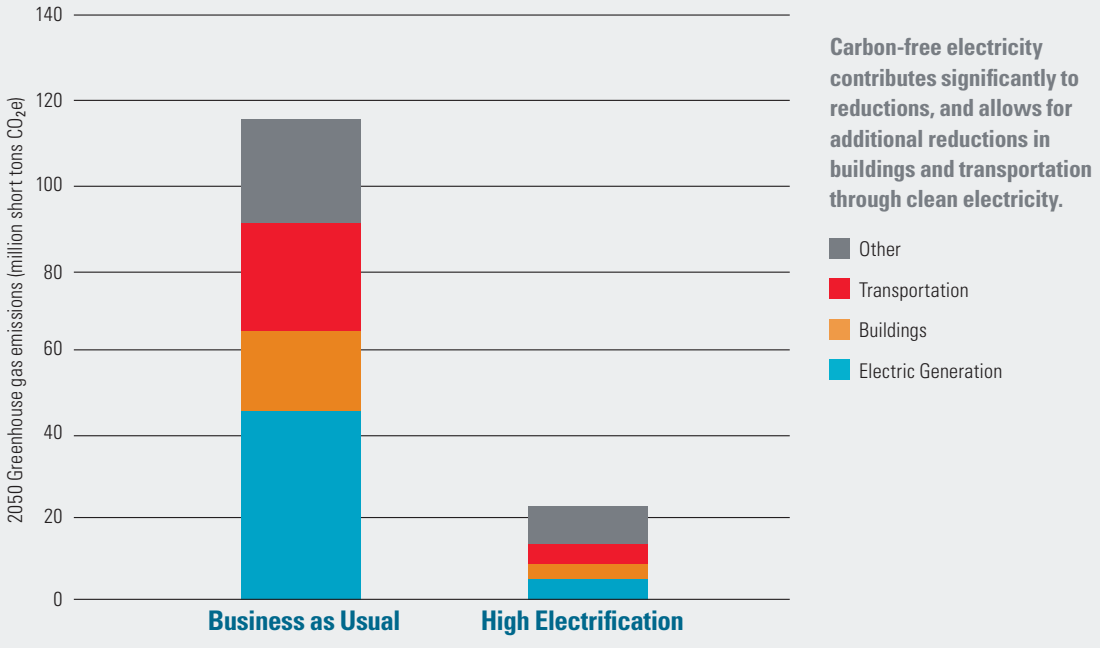
Low-carbon electricity and electrification: a Minnesota example

Removing carbon from electricity and electrifying other parts of the economy can be mutually reinforcing. Low-carbon electricity allows transportation, buildings and other major emitting sectors to reduce emissions. At the same time, flexible loads, such as electric vehicles and appliances that can charge at times of high renewable generation, may allow us to integrate more renewable resources than we could otherwise.

Xcel Energy engaged Energy+Environmental Economics (E3) to explore the feasibility of deep carbon reductions, both for the Xcel Energy system and for Minnesota statewide. E3 created a Minnesota PATHWAYS model looking at how the state could achieve its statutory economy-wide goal to reduce greenhouse gas emissions 80 percent from 2005 levels by 2050, with a primary focus on electricity, transportation and buildings.

The chart below illustrates this potential, focusing on 2050. It compares a business-as-usual scenario in which carbon is not reduced from electricity, and there is little or no electrification of other sectors, to what could be achieved in a "high electrification" scenario designed to meet the state's economy-wide 80 percent reduction goal. In this scenario, virtually all vehicles, space heating and water heating switch to electric alternatives by 2050. To supply these new loads, total statewide electricity demand in 2050 is 60 percent higher than 2015. Meanwhile, the electric sector reduces carbon, supplying over 90 percent carbon-free electricity in 2050. As a result, direct carbon emissions from electricity are reduced by about 40 million tons, as shown by the blue bars. Emissions from buildings, transportation and other sectors also decrease dramatically, with electrification enabling 35 million tons of that reduction through low-carbon electricity. Just as electricity is an essential service, natural gas service is as well, as it plays a critical role in keeping our customers comfortable and safe. When we review these options, we need to keep the affordability of space heating a primary objective along with the affordability of our electric business.

Carbon Reductions in the Electric Sector Drive Compounding Reductions throughout the Economy



Credit: Energy+Environmental Economics.

Xcel Energy's Electric Vehicle Strategy

The future of transportation is dramatically changing to include more electric-powered transportation options than ever before — as well as more autonomous features in vehicles and new (often shared) mobility services. Utilities are uniquely positioned to work with customers, communities and electric vehicle (EV) stakeholders to ensure this change benefits all customers, the environment and the energy grid that we all rely upon.

Through our current EV strategy, we are focused on:

- Making it easier for customers — from individual households to public and private sector fleets — to adopt EVs
- Creating the infrastructure needed to charge EVs
- Establishing time-varying rates and technological controls to ensure that EVs can charge as much as possible on low-cost, low-carbon energy

While EVs create a significant opportunity for drivers and fleet operators to save on fuel and other costs, barriers exist to wider-scale adoption, such as customer awareness, high up-front costs and the availability of charging infrastructure. Our plans will help overcome these barriers by developing new services, piloting them and then rolling out our most successful ideas to customers on a broader scale.

In Minnesota, we are engaging customers who are interested in adopting electric vehicles and buses. We hope to better understand their needs and barriers to adoption so we can work collaboratively toward solutions that could benefit all customers down the road. We expect these discussions will provide opportunities for us to pilot a variety of solutions that will inform our stakeholders and policy makers so we can scale solutions best suited to benefit all Minnesotans in the coming years.

As we pursue our EV Plan, we are focused on these objectives:

- Empower customers with information, tools and options
- Increase access to electricity as a transportation fuel in an equitable manner
- Encourage efficient use of the power grid and integrate renewable energy
- Improve air quality and decrease carbon emissions
- Ensure reliability, interoperability and safety of equipment
- Leverage public and private funding opportunities
- Provide benefits to all customers, both EV drivers and non-EV drivers
- Ensure transparency and measure results

Driving **Change**

By mid-century, we aspire to serve customers with carbon-free electricity. Even though this goal is decades away, we are a long lead time business and should begin now to identify and address the barriers to reaching it — especially if we are to maintain the affordable, reliable service that customers need and expect.

After reviewing national and international studies on climate change and through our going work with stakeholders, we believe reducing carbon emissions reliably and affordably is a top priority and must be the primary focus of our clean energy transition. To effectively achieve this shared objective, we must remain disciplined and concentrate on those efforts that produce the greatest carbon reductions at the lowest cost to customers.

We are optimistic that by staying focused we can make this transition and have identified the following drivers that will make the change possible:

- Protect energy reliability and affordability
- Support from our states and stakeholders
- A constructive policy environment and framework
- Availability of cost-effective, carbon-free dispatchable technologies

While our vision is ambitious, we believe these drivers implemented together will make it possible to transform our operations and the industry overall. Our plan is to continue working proactively and collaboratively in all these areas and to advance the solutions that emerge.

Protect Energy Reliability and Affordability

Cost is a major consideration for our clean energy strategy, and so far, we have successfully reduced carbon emissions while keeping energy costs low for customers. In fact, the average Xcel Energy residential customer electric bill has decreased 3 percent in the past five years. Our residential electric bills are on average about $28 lower per month than the national average. In our largest service territories, Minnesota and Colorado, customer electric bills are 22 percent and 36 percent below the national average respectively. We must continue to develop and invest in cost-effective transformative plans and in technologies with proven economic value for customers.

Energy reliability is also a fundamental requirement. Today, we are achieving far greater levels of renewable energy on our system than the industry ever believed possible. There are hours on our system when renewable generation delivers more than 50 percent of customers' electricity, and at the end of 2018, we achieved an hourly renewable generation record of 72 percent on our Colorado system. We expect these hourly records to increase under our current plans, we project that renewables will generate almost half of our power on an annual basis by 2021. As we deploy more renewable energy resources, managing the stability and reliability of the energy grid becomes increasingly difficult with fewer resources that can be dispatched to manage the variability of wind and solar energy. We will be focused on how to make sure that we take care to have sufficient resources to meet swings in load and generation as our integration of more renewable energy becomes more challenging.

Support from our States and Stakeholders

By working with the states we serve, we have successfully executed our clean energy strategy and plans.

Our four operating companies work under regulated conditions largely determined by state public utilities commissions. Every few years, we go through a process to determine the resources necessary to serve customers' future energy needs. This state resource planning process is critical to ensuring reliable energy and maintaining reasonable customer bills. Our carbon vision is not a single resource plan. Implementing our clean energy transition and achieving our goals will happen through many iterations of resource planning before our state utilities commissions between now and 2050.

Stakeholder participation is an important component to resource planning, and stakeholder support is essential to our clean energy progress. We will continue constructive engagement with our customers, investors, regulators, environmental groups, community leaders, policy makers and others to develop solutions and implement plans to achieve our goals.

We believe this model of state leadership can go even further in driving cost-effective emission reductions and clean energy investment. If advanced, federal policy should encourage utilities to work with states and invest as the conditions are right — when customers and the economics and technology are ready and without imposing significant, unnecessary costs on utility customers.

A Constructive Policy Environment and Framework

We are proving that the vertically integrated utility model with regulatory oversight is a cost-effective way to transition the energy system and achieve significant carbon reductions. This model provides inherent system value through efficiency, optimization and economies of scale that benefit all customers. It also balances the allocation of risks and benefits between the utility, its customers and even different customer classes.

Every customer on the energy grid shares in the transition to clean energy and can credibly claim the same carbon reduction. Policies that enable large businesses to sign direct contracts with renewable developers, may help individual companies to achieve their goals. However, they do not provide all customers with affordable, carbon-free energy and may even result in a more expensive energy system overall.

We have seen remarkable examples of the transformation that is possible and know from experience that our ambitious carbon transition is achievable if stakeholders and policy makers continue to recognize the economic and environmental benefits that utilities provide. As we continue this transition and go above and beyond in reducing carbon emissions, there may be opportunities to provide appropriate incentive to encourage and reward the industry's progress toward carbon reductions economy-wide.

Large-scale, universal resources — conventional, renewable and advanced — are by far the most cost-effective electricity generating resources available. While distributed energy resources are important for customers who want to invest in them and may play important roles at the distribution system level, these resources cannot accomplish what large-scale resources do in terms of carbon reduction at scale. Public policy should recognize the economic benefits that large, universal resources provide to achieve our ambitious goals affordably and reliably for customers. Hidden and unfair subsidies to support high-priced resources only serve to increase the cost of clean energy and reduce the ability of the nation to make this transition.

Similarly, nuclear generation plays a vital role in our carbon transition and provides a significant portion of our carbon-free energy in the Upper Midwest. We need policies at the state and federal levels that allow us to continue the cost-effective operation of these important assets at least through the end of their current operating licenses.

We must also address emissions from fossil plants, especially from our remaining coal generation. We need policies that support coal operations which reduce emissions and offer investment recovery for the remaining value of coal plants which retire early. We also need help to minimize the impact on communities that depend on these plants.

All of these resources belong to the larger energy grid, which is enabling our carbon transition. As stewards of the grid, utilities own, operate and maintain this asset; raise and deploy capital to finance its growth and operation; and work with regulators to manage the risks associated with investments made on behalf of customers. Regulatory policy should ensure utilities continue to perform these critical functions to maintain the reliability, security and resilience of the energy grid during this transition.

Availability of Cost-effective, Carbon-free, Dispatchable Technologies

New cost-effective technologies have enabled our company and industry's progress in transitioning the nation's generating fleet and reducing carbon emissions. For at least the next decade, existing wind, solar, battery and natural gas technologies will continue to serve a growing portion of our energy needs while reducing carbon emissions and saving our customers money.

However, renewable generation and storage alone face significant technical and economic challenges if relied on exclusively to achieve carbon-free electricity. For example, the relatively short duration energy storage available today and anticipated in the future does not address seasonal challenges that arise when a system dependent on renewable resources experiences several days or weeks with low wind or solar generation. Even with continually declining prices, variable wind and solar resources are expected to provide diminishing value at high saturations. Fully relying on renewable sources could result in a costly overbuilding of the system where each incremental megawatt provides less capacity value, renewable curtailments reach high levels and massive investments in transmission and storage are required.

We need a suite of new, carbon-free resources that can be dispatched to complement our continued adoption of renewable energy, energy efficiency and demand response. Our research shows that these new resources will be the key to achieving a carbon-free generation fleet without a costly overbuilding of the energy grid. Others studying this issue have reached similar conclusions, including the MIT Energy Initiative, Energy+Environmental Economics and Vibrant Clean Energy.[18] These technologies may include carbon capture and storage, power to gas, seasonal energy storage, advanced nuclear or small modular reactors, deep rock geothermal and others not yet imagined.

Each of these options holds promise, but they will require considerable investment and further research and demonstration to become viable solutions at the cost and scale at which the electric sector will need them. Federal and state policies must support this development. We can also send clear signals to the market around price, capabilities and timing for when these technologies will be needed. In this way, utility resource plans provide the market signal — the "technology pull" — from which the private sector and national laboratories and federal agencies can align their investments, research and assets.

Conclusion

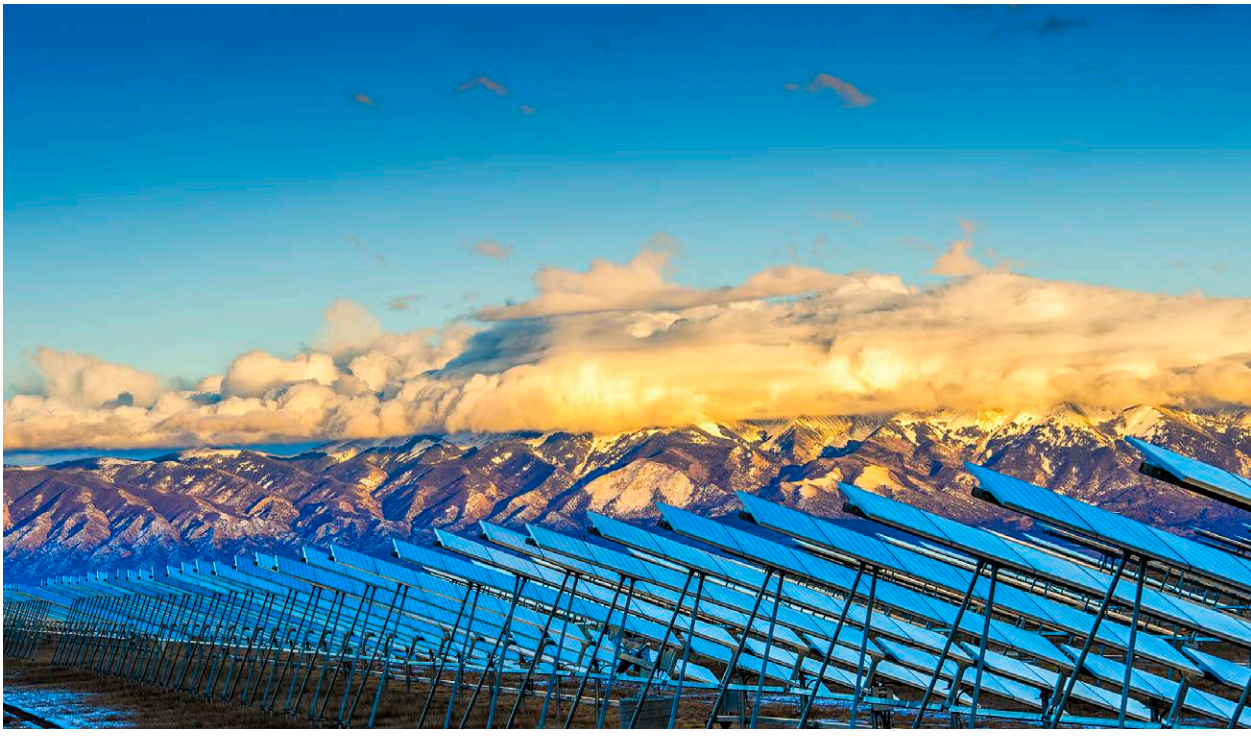
The finish line is clear — we aim to serve all customers by 2050 with carbon-free electricity. Through our analysis with the University of Denver, we are confident that both our interim and 2050 goal are the right goals for our customers but also to help limit warming to 2 C and possibly even 1.5 C.

Our vision is just the start. We will begin work now even though 2050 is decades away. Today, the technology and market exists to reach our interim goal and reduce carbon emissions 80 percent by 2030, but significant changes are needed to achieve reliable, affordable carbon-free electricity to serve our customers. We look to our partners to help us drive the advancements in technology and constructive policy to make it happen. While there may be differences of opinion around the details of how we get there, we are all in the same race together to reduce and eventually eliminate carbon.

Reducing carbon emissions should be the ultimate and shared objective. We must remain focused on this outcome and the drivers that will get us there as efficiently and cost effectively as possible.

As we work to make this vision possible, we will position our company and customers for success in a low-carbon future and provide greater long-term value for all stakeholders. We believe we can manage both the risks and capture the opportunities presented by this transition, and in the end, provide what our customers and other stakeholders want and need from us.

We are optimistic that through collaboration and with ingenuity and innovation, we will realize our vision for a carbon-free energy future.



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1 A summary of the Paris climate agreement, ratification status and text of the agreement are available at https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

2 IPCC Special Report, Summary for Policymakers, page SPM-4.

3 IPCC Special Report, Summary for Policymakers, pages SPM-15 to SPM-24, and EPRI analysis of IPCC Special Report.

4 U.S. Global Change Research Program, Volume II: Impacts, Risks, and Adaptation in the United States - Report-in-Brief. Chapter 29, Reducing Risks through Emissions Mitigation, page 168. Available at https://nca2018.globalchange.gov.

5 EPRI is a non-advocacy, nonprofit, scientific research organization with a public benefit mandate. See http://eea.epri.com/ and www.epri.com/sustainability to learn more about EPRI's efforts to better understand the technical dimensions of company climate scenario analysis and GHG goal setting.

6 EPRI focused on the 2 C goal because the IPCC's AR5 database is the largest source of peer-reviewed scenarios available with over 1,000 scenarios. The IPCC Special Report on Global Warming of 1.5 °Celsius, and accompanying emission scenario database, were not available at the time EPRI began its work. As discussed in the EPRI study, 2 C pathways are extremely challenging — geophysically, technologically, economically, and politically — which creates uncertainty about their attainability. Uncertainty about the attainability of 1.5 C pathways is even greater.

7 Negative emissions technologies include biomass energy with carbon capture and storage, large-scale afforestation, direct air capture or other technologies yet to be developed. All face significant technology, cost, land use and social constraints at present.

8 IPCC, 2018: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press. Hereafter, "IPCC SR 1.5 C."

9 Huppmann, D. et al. IAMC 1.5°C Scenario Explorer and Data hosted by IIASA. Integrated Assessment Modeling Consortium & International Institute for Applied Systems Analysis, 2018. doi: 10.22022/SR15/08-2018.15429 | url: data.ene.iiasa.ac.at/iamc-1.5c-explorer.

10 These categories follow the grouping used in the IPCC report in ref. 1. The lower likelihood of achieving the target in the 1.5 C case (50 percent) is used because of the difficulty of achieving it with higher likelihood. "Slightly exceeding" the target is defined as staying below 1.6 C.

11 We use the phrase "industrialized countries" to refer to the region defined in the IPCC database as "OECD90+EU," which contains countries that were members of the OECD as of 1990, as well as current EU member countries and candidates. Note this does not include Russia and other members of the Former Soviet Union (the "REF" region in the database). Specific countries included are: Albania, Australia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Macedonia, Montenegro, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America.

12 See IPCC Special Report, Summary for Policymakers, page SPM-21: "Pathways limiting global warming to 1.5°C with no or limited overshoot would require rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems (high confidence). These systems transitions are unprecedented in terms of scale, but not necessarily in terms of speed, and imply deep emissions reductions in all sectors, a wide portfolio of mitigation options and a significant upscaling of investments in those options (medium confidence)… The rates of system changes associated with limiting global warming to 1.5°C with no or limited overshoot have occurred in the past within specific sectors, technologies and spatial contexts, but there is no documented historic precedent for their scale (medium confidence)."

13 Xcel Energy carbon emissions targets and limiting warming to less than 2 degrees C. Brian O'Neill and Steve Hedden, December 31, 2018. Frederick S. Pardee Center for International Futures - Josef Korbel School of International Studies at the University of Denver.

14 Under integrated resource planning statutes in Minnesota, utilities must apply both a range of proxy prices for future carbon dioxide regulatory costs, and ranges for externality damages for carbon dioxide and other pollutants. Under Colorado public utilities commission rules, utilities apply carbon dioxide regulatory costs; there is no general requirement to apply carbon dioxide externality values, but Xcel Energy in its latest Electric Resource Plan cycle was ordered to include a sensitivity using an externality value.

15 See https://www.eia.gov/todayinenergy/detail.php?id=37392.

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