

APPENDIX P1 – E3 SUMMARY

I. OVERVIEW OF ANALYSIS CONDUCTED BY ENERGY AND ENVIRONMENTAL ECONOMICS

We retained Energy and Environmental Economics, Inc. (E3) to provide analysis to inform our Resource Plan. E3 is a recognized industry-leading firm based in San Francisco and consults extensively with utilities, developers, government agencies, and environmental groups on clean energy issues. E3's experience analyzing the impacts of economy-wide decarbonization and the impacts of decarbonization on utility systems in other parts of the country was very valuable to us in evaluating the impacts of decarbonizing our Upper Midwest System and developing our Preferred Plan.

E3's analysis is provided in two reports. The first report provides their analysis on decarbonizing our Upper Midwest System (System Study). For this analysis, E3 performed an electricity portfolio optimization analysis that identifies a range of strategies to meet our greenhouse gas reductions goals. The second report provides E3's analysis on achieving the Minnesota economy-wide goal of an 80 percent reduction in greenhouse gases below 2005 levels by 2050 (Pathways Study). E3 presented its analysis at stakeholder workshops in September and October of 2018 and April 2019.

A. Upper Midwest System Study

For the System Study, E3 performed independent modeling and analysis of our system to inform our Resource Plan using two models:

- The RESOLVE model, which evaluates and optimizes the least-cost portfolios of resources to meet system demand considering carbon and other constraints,
- The RECAP model, which evaluates the reliability of electric energy and system capacity of the optimized resource portfolios over thousands of simulated weather years.

E3 used scenario analysis to examine the impacts of achieving deep carbon reductions in our generation portfolio in accordance with our long-term goals. Each scenario examined was designed to achieve carbon reduction milestones of 85% below 2005 levels by 2030 and 95% below 2005 levels by 2045. As discussed in detail in the report, these scenarios varied assumptions on the retirement of our nuclear and coal plants and the ability to add new gas-fired resources, the impacts of high electrification, gas prices, technology costs, and the ability to sell surplus generation into the MISO market.

The System Study contains several key findings that inform our Resource Plan:

- 1. The study suggests that we can achieve substantial reductions in carbon emissions from our Upper Midwest portfolio at relatively low cost.**
Across the 21 scenarios examined in this study that achieve deep carbon reductions during the study horizon, the lowest-cost scenarios reduce carbon at a levelized cost of \$15-20 per ton. The ability to achieve such large emissions reductions at such a relatively low cost results from several converging factors: (1) low natural gas prices, which enable low-cost fuel switching from coal to gas; (2) the relatively low (and falling) costs of new wind and solar resources due to technology improvements over the past decade; (3) a potential to increase deployment of energy efficiency and other demand-side programs to manage load growth; and (4) anticipated reductions in future battery storage costs, which enable integration of high penetrations of renewable generation.
- 2. The lowest-cost near-term opportunity to reduce carbon in Xcel's Upper Midwest system is to replace coal generation with a combination of renewables, storage, natural gas and efficiency.** E3's analysis suggests that accelerating the retirement of our remaining coal plants and replacing them with a portfolio of efficiency, renewables, storage, and natural gas generation provides the least-cost pathway to reducing emissions consistent with our 2030 goals.
- 3. A diverse portfolio of resources—including nuclear—offers the least-cost long-term pathway to deep carbon reductions.** The scenario analysis conducted in this study suggests that under most circumstances, extending the licenses of both Monticello and Prairie Island to allow continued operation provides a least-cost option to meeting long-term carbon goals. This is due not only to the plants' ability to generate carbon-free electricity at relatively low cost but also, and perhaps more significantly, to the fact that nuclear generation (unlike wind, solar, or energy storage), as a "firm" resource, can generate at its full nameplate capacity for sustained periods when needed to meet reliability needs. This unique combination of characteristics makes existing nuclear plants inherently valuable to meeting our long-term carbon goals. All else equal, levelized cost of carbon abatement was higher in scenarios that did not allow nuclear relicensing.
- 4. While new resources like wind, solar, and storage will play a central role in supplying carbon-free energy to Xcel's customers, these resources alone cannot meet Xcel's resource adequacy needs at reasonable costs.** The reliability analysis conducted in the study highlights the limitations of renewable and storage resources to meet resource adequacy needs: due to

variability of renewable generation and limits on duration of energy storage with today's technologies, these resources offer less capacity value than firm resources that can produce at full capacity when needed. Further, because their marginal capacity value declines with increasing penetration, wind, solar, and storage offer a relatively poor substitute for traditional firm capacity resources in meeting reliability needs at scale. Taken to an extreme, this study shows that a system designed to rely solely on renewables and storage to meet reliability needs would require prohibitively large investments. These findings underscore the need for an evolving approach to resource adequacy as the system as a whole incorporates greater amounts of renewables and storage. Such an approach would ensure that sufficient resources are available even when variable renewables and storage alone cannot produce sufficient levels of generation to meet load.

- 5. Natural gas plants will be useful to ensure a reliable system but will operate at low capacity factors.** Some form of firm, dispatchable capacity is likely necessary to complement large anticipated investments in efficiency, renewables, and storage that will be necessary to decarbonize Xcel's energy supply. **Error! Reference source not found.** shows that among all low-carbon scenarios considered in this study, the least-cost options rely heavily on firm capacity resources to meet resource adequacy needs. In Xcel's case, investing in 2,000 to 4,000 MW of new gas generation capacity will lower the costs of achieving long-term carbon goals. All else equal, the levelized cost of carbon abatement was higher in scenarios that did not allow new gas. In the extreme, providing reliable electricity in a scenario with no dispatchable gas was modeled to require 36 GW of wind and solar, 24 GW of storage, and impose \$4.4 billion per year in incremental fixed costs. As technology continues to improve, some of the electricity system values provided by gas generation may be able to be provided by a combination of longer-duration storage, demand response, and carbon-free dispatchable technologies that are not commercial today.

B. PATHWAYS Study

For the PATHWAYS study, E3 developed a set of long-term economy-wide, deep decarbonization scenarios for the state of Minnesota. These scenarios provide an exploration of the cross-sectoral implications of meeting economy-wide carbon reduction goals, and highlight the role of Xcel Energy, and the electric sector as a whole, in meeting the state's economy-wide carbon goal. The PATHWAYS study highlights the central role of the electric sector in reducing economy-wide greenhouse gas emissions by supplying clean energy to new loads as more fossil-fueled end uses convert to electricity.

Key finds from the PATHWAYS study include:

1. **Electrification and low-carbon electricity are necessary (but not sufficient) to reach statewide goals.** The analysis demonstrates how increased reliance on low-carbon electricity enables emission reductions by avoiding direct combustion of fossil fuels in households, businesses, and vehicles across a number of scenarios. Under a high electrification scenario, switching multiple end uses to very low-carbon electricity could enable an estimated 35 million tons of CO₂ reductions per year in other sectors by 2050, in addition to reductions in the electric sector itself.
2. **Buildings and transportation have significant potential to drive load growth, especially after 2025.** The analysis also highlights the significant potential for adoption of new electric appliances and vehicles, and the potential impact on total electricity requirements for Minnesota utilities. Transportation and building electrification drive electric load growth, especially after 2030, particularly in a future with constraints on bioenergy. Electrification of space heating has a particularly large impact on both total load (MWh) and peak demand (MW), primarily due to two factors: cold-climate efficiency challenges with electric air source heat pumps, and the greater difficulty (compared to electrified transportation or water heating) of limiting heating loads to off-peak hours.
3. **Reasonable electric rates and low costs for new electric devices are essential for electrification.** The levels of electrification modeled in buildings and transportation are dependent on consumer adoption, which will benefit from reductions in capital costs and reasonable electric rates, even as the electric grid continues to decarbonize.

C. Relation to the Company's Resource Plan Analysis

By design, the scope of analysis conducted in E3's System Study overlaps considerably with the internal analysis conducted to develop our Preferred Plan. Wherever possible, the E3 studies relied on the same numerical inputs and assumptions as used to develop our Preferred Plan, supplemented by publicly available data sources where necessary. This approach was chosen to test the hypothesis that Xcel's internal analysis should generally align with the results obtained by an unbiased third-party using rigorous industry-standard approaches.

The PATHWAYS study provides context for the role of the electricity sector in reducing statewide carbon emissions. The PATHWAYS study explores scenarios that

could achieve an 80 percent reduction in economy-wide greenhouse gas emissions, but it is not a least-cost optimization. As discussed in Appendix F4, the PATHWAYS study was also used to develop a high electrification load forecast sensitivity that was analyzed in E3's System Study and our Strategist modeling.