AMERICAN EXPERIMENT

THE HIGH COST OF 100 PERCENT CARBON-FREE ELECTRICITY BY 2040

Governor Walz's Proposal Would Cost Minnesota $313 Billion Through 2050 and Lead to Blackouts.

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Executive Summary

- Minnesota Governor Tim Walz's proposal for a 100 percent carbon-free electric grid by 2040 will cost Minnesota families and businesses an additional $313.2 billion (in constant 2022 dollars) through 2050, compared to operating the current electric grid.
- Minnesota electricity customers will see their electricity expenses increase by an average of nearly $3,888 per year, every year, through 2050.
- According to the economic modeling software IMPLAN, higher electricity expenses under the Walz Proposal would cost Minnesota more than 79,000 jobs and reduce the state's annual gross domestic product (GDP) by $13.27 billion each year, the equivalent of 3.2 percent of the state's 2021 GDP.
- The Walz Proposal would reduce the reliability of the grid by making the state more vulnerable to fluctuations in output from weather-dependent energy sources like wind and solar.
- Under the Walz Proposal, the electric grid would experience capacity shortfalls, meaning there is not enough electricity on the grid to prevent blackouts in two of the three years studied due to weather-driven fluctuations in electricity generation from wind and solar facilities.
- Shockingly, Minnesota would experience a devastating 55-hour blackout in late January if wind and solar output is the same as it was in the year 2020, and electricity demand was the same as 2021.
- This blackout would result in nearly $1.77 billion of lost GDP, and countless billions more in damaged property from furnace failures and frozen pipes, not to mention the human cost of people being dislocated from their homes to keep warm or dying from hypothermia or carbon monoxide poisoning.
- In contrast, a Lower-Cost Decarbonization (LCD) energy portfolio, focused on providing reliable, affordable electricity while also decarbonizing 98 percent of the electric grid with nuclear energy, coal plants fitted with carbon capture and sequestration equipment, hydroelectric power, and battery storage, would cost $224 billion less than the Walz Proposal.
- No blackouts would occur in this diverse LCD portfolio in any year studied.
- According to the economic modeling software IMPLAN, higher electricity expenses would cost Minnesota 22,000 jobs under a LCD Scenario, and reduce the state's annual GDP by $3.8 billion, approximately one percent of the 2021 total.
- Minnesotans would benefit most from investing in reliable electricity generation technologies, which provide superior reliability value at a fraction of the cost of the Walz Proposal.
- Both proposals reduce emissions at a cost that is higher than the Social Cost of Carbon estimates created by the Obama administration, meaning the costs of reducing emissions exceed the benefits. It is better to do nothing than implement either of these plans.

Authors' Note*:* This report is a continuation of the work performed by Center of the American Experiment modeling the cost of renewable energy mandates in states throughout the country. Portions of this report have been repurposed and modified to reflect Governor Walz's proposal of reaching 100 percent carbon-free electricity by 2040.

Policy Recommendations

Our research leads us to seven common-sense policy recommendations that would reduce the cost of electricity in Minnesota and offer more affordable, and more effective, options for reducing carbon dioxide (CO_2) emissions than renewable energy sources such as wind and solar. If adopted, these recommendations would save Minnesota electricity consumers billions of dollars in the coming decades.

1. **Legalize the construction of new nuclear power plants in Minnesota:** Minnesota state law has prohibited the construction of new nuclear power plants since 1994. If Minnesota lawmakers want to show true leadership on reducing CO_2 emissions, they should seek to provide the greatest and most sustainable reduction in emissions for the lowest possible cost. Ending Minnesota's nuclear ban is the only way to provide reliable, affordable, emissions-free electricity.

2. **Start a nuclear study committee:** Minnesota lawmakers should designate a task force to explore least-cost solutions for nuclear power — including Generation III reactors built by South Korean firms that recently have been granted key safety and design approvals by the Nuclear Regulatory Commission (NRC) — and Small Modular Reactors (SMRs).

3. **Issue a moratorium on coal and natural gas plant closures:** The 15-state electric grid to which Minnesota belongs, the Midcontinent Independent Systems Operator (MISO), currently has a 1,200-megawatt (MW) capacity shortfall, which means we don't have enough reliable power plant capacity online to meet our expected peak electricity demand, plus a margin of safety.

   For context, 1,200 MW is the amount of power plant capacity needed to power about half of the homes in Minnesota on an average hour. The shortfall could grow to 2,600 MW by 2023 and 10,900 MW by 2027.

   We are in a reliability hole, and the first thing we need to do is stop digging. Policymakers should issue a moratorium on closing existing coal, nuclear, and natural gas plants, and plan to utilize these reliable plants for the entirety of their useful lifetimes.

   Minnesota ratepayers have financed billions of dollars in existing coal and natural gas infrastructure and deserve to reap the benefits of their investment through lower electricity prices while planning for a carbon-free future.

"If adopted, these recommendations would save Minnesota electricity consumers billions of dollars in the coming decades."

4. **Allow hydroelectric power generated in Canada to count toward Minnesota's carbon-free goals:** Minnesota currently purchases substantial quantities of carbon-free hydroelectricity from Canada, but Minnesota state law does not allow these purchases to count as "renewable." This common-sense change to current law would incentivize more investment in reliable, affordable, carbon-free hydroelectric power and allow Minnesota to meet its current renewable energy mandates at lower cost.

5. **Require utility companies to factor into their Integrated Resource Plans the "All-In Cost" of wind and solar:** Utilities like Xcel Energy must make the case to utility regulators that wind and solar are low cost and will not impair grid reliability. Currently, these companies are not required to attribute to new wind and solar facilities the massive costs associated with integrating these intermittent resources on to the electric grid.

   This must change, and utilities should be required to attribute the cost of additional transmission, property taxes, utility profits, load balancing costs, and overbuilding and curtailment costs to the wind and solar facilities that necessitate them. Our research finds that when these factors are accounted for, wind would cost more than $270 per megawatt hour (MWh), and solar would cost more than $470 per MWh, under the Walz Proposal.

6. **Enact the "Get What You Pay For" Act:** A fundamental problem with the monopoly utility model is that utilities can recover the full cost of an asset, plus a rate of return, regardless of whether that asset contributes to the grid's reliability. We believe ratepayers should only pay for the reliable portion of energy sources.

   For example, MISO gives wind turbines a 17 percent capacity accreditation, which assumes wind will produce 17 percent of its potential when needed most.

   Under this legislation, a Minnesota company would recover from ratepayers only 17 percent of the wind turbine cost, with the remainder paid by shareholders. This would protect ratepayers from large cost increases stemming from wind and solar construction by shifting costs to company shareholders.

7. **Acknowledge that increasing Minnesota's renewable energy mandate would be repeating our energy mistakes and expecting different results:** Mandating that 100 percent of Minnesota's electricity come from carbon-free resources by 2040 without legalizing new nuclear power plants or large hydroelectric power would cost Minnesotans $313 billion — a cost of nearly $3,900 per family per year — and potentially cause a 55-hour blackout in January. This is an enormous price to pay in exchange for potentially averting 0.00096° C of warming by 2100.

Introduction

Minnesota sits at an energy crossroads.

Since enacting the Next Generation Energy Act (NGEA) in 2007, which required that 25 percent of the state's electricity come from wind and solar power by 2025, electricity prices have risen dramatically, and the reliability of our electric grid has grown increasingly fragile.

Data from the U.S. Energy Information Administration (EIA) shows that Minnesota's electricity prices have risen more than twice as fast as the national average since 2007, and the North American Electric Reliability Corporation (NERC) recently issued a dire report concluding the Upper Midwest, including Minnesota, does not have enough reliable power plants online to meet electricity demand with a margin of safety.

This shortfall of reliable power plants exists because too many electric companies have shuttered their reliable coal, natural gas, and nuclear power plants and are becoming increasingly reliant on weather-dependent wind and solar power, increasing the risk of rolling blackouts this summer.[1,2]

Minnesotans have two options. Option 1: We can continue to pursue the same energy policies that brought us to this situation while hoping for different results, or Option 2: We can correct course and focus on providing reliable, affordable electricity to the families and businesses that rely upon it, while seeking cost-effective ways to improve environmental outcomes.

Unfortunately, it appears Minnesota Governor Tim Walz will pursue Option 1. In January 2021, Governor Walz announced his intention to lobby the legislature to pass a law mandating that 100 percent of Minnesota's electricity come from carbon-free resources by 2040.[3]

Importantly, the governor makes no mention of legalizing the construction of new nuclear power plants, and his proposal would not count the electricity generated by large hydroelectric dams in Canada that Minnesotans already buy as a "carbon-free" energy source. As a result, the Walz Proposal is effectively a wind, solar, and battery storage mandate, a policy that will cause electricity prices to increase substantially and reduce the reliability of the grid.

"Since enacting the Next Generation Energy Act in 2007, electricity prices have risen dramatically, and the reliability of our electric grid has grown increasingly fragile."

Some people believe that replacing coal and natural gas-fired power plants with wind turbines, solar panels, and battery storage technologies will be easy to accomplish and reduce electricity prices. That belief is not supported by the physics of the electrical system or the real-world experience of states with high penetrations of wind and solar power.

California experienced rolling blackouts in the summer of 2020, and preventing them from occurring again remains an ongoing challenge. Adding insult to injury, California's electricity prices have increased four times faster than the national average since 2008, when then-Governor Arnold Schwarzenegger signed an executive order requiring 33 percent of California's electricity to be renewable by 2020.[4,5] In 2018, California passed a law mandating that 100 percent of its electricity come from carbon-free resources by 2045, further causing prices to increase and reliability to falter.[6]

The biggest problem with relying on wind and solar is that their electricity generation is erratic. Wind turbines and solar panels can produce electricity only when the wind is blowing or the sun is shining. Furthermore, many people seem to think of the grid as a device that stores electricity for later use, like a giant bathtub that fills with power that can be accessed at a later time. This misconception leads people to believe that wind and solar can increase the availability of electricity on the grid and improve reliability.[7] They cannot.

These physical realities mean that enacting California-style energy policies in Minnesota will yield California-style results.

This study assesses how Governor Walz's proposal to make Minnesota's electricity grid 100 percent carbon-free by 2040 (the "Walz Proposal") would greatly increase costs for families and businesses in Minnesota and make the grid more fragile.

It also assesses an alternative scenario, which we call the Lower Cost Decarbonization (LCD) Scenario. Here, emissions reductions are achieved by utilizing reliable technologies such as new nuclear power plants — including large nuclear power plants built by South Korean firms called APR-1400s and small modular reactors (SMRs). The LCD Scenario also utilizes carbon capture and sequestration (CCS) technology on existing coal plants in North Dakota (which currently provide a share of Minnesota's electricity), battery storage, and large hydroelectric facilities in Canada.

These technologies offer superior value to wind and solar because they are dispatchable, meaning they can be turned up or down to provide electricity when needed. As a result, the LCD Scenario delivers 98 percent emissions-free electricity that is much more reliable and affordable than the Walz Proposal.

Section I: Scenarios Modeled

What is the Walz Proposal?

On January 21, 2021, Minnesota Governor Tim Walz released a proposal for Minnesota's electricity grid to achieve 100 percent carbon-free electricity by 2040.

While this proposal was light on details, the governor's Climate Action Framework draft document, which lays out the governor's vision for the future of energy policy in Minnesota, establishes benchmarks requiring that 40 percent of the state's electricity come from wind or solar by 2025, and 55 percent of the state's electricity come from these sources by 2035, before reaching 100 percent carbon-free by 2040.[8]

Importantly, the Walz Proposal does not list nuclear power — the largest source of emissions-free power in Minnesota — as a "qualifying carbon-free resource," nor does it allow electricity generated at large Canadian hydroelectric facilities to qualify as "carbon-free."[9,10,11]

> **"The Walz Proposal would require all of the existing coal, natural gas, and oil-burning power plants in the state to be retired no later than December 31, 2039."**

The only "qualifying carbon-free sources" listed in the Climate Action Framework are wind, solar, biomass, in-state hydro, or geothermal power, essentially making the Walz Proposal a 100 percent wind, solar and battery storage mandate that also utilizes existing nuclear and small hydroelectric power plants located in Minnesota.

The Walz Proposal would require all of the existing coal, natural gas, and oil-burning power plants in the state, which generated 42.5 percent of Minnesota's total electricity consumption in 2019, to be retired no later than December 31, 2039.

This analysis examines the cost and reliability implications of complying with the Walz Proposal and compares it to the LCD Scenario, which prioritizes providing the most reliable, carbon-free electricity at the lowest possible cost for Minnesota families and businesses.

We conclude that complying with the Walz Proposal will make maintaining a reliable electric grid exponentially more expensive and difficult, while the LCD Scenario will provide reliable electricity and reduce carbon dioxide emissions at a much lower cost than the Walz Proposal.

Readers should note that this analysis does not account for federal subsidies paid to wind and solar facilities, nor potential subsidies for CCS operations. This methodology is appropriate because federal subsidies would not reduce the cost of producing energy using these resources; they would simply shift who pays for it.

This analysis also assumes that electricity consumption in Minnesota will remain constant at approximately 71.4 million MWhs from 2021 through 2050.[12,13] This assumption is conservative because proponents of renewable energy mandates often promote the widespread adoption of electric vehicles and the broader electrification of the energy sector for purposes such as home and water heating. Doing so would dramatically increase the need for electricity generation and would require even more capacity additions to comply with the Walz Proposal.

The additional costs associated with rising levels of electrification are not analyzed in this study because this analysis is designed to show the difference in cost to meet the same amount of electricity demand as the current grid, providing an apples-to-apples comparison of the cost of electricity in Minnesota with, and without, the Walz Proposal and LCD Scenario.

The appendix explains the assumptions and factors considered by our model.

What is the LCD Scenario?

The Lower Cost Decarbonization (LCD) Scenario seeks to provide the most reliable and affordable path to reducing carbon dioxide emissions from the electricity sector by 98 percent by 2040.

Under the LCD Scenario, electric companies in Minnesota would continue to utilize existing nuclear, coal, and natural gas power plants on their electric systems until their original retirement dates. These coal and natural gas plants would be gradually replaced by carbon-free resources, such as nuclear power or battery storage, through 2040.

"The Lower Cost Decarbonization (LCD) Scenario seeks to provide the most reliable and affordable path to reducing carbon dioxide emissions from the electricity sector by 98 percent by 2040."

Under the LCD Scenario, Xcel Energy and Minnesota Power would continue operating the Sherburne County, A.S. King, and Clay Boswell coal-fired power plants beyond 2030. Other utilities, like Otter Tail Power, would continue to utilize coal and natural gas plants located in North and South Dakota through 2040.

Keeping these facilities online would allow Minnesota families and businesses to benefit from reliable, low-cost electricity while new, carbon-free nuclear power plants are constructed.

The LCD Scenario also allows the large hydroelectric power that Minnesota already buys from Canada to count as "carbon-free," because hydroelectric power produces no carbon dioxide emissions. The LCD Scenario also incorporates proposals made by owners of coal plants in North Dakota, which send their electricity to Minnesota over high-voltage transmission lines, to retrofit their plants with

CCS equipment. This equipment would act like a catalytic converter on the coal plants, capturing the carbon dioxide coming out of the plant and storing it safely underground.

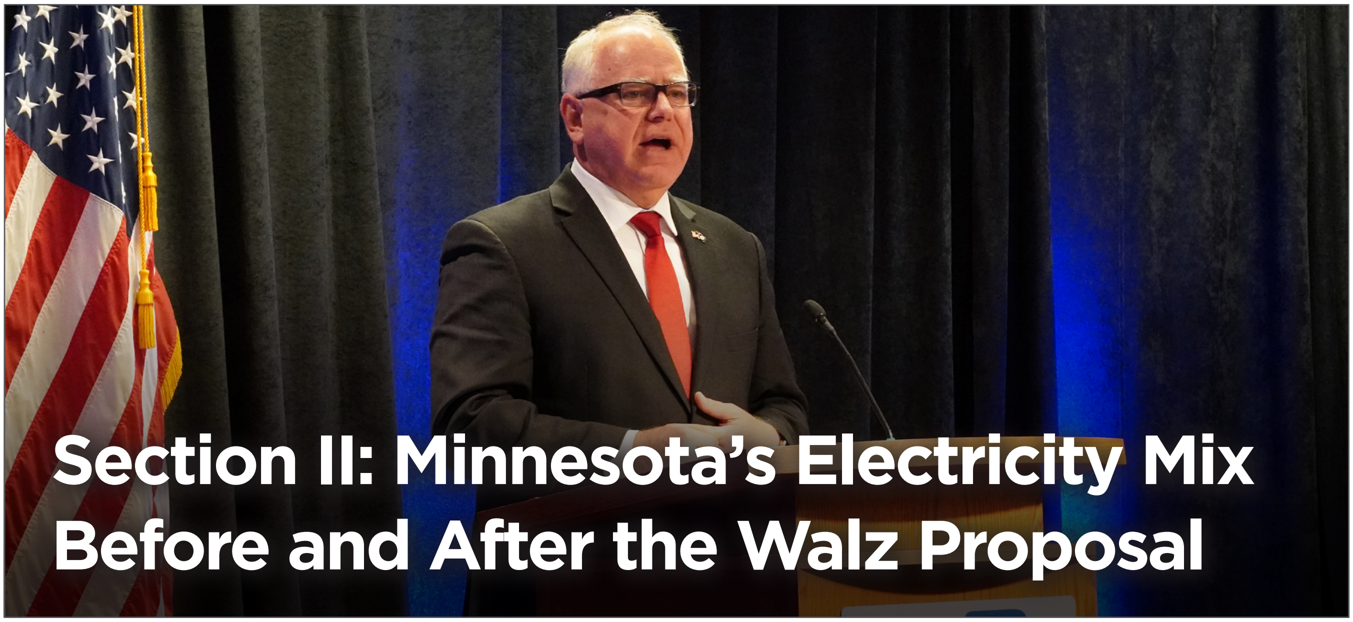
New nuclear facilities would take two primary forms: APR-1400s, which are large nuclear power plants built by South Korean firms, and Small Modular Reactors (SMRs).

The APR-1400 is a 1,400 MW power plant built by the Korea Electric Power Corporation (KEPCO). This reactor was selected because it has a track record of being built in a timely manner in other countries. For example, in December 2009 the United Arab Emirates awarded a contract to KEPCO to build four, APR-1400s, with construction beginning in 2012. In April 2021, the first reactor began commercial operation, with the second reactor joining it in March 2022. The third unit is expected to begin commercial operation early next year.[14] The APR-1400 represents a nuclear power plant that has been built at scale in a timely fashion.

SMRs are used because they offer superior flexibility compared to APR-1400s or coal plants with CCS, and thus are more suited to meeting electricity demand as it increases and decreases throughout the course of a day.[15]

The LCD Scenario also includes 2,500 MW of battery storage to provide electricity during periods of peak demand. These batteries are charged using the output of reliable nuclear power plants.

Because wind turbines and solar panels are not dispatchable energy sources, they do not contribute to maintaining a reliable electric grid in any meaningful way. They represent a costly premium on the electricity system. In the LCD Scenario, Minnesota's existing wind and solar facilities are allowed to retire at the end of their useful lives — 20 years for wind turbines and 25 years for solar panels — instead of being replaced with new wind and solar installations.



Section II: Minnesota's Electricity Mix Before and After the Walz Proposal

In 2019, Minnesota derived 24.7 percent of its electricity from coal, 19.5 percent from nuclear, 17.5 percent from natural gas, 15.2 percent from wind, 11 percent from imports from Canada (mostly hydroelectricity), 7 percent from imports of electricity from other states (mostly imports of coal and wind-generated electricity in North Dakota), 1.7 percent from solar, 1.5 percent from hydroelectric, and 1.2 percent from wood (see Figure 1).[16,17]

Under the Walz Proposal, this electricity mix would be required to shift dramatically.

Readers should note that 2021 data were not available at the time of these writing. Data from 2019 are used for electricity generation data in this analysis because 2020 data are likely distorted due to the COVID-19 pandemic. For example, in 2020 interstate imports were the highest they had been since 2014, while international imports were the lowest since 1990. The only data used from 2020 is for installed capacity numbers, which are the most recent data available.

> **"Maintaining grid reliability would be much less costly if natural gas were used instead of battery storage, but these plants would need to be shut down by 2040 under the Walz Proposal."**

In our analysis, we assumed the Walz Proposal would allow Xcel Energy to retain and relicense its existing nuclear power plants, and that electricity generated from these plants would be counted as carbon-free under the 100 percent carbon-free mandate.[18]

No new nuclear power facilities would be built under the Walz Proposal because under current Minnesota law, it is illegal to build them.

To achieve 100 percent carbon-free electricity by 2040, all utility companies will be required to replace electricity currently generated with coal, natural gas, and oil with qualifying renewable energy sources such as wind turbines, solar panels, and battery storage facilities by 2040.[19]

Maintaining grid reliability would be much less costly if natural gas were used instead of battery storage, but these plants would need to be shut down by 2040 under the Walz Proposal. Because natural gas plants have lifespans of

FIGURE 1

2019 Minnesota Electricity Consumption by Source

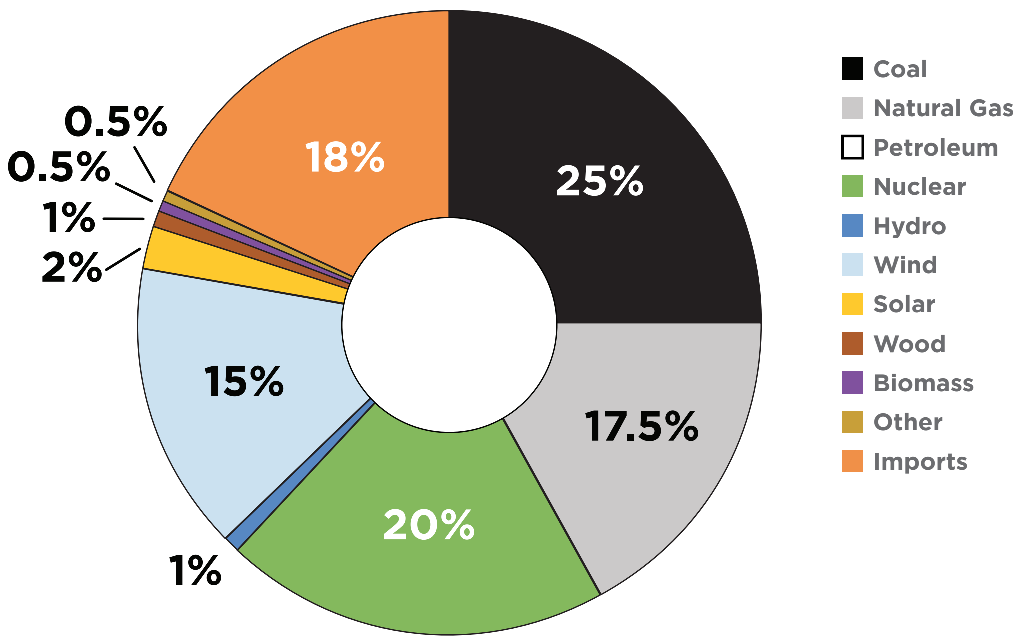


Figure 1. Coal, nuclear, natural gas, and electricity imports accounted for 80 percent of the electricity consumed in Minnesota in 2019. Wind accounted for 15 percent, solar for 2 percent, and wood for one percent. Numbers exceed 100 percent due to rounding

30 or more years, any gas plant built between now and 2040 would be required to shut down before the end of its useful life under the Walz Proposal, which would force Minnesota families and businesses to pay millions of dollars for power plants they would not be using.

Our analysis excludes the possibility of natural gas additions. Consistent with the goals of the Walz Proposal, this report calculates the cost of using battery storage technology to provide electricity to the grid when the wind is not blowing or the sun is not shining.

Generation mix under the Walz Proposal

Our model calculates the generation mix resulting from compliance with the Walz Proposal in Minnesota using wind and solar generation with battery storage. Figure 2 shows Minnesota's electricity mix in 2040, and Figure 3 shows the annual share each source of electricity contributes to the state's total electricity consumption.

Under the proposal, we project that Minnesota utilities would be required to invest heavily in wind, solar, and battery storage technologies. As a result, by 2040, 65 percent of Minnesota's electricity would come from wind, 16 percent would come from existing nuclear plants, 11 percent would come from solar, 4 percent would be supplied by battery storage, and hydro, wood, and biomass would each contribute one percent to the state's electricity supply. None of the state's electricity would come from coal, natural gas, or oil.

FIGURE 2

Walz Proposal Electricity Consumption by Source, 2040

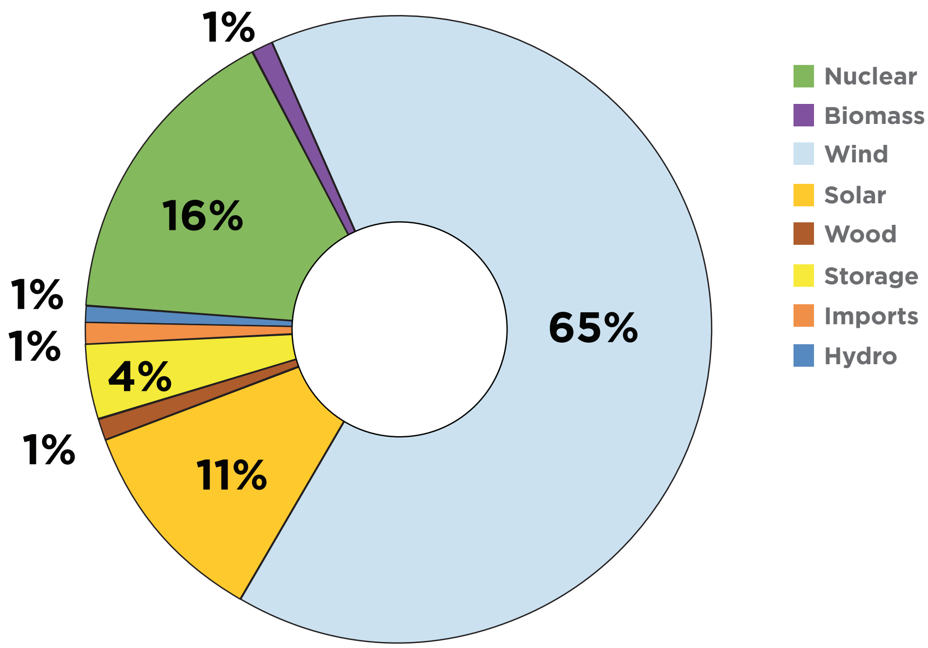


Figure 2. Wind power will become the largest source of electricity in Minnesota by 2040, with nuclear power providing the second-largest source of energy and solar contributing the third-largest share.

Generation mix under the LCD Scenario

Under the LCD Scenario, Minnesota would derive 10 percent of its electricity from coal plants in North Dakota (Coal Creek and a portion of Milton R. Young) that are retrofitted with CCS equipment, 18 percent from existing nuclear plants, 31 percent from new APR-1400 nuclear plants, 27 percent from SMR nuclear plants, 1.5 percent from in-state hydro, one percent from solar, wind, and wood, less than one percent from battery storage and biomass, and eight percent from imports of hydroelectricity from Canada (see Figure 4).[20]

The changing resource mix in the LCD Scenario can be seen in Figure 5. In-state coal and natural gas generation reaches zero by 2040 and nuclear power consistently grows its share during this timeframe.

"The changing electricity generation mix under the Walz Proposal will have profound impacts on the cost of electricity."

The changing electricity generation mix under the Walz Proposal will have profound impacts on the cost of electricity for Minnesota families and businesses and on the reliability of the electric grid. In contrast, the LCD Scenario would maintain reliability and reduce emissions at a significant but far lower cost.

FIGURE 3

Walz Proposal Share of Annual Electricity Consumption

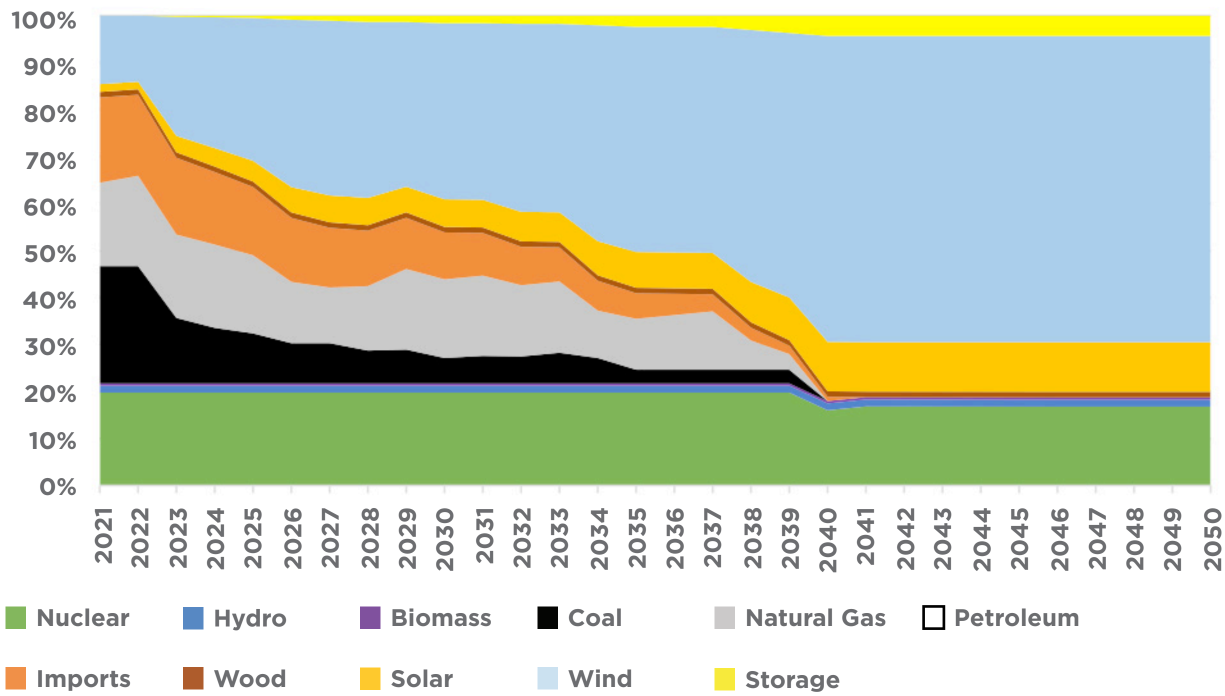


Figure 3. Natural gas generation declines by 2040 as wind grows to 65 percent of electricity consumption.

Are either of these plans realistic?

Both the Walz Proposal and the LCD Scenario will require massive buildouts of new power plant capacity on aggressive timelines that may not even be possible.

Wind and solar advocates likely will claim that the planned nuclear power buildout of 10,715 MW in the LCD Scenario is unrealistic, citing cost overruns and delays at the construction of the Vogtle nuclear power plant in Georgia, the only nuclear power plant currently under construction in the United States.

On the other hand, the massive capacity buildouts required to implement the Walz Proposal, which total nearly 100,500 MW and dwarf buildouts required by the LCD Scenario, are unlikely to occur by 2040.

Wind and solar additions in Minnesota historically have taken much longer than the timeline established by the Walz Proposal. For example, between 2007, when the NGEA was signed into law, and the end of 2020, Minnesota had built just 3,481 MW of new wind facilities. The Walz Proposal would require a total wind capacity of 47,400 MW to be in service in the next 18 years, a capacity addition of 43,000 MW. This means Minnesota would need to build more than 12 times more wind facilities in the next 18 years than it has built in the previous 15 years.

FIGURE 4

LCD Scenario Electricity Consumption by Source, 2040

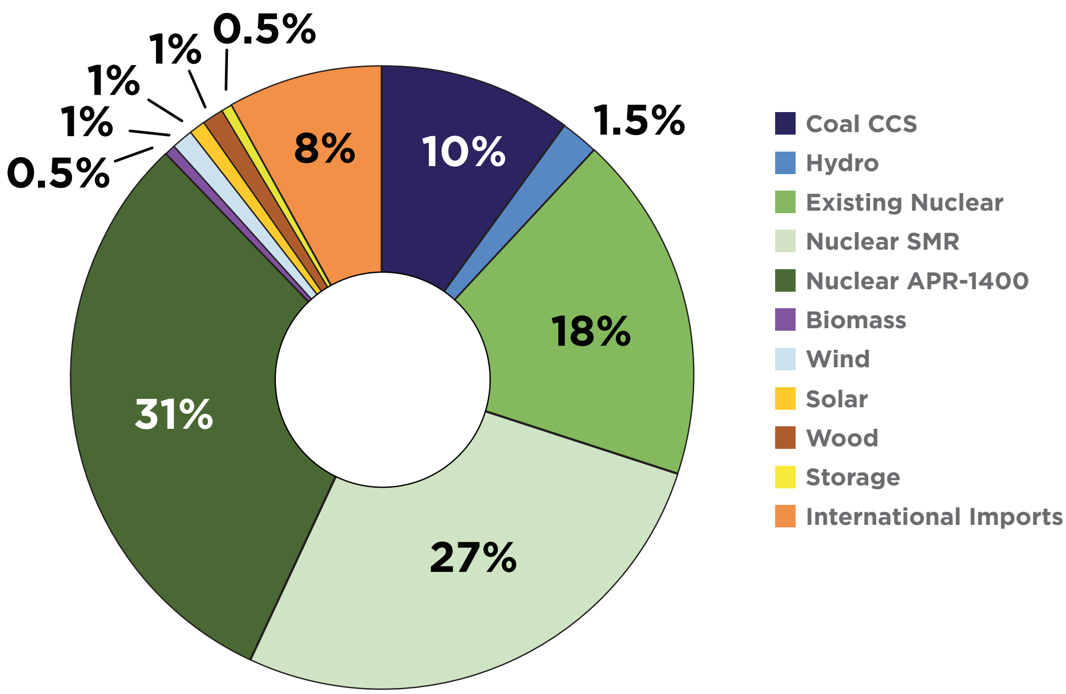


Figure 4. Under this scenario, nuclear power becomes the largest source of electricity in Minnesota, accounting for 76 percent of total electricity consumption. Totals do not add up to 100 percent due to rounding.

Solar installations in the Walz Proposal total nearly 15,390 MW. Minnesota had 1,018 MW of solar installed as of 2020, meaning solar installations would require a 13-fold increase by 2040. This may be more achievable than the wind buildout, but it would still be a significant feat.

Battery storage is also a challenge. The 35,450 MW of battery storage needed for the Walz Proposal includes roughly 141,800 MWhs of capacity. This is 19 percent of the 741,000 MWhs expected to be installed globally by 2030, according to an analysis by Wood Mackenzie.[21] It is unlikely that Minnesota alone will host nearly one-fifth of this global capacity.

Lastly, the Walz Proposal would require — at minimum — a 58 percent increase in high voltage transmission lines, requiring 5,795 miles of new transmission in the state. These lines take eight to 10 years to build — if they get built at all.[22] In 2011, President Barack Obama attempted to accelerate the completion of seven major new transmission lines. Only two were finished.[23]

While we can model the theoretical cost of attempting to power a grid with both the Walz Proposal and the LCD Scenario, that does not mean either plan will materialize in the real world. The most realistic read of the situation is that eliminating greenhouse gas emissions from the electricity sector is unlikely to be technically or economically feasible by 2040.

FIGURE 5

LCD Scenario Share of Annual Electricity Consumption

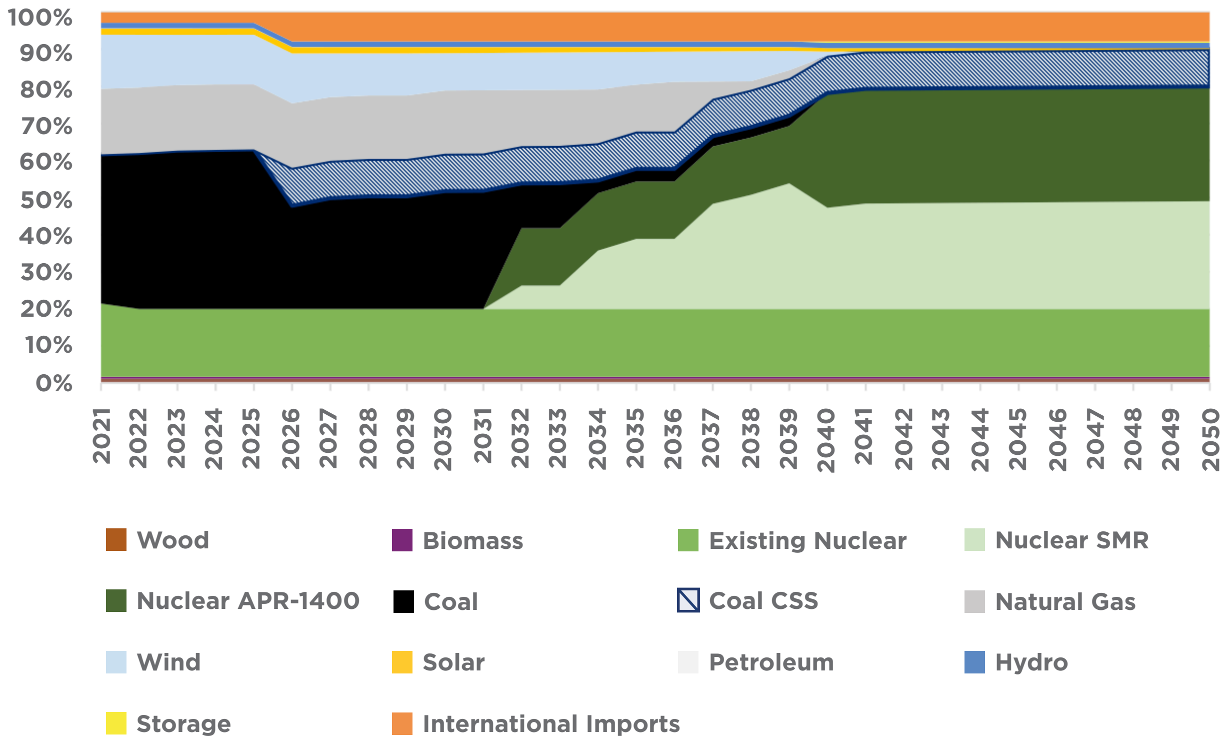


Figure 5 shows the annual share of total electricity consumption provided by each source of electricity.

Section III: Comparing the Costs of the Walz Proposal and LCD Scenario

Reducing carbon dioxide emissions, regardless of the method, is an expensive endeavor. Both the Walz Proposal and LCD Scenario will increase the cost of electricity for Minnesota families and businesses, but consumers would be forced to spend $224 billion more under the Walz Proposal than under the LCD Scenario, through 2050.

Our modeling indicates that complying with the Walz Proposal will cost an additional $313 billion (in constant 2022 dollars) compared to operating the current electric grid. This would triple electricity prices, with rates rising from 10.57 cents per kilowatt hour (KWh) in 2020 to 32.91 cents per KWh in 2040. As a result, the cost for each Minnesota utility customer would increase by $6,500 in 2040, the equivalent of paying an additional $555 per month (see Figure 6).[24]

> **"Our modeling indicates that complying with the Walz Proposal will cost an additional $313 billion (in constant 2022 dollars) compared to operating the current electric grid."**

In contrast, the costs associated with the LCD Scenario would total $89.5 billion, which translates to a near doubling of electricity prices, with prices rising 9.59 cents per KWh, from 10.57 in 2020 to 20.16 cents per KWh in 2040, resulting in an average additional cost of $2,464 for each utility customer in Minnesota that year — an additional $200 per month.

Therefore, by 2040, the Walz Proposal will cost more than $4,000 more per customer per year relative to the LCD Scenario.

Figure 6 shows the average additional cost of complying with the Walz Proposal and LCD Scenario from 2022 through 2050, compared to the current cost of electricity. This number is obtained by dividing the annual cost of the programs among all Minnesota utility customers, including residential, commercial, and industrial electricity users. The Walz Proposal immediately increases electricity costs as more wind and solar facilities are built, whereas costs remain low through 2031 under the LCD Scenario.

FIGURE 6

Annual Additional Cost Walz Proposal vs. LCD Scenario

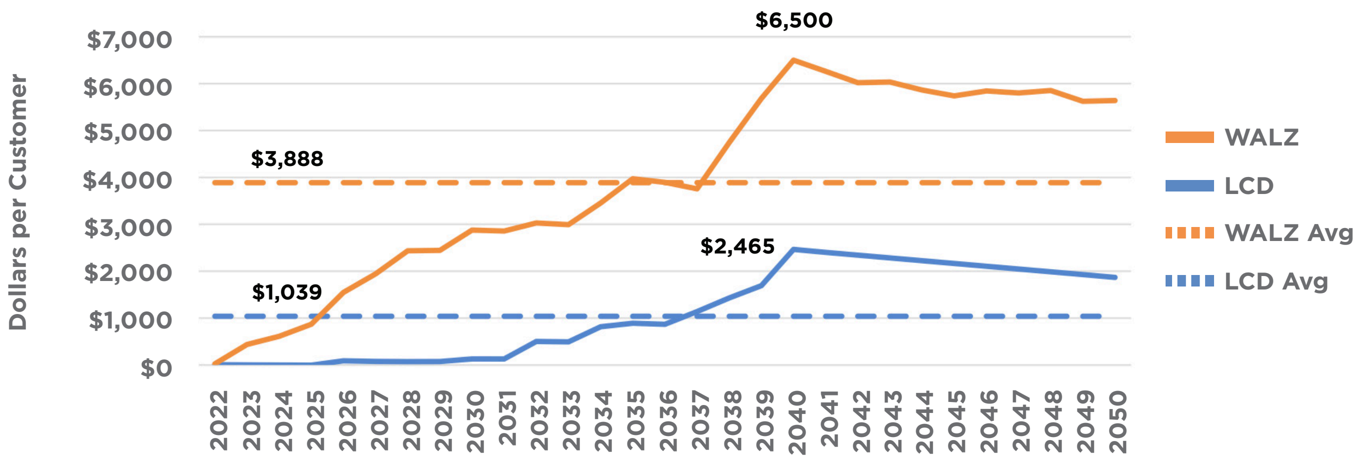


Figure 6. Annual costs for Minnesotans increase by an average of $3,888 under the Walz Proposal. Costs peak at $6,500 in 2040. The LCD Scenario would cost an average of $1,039 per year, with costs peaking at $2,465 in 2040.

FIGURE 7

Annual Additional Cost for Residential Customers

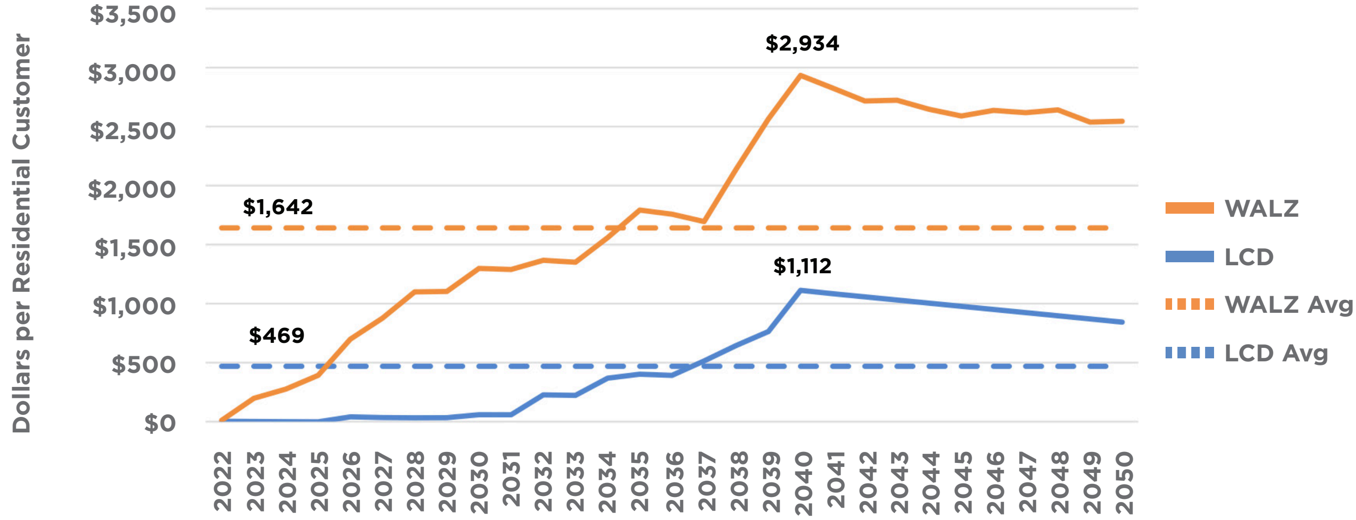


Figure 7. Costs begin rising immediately in the Walz Proposal as construction of new wind and solar facilities begins. Costs are low in the initial years of the LCD Scenario because existing power plants are being utilized.

FIGURE 8

Annual Additional Cost for Commerical Customers

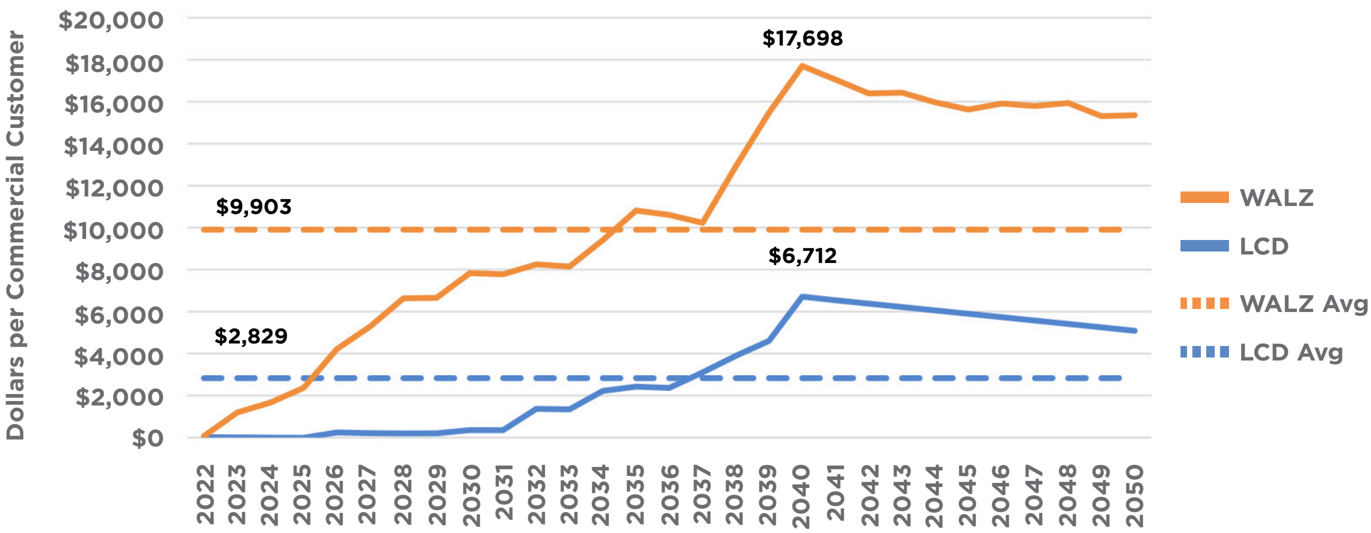


Figure 8. Costs for commercial customers begin rising immediately in the Walz Proposal as construction of new wind and solar facilities begins. Costs peak at nearly $18,000 per business in 2040. Costs are much lower in the LCD Scenario.

Residential customers

Under the Walz Proposal, residential electricity prices would more than triple by 2040, causing residential customers to see their annual electricity costs increase by an average of $2,934 that year, an increase of $244 per month (see Figure 7). Residential customers would see annual average electricity prices nearly double under the LCD Scenario in 2040, causing an average additional cost of $1,112 per residential customer that year compared to the current electric grid. This translates into a monthly increase of $90 per residential customer.

"Under the Walz Proposal, residential electricity prices would more than triple by 2040, causing residential customers to see their annual electricity costs increase by an average of $2,934 that year."

Commercial customers

Under the Walz Proposal, commercial customers would see their electricity costs increase by $17,698 per year in 2040, a monthly increase of $1,475. Under the LCD Scenario, the average commercial customer would end up paying an additional $6,712 in 2040 (see Figure 8).

Industrial customers

Industrial companies in Minnesota are significant users of electricity and would be hit hard under the Walz Proposal. Those users would see yearly

FIGURE 9

Annual Additional Cost for Industrial Customers

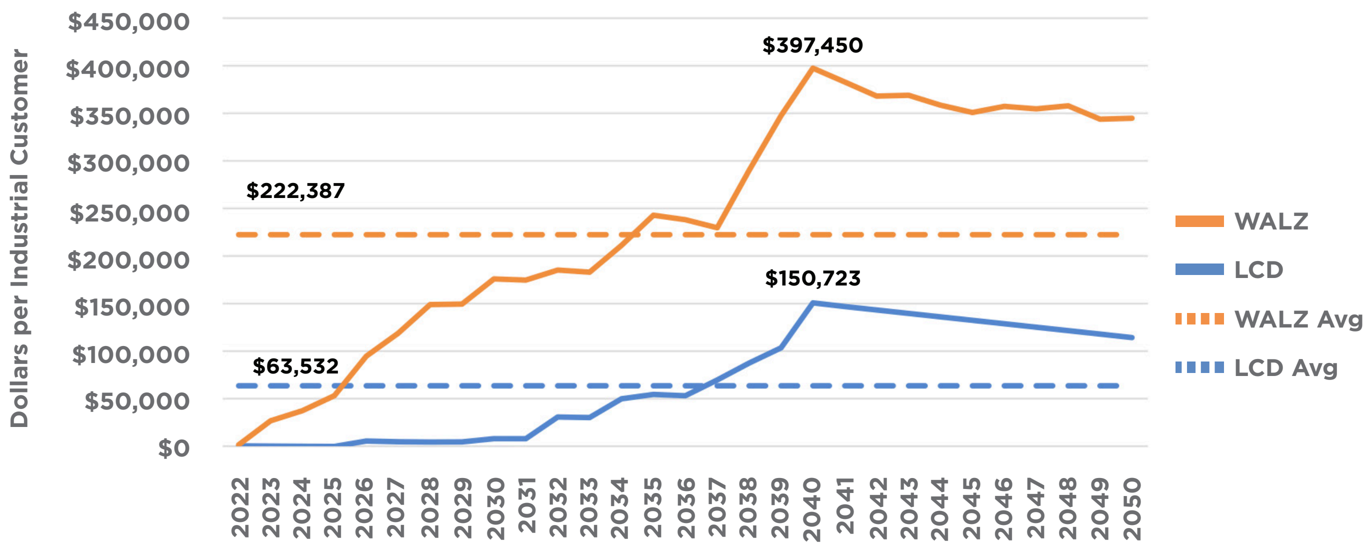


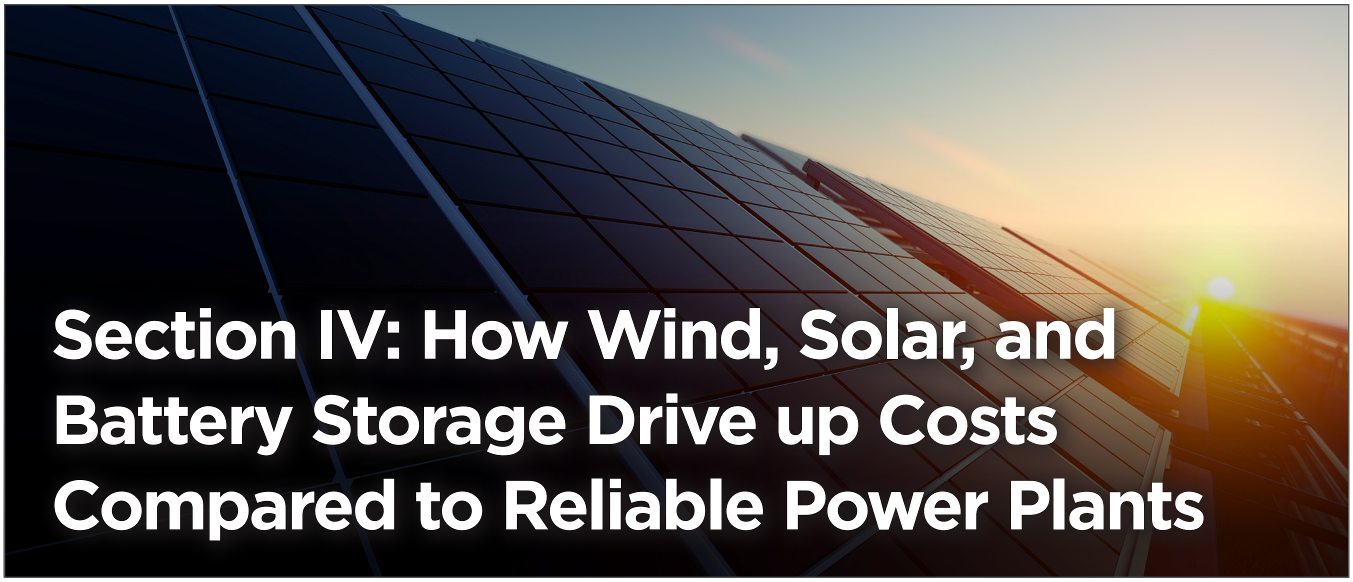
Figure 9. Industrial electricity consumers would experience cost increases of nearly $400,000 per year under the Walz Proposal. The LCD Scenario would cost an additional $151,000 per year.

electricity costs increase by $397,450, on average, in 2040 (see Figure 9). Under the LCD Scenario the average industrial electric bill would increase by $150,723 that year.

Walz Proposal compliance costs are driven by the need to build enough wind turbines, solar panels, battery storage facilities, and transmission lines to meet the proposal's stipulation that Minnesota's electric grid be carbon-free by 2040.

Other factors that increase costs include rising property taxes resulting from having nearly five times more capacity on the system than in 2020, and utility profits that would result from their state-approved rate of return on undepreciated assets.

LCD Scenario costs are driven by relicensing Minnesota's nuclear power plants, building new nuclear plants to replace retiring coal plants, building battery storage facilities, and retrofitting existing coal plants with CCS technology.



Section IV: How Wind, Solar, and Battery Storage Drive up Costs Compared to Reliable Power Plants

Thus far, this report has summarized the cost difference between the Walz Proposal and the LCD Scenario. In this section, we will discuss how attempting to run a reliable electric grid using mostly wind, solar, and battery storage drives up costs to a much greater extent than building a grid using reliable power plants.

The most important thing to know about the electric grid is that the supply of electricity must be in perfect balance with demand at every second of every day.[25] If demand rises as Minnesotans turn on their air conditioners, an electric company must increase the supply of power to meet that demand. If companies are unable to increase supply to meet demand, grid operators are forced to cut power to consumers to keep the grid from crashing.

> **"The most important thing to know about the electric grid is that the supply of electricity must be in perfect balance with demand at every second of every day."**

Generating more electricity is relatively easy with dispatchable power plants — plants that can be turned up or down on command — like those fueled with coal, natural gas, and nuclear fuel. But adjusting to second-by-second fluctuations in electricity demand is much more difficult with wind and solar, whose electricity production is dependent on second-by-second fluctuations in the weather. As a result, it is much more difficult to provide reliable power as we become more reliant upon wind and solar to meet our energy needs.

It is possible to mitigate some of the inherent unreliability of wind and solar by vastly increasing the amount of wind and solar capacity on the grid (known as "overbuilding" wind and solar installations) to allow electricity demand to be met even on cloudy or low-wind days, and curtailing, or turning off, much of this capacity when wind and solar production is higher. Other mitigation strategies include building more transmission lines and battery storage facilities. Each of these mitigation strategies, however, is a major driver of cost for the entire electric system.

These mitigations come with other

FIGURE 10

Walz Proposal Total Capacity in 2020, 2030, and 2040

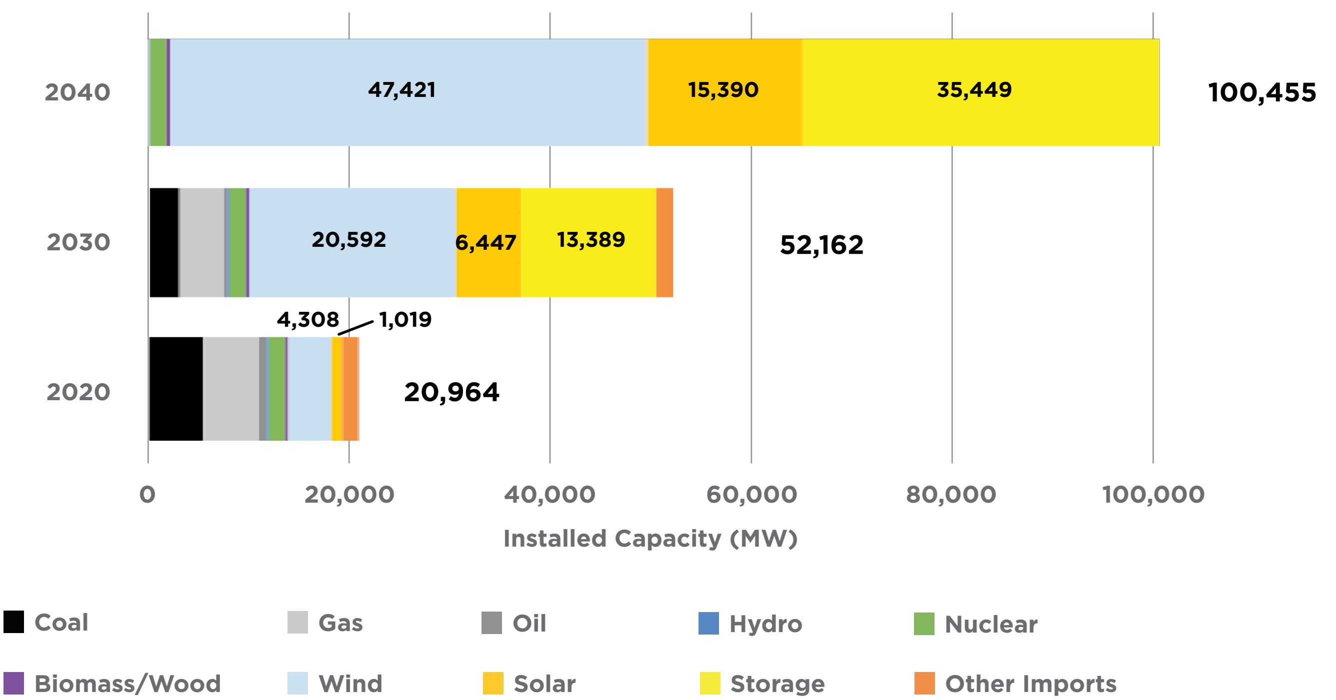


Figure 10. Complying with the Walz Proposal would require nearly 5 times more installed capacity on the electric grid Minnesota relies upon to maintain a reliable system based on 2021 wind and solar output. This massive buildout of capacity would drive significant cost increases for families and businesses.

additional costs, including higher profits for investor-owned utilities like Xcel Energy, and higher property taxes. Each of these additional costs will be discussed in greater detail below.

Increasing electricity generation capacity

Building and operating new power plants is expensive. The Walz Proposal would greatly increase the amount of new power plant capacity on Minnesota's electric grid, while the LCD Scenario would build far less new capacity. As a result, the Walz Proposal is far more expensive.

In 2020, Minnesota had 17,911 MW of installed power plant capacity on the grid and relied upon 3,053 MW of import capacity — supplying 12.4 million MWhs of electricity — to meet electricity demand. These imports came from Canada, and other states.

Under the Walz Proposal, the amount of capacity that Minnesota relies upon would increase from 20,964 MW in 2020 to 52,162 MW by 2030 and 100,455 MW by 2040. This means the Walz Proposal would require nearly 5 times more power plant capacity than is currently

FIGURE 11

Walz Proposal Hourly Electricity Supply During Peak Demand

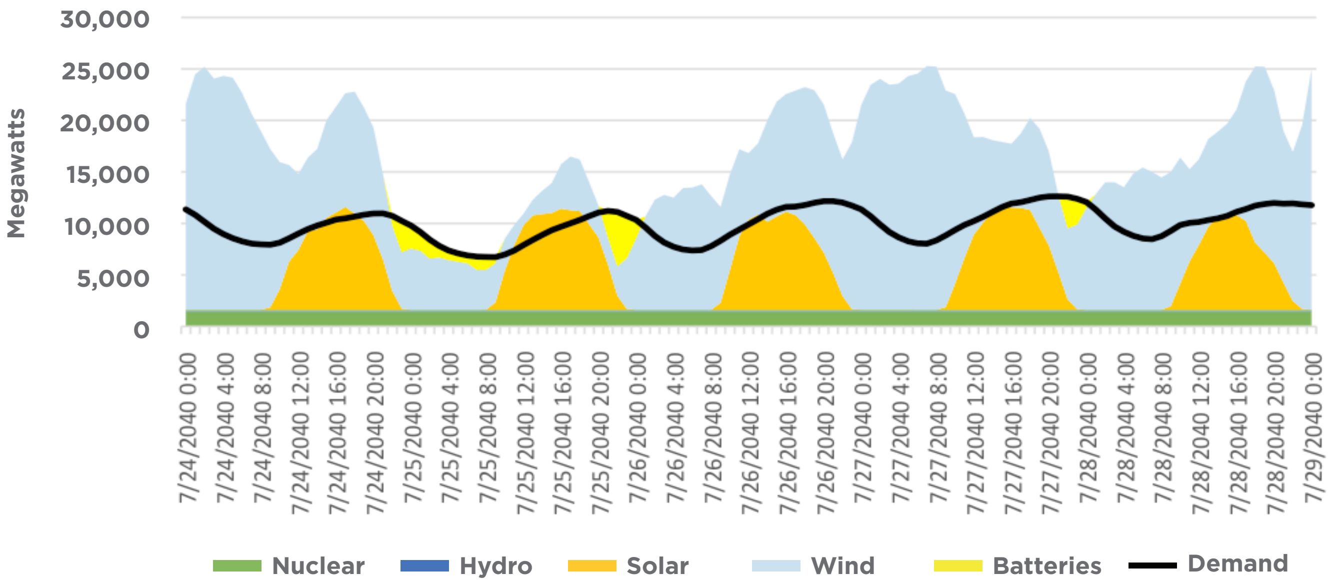


Figure 11. Battery storage is needed to help meet electricity needs during periods where wind and solar generation is insufficient to meet demand. The batteries are charged by the solar panels and wind turbines when their generation exceeds the blue demand line and discharged when wind and solar are unavailable.

used to meet Minnesota's electricity demand (see Figure 10).

While adding power plant capacity to the grid may sound like a good thing, increasing capacity merely to meet renewable energy mandates rather than meeting electricity demand is an unnecessary cost that will harm Minnesota families and the state's economy.

Solar, wind, and battery storage capacity increase most, nuclear power plant capacity remains constant, and coal and natural gas are phased out by 2040 to comply with the Walz Proposal.

Wind installations under the Walz Proposal would increase from 4,300 MW of installed capacity in 2020 to 47,421 MW of capacity in 2040. Solar capacity would grow from 1,018 MW in 2020 to 15,390 MW in 2040, and battery storage would increase from 16 MW in 2020 to 35,449 MW, with four hours of storage per MW, in 2040.[26]

It is important to note that our model selected these quantities of solar, wind, and battery storage resources because they were the most cost-effective portfolio for meeting the carbon-free energy mandates proposed by Governor Walz and maintaining grid reliability under 2021 electricity demand and wind and solar generation conditions.

Building these solar panels, wind turbines, and battery storage facilities would cost $67 billion, $19 billion, and $46 billion, respectively, while repowering these facilities at the end of their 20- to 25-year useful lives would cost an additional $63 billion.[27] Battery storage facilities

FIGURE 12

Minnesota Installed Capacity: Current vs. LCD Scenario and Walz Proposal in 2040

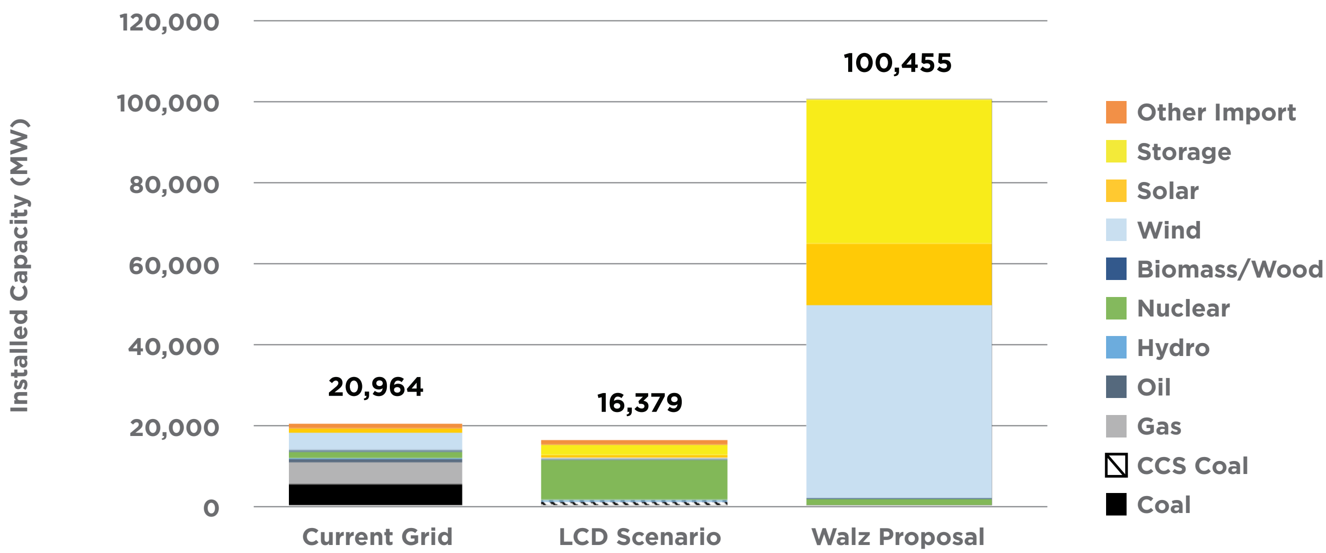


Figure 12. This graph shows the amount of capacity serving Minnesota in 2021 and in 2040 for both the LCD Scenario and Walz Proposal.

are needed to comply with the Walz Proposal because these facilities allow Minnesota to store for later use the excess electricity generated by solar and wind.

Figure 11 shows the electricity provided by each resource from July 24 to July 29 2040, which shows the period in time where electricity demand is the highest — frequently referred to as peak electricity demand. Electric grids must be built to accommodate this demand plus a margin of safety — called a "reserve margin" — much the same way a bridge must be built to handle its maximum capacity plus a factor of safety, making it stronger than its expected maximum load.

This graph, which is based on actual 2021 federal data for electricity demand and generation of power plants in the MISO region, shows a hypothetical week in 2040 under the Walz Proposal.

The black line shows electricity demand throughout the week. Solar generation, shown in orange, increases in the morning and peaks in mid-afternoon, before falling off in the early evening.[28] Wind generation is shown in light blue, and it varies considerably based on wind speeds. Battery storage, shown in yellow, provides electricity during the hours when wind and solar generation is insufficient to meet electricity demand.

A portion of the extra wind and solar power must be used to charge the batteries. Once the batteries are fully charged, any additional solar or wind power that is generated is curtailed, or turned off. Curtailment is expected to become increasingly common as more wind and solar are placed into service on the grid.[29]

How reliable power plants keep costs lower for consumers

The amount of additional capacity needed under the LCD Scenario would be far lower than the Walz Proposal because the LCD Scenario prioritizes the continued operation of reliable coal and natural gas power plants in Minnesota through the end of their useful lives and the construction of new nuclear plants and other dispatchable technologies to replace them.

Additionally, it allows for the continued use of coal plants fitted with CCS equipment in neighboring North Dakota, as well as large hydro plants in Canada. Indeed, the amount of installed capacity on the electric system serving Minnesota would actually shrink under the LCD Scenario because it would shed wind and solar capacity, which do not contribute meaningfully to reliable capacity.

Minnesota's coal plants are currently scheduled to close many years before their original retirement dates. In the LCD Scenario, these coal plants would be left online until their original closure dates to provide reliable, affordable electricity to Minnesotans while new nuclear power plants are being built, a process that will take at least 10 years for construction.

Figure 12 shows the amount of capacity currently serving Minnesota shrinking from 20,964 MW in 2020 to 16,379 MW in 2040 under the LCD Scenario. It also shows that the Walz Proposal would require 6.1 times more capacity than the LCD Scenario.

In the LCD Scenario, a total of 10,715 MW of new capacity is added to the grid through 2040. Of these additions, more than 5,400 MW are nuclear SMR technology, 2,800 MW are nuclear APR-1400 technology, and 2,500 MW are four-hour battery storage facilities. Additionally, nearly 15,700 MW of existing capacity is retired, including 4,150 MW of coal, 5,460 MW of natural gas, nearly 800 MW of oil, more than 4,300 MW of wind, and more than 900 MW of solar.

The amount of new power plant capacity added in the LCD Scenario is substantial, but it is far lower than the Walz Proposal because the new power plants are dispatchable, meaning they can be turned up or down as needed. This is crucial because it means there is no need to overbuild for reliability. As a result, the LCD Scenario reduces emissions by 98 percent compared to 2021 at a much lower cost.

"The amount of additional capacity needed under the LCD Scenario would be far lower than the Walz Proposal because the LCD Scenario prioritizes the continued operation of reliable coal and natural gas power plants in Minnesota through the end of their useful lives."

Transmission costs

Transmission lines are important: It does no good to generate electricity if it cannot be transported to the homes and businesses that rely upon it.

Transmission costs are driven by the need to build new infrastructure to connect wind turbines and solar panels to the rest of the electric grid. These facilities are often located in rural areas far from populous regions of Minnesota, where the most electricity will be consumed.

The Electricity Futures Study published by the National Renewable Energy Laboratory (NREL) shows the amount of transmission required to accommodate more wind and solar increases as they supply ever-greater quantities of electricity. The amount of transmission needed grows exponentially as wind and solar market share increase beyond 60 percent (see Figure 13).[30]

FIGURE 13

New Transmission Capacity Requirements for Wind and Solar Integration

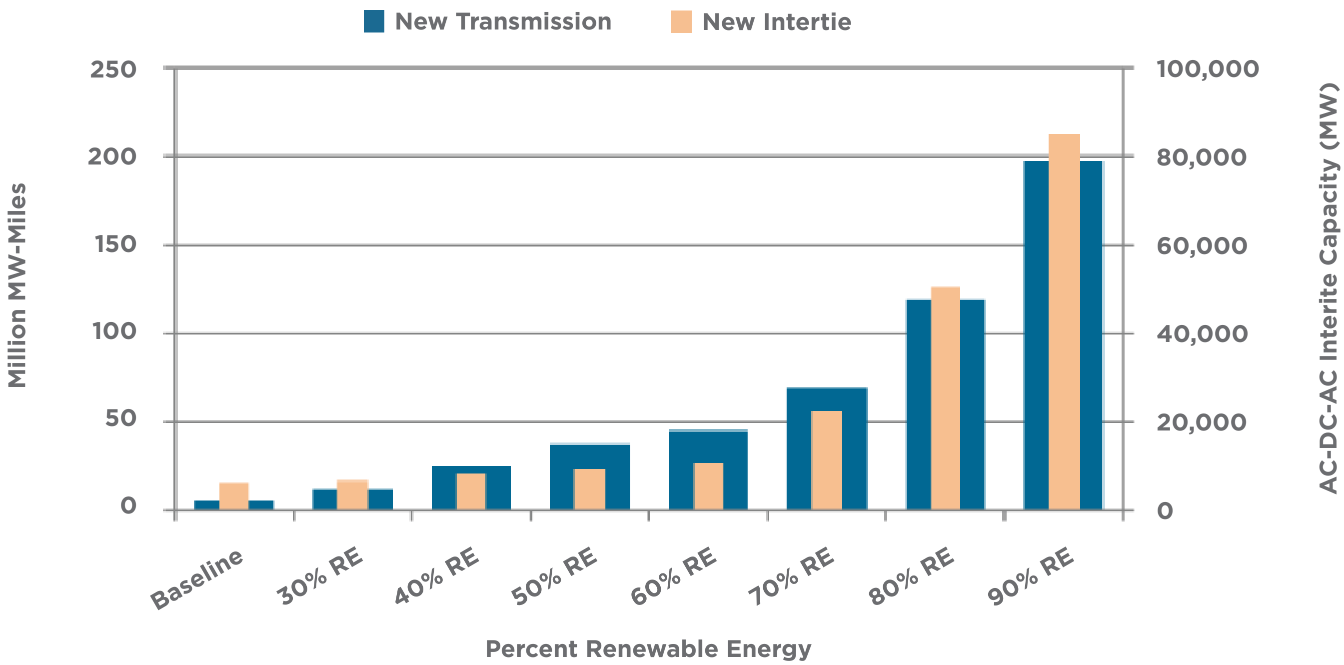


Figure 13. NREL estimates show the amount of transmission needed increases dramatically as the percentage of electricity being provided by intermittent renewable energy sources grows.

To achieve a grid powered by 80 percent solar and wind in the United States would require the construction of approximately 115 million MW miles of transmission lines. For context, NREL estimates there are currently between 150 and 200 million MW miles of transmission lines in the United States, meaning a grid powered by 80 percent renewable energy would require a 58 to 76 percent increase in transmission infrastructure.[31]

Assuming similar increases in transmission lines would be needed for each state, Minnesota's grid — which would be powered by 77 percent solar and wind, and four percent by batteries charged using wind and solar, under the Walz Proposal — would require the amount of existing transmission lines to increase by 58 to 76 percent to accommodate higher penetrations of intermittent renewable energy.

A Renewable Integration Impact Analysis (RIIA) study by MISO suggests most of the required increases in transmission capacity would occur in high voltage transmission lines, meaning those over 230 kilovolts (kV), with the largest increases needed for lines over 345 kV.[32]

Minnesota currently has 2,094 miles of transmission lines that are 230 kV, 3,034 miles of 345 kV, and 667 miles of high voltage direct current transmission lines (HVDC). According

FIGURE 14

Xcel Energy Annual Property Tax Expense

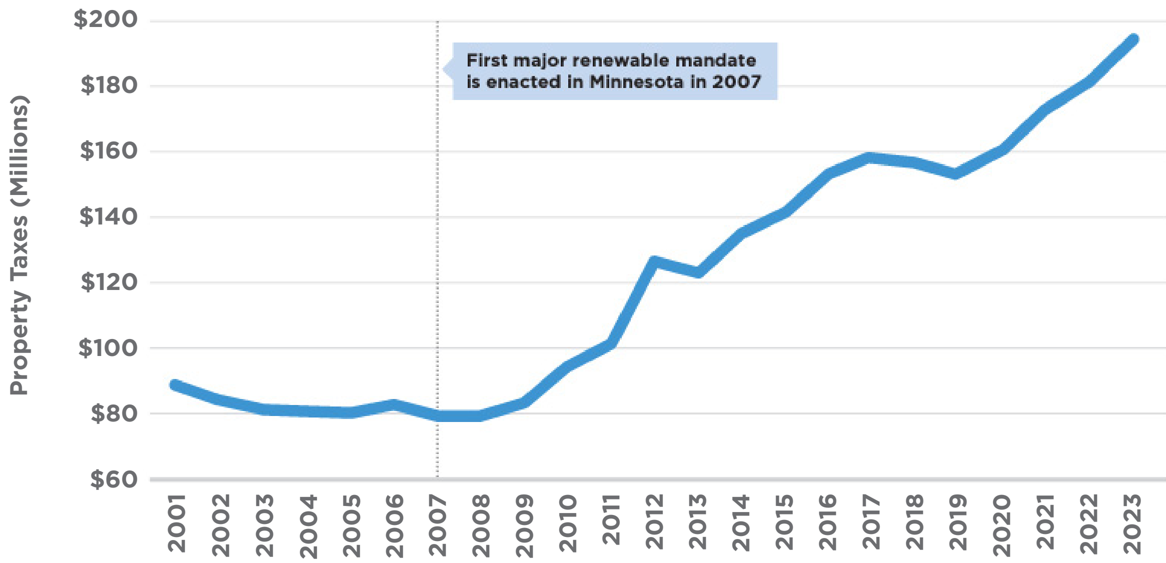


Figure 14. Property taxes increase as more intermittent renewable energy sources are added to the grid because there is more property to tax.

to our assumptions based on NREL estimates, these transmission line miles would increase by 58 percent — the low end of NREL estimates — under the Walz Proposal.

Transmission lines in Minnesota routinely cost $3.2 million per mile for 230 kV lines, $5.2 million per mile for 345 kV lines, and $2.6 million per mile for HVDC lines.[33] We estimate building enough transmission lines to comply with the Walz Proposal would cost $14 billion.

The LCD Scenario, in contrast, would require minimal transmission buildout, increasing transmission costs by $1 billion by 2050 to accommodate new nuclear power plants built near existing power plant infrastructure in Minnesota.[34]

Utility returns

Because investor-owned utilities (IOUs) in Minnesota, such as Xcel Energy, Minnesota Power, and Otter Tail Power, are regulated monopolies, they are not allowed to make a profit on the electricity they sell.

Instead, they are guaranteed a 10.2 percent profit, or rate-of-return on equity, when they spend money on capital assets such as power plants, transmission lines, and even new corporate offices, if the Minnesota Public Utilities Commission (PUC) approves those expenses. This report utilizes the capital structure of Xcel to estimate utility returns.[35]

The Walz Proposal would require utilities to spend $195 billion on new infrastructure, whereas capital expenditures in the LCD Scenario would be $57.7 billion. As a result,

FIGURE 15

Total Additional Cost Breakdown of Walz Proposal vs. LCD Scenario

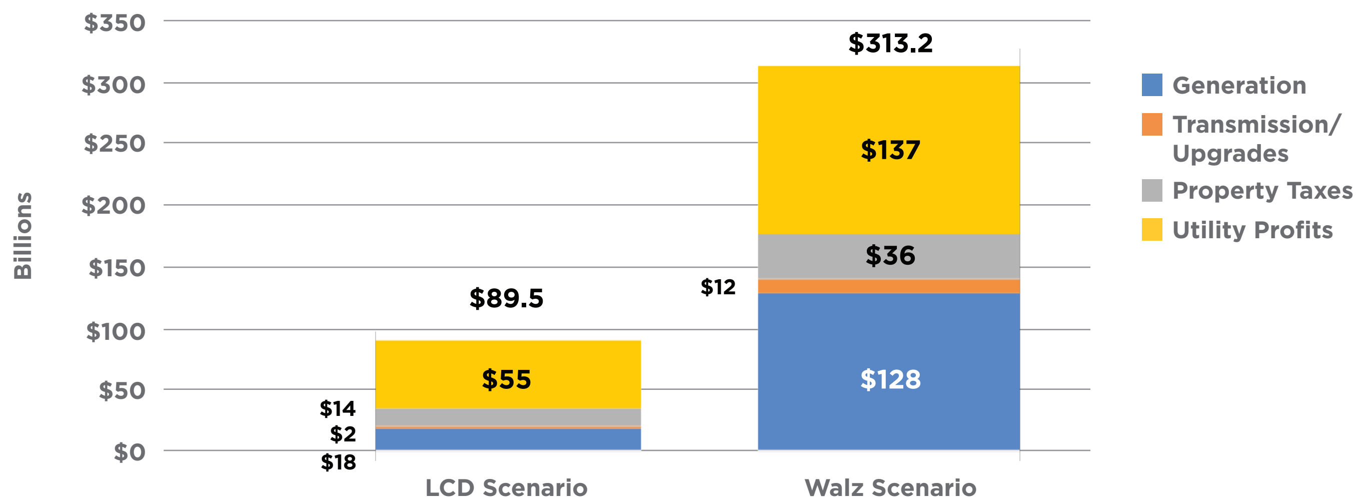


Figure 15. The Walz Proposal would cost 3.5 times more than the LCD Scenario through 2050, with costs driven by higher utility profits and additional generation costs. Capital costs are spread out beyond the 2050 study horizon, and are not entirely captured in this bar chart.

additional corporate profits for investor-owned utilities would be far higher under the Walz Proposal, $137.4 billion, than under the LCD Scenario, $55 billion. This makes the utility returns the second-largest expense in each scenario, after capital costs for building new power plants.

The government-approved rate of return on new power plants, regardless of their reliability, gives IOUs a powerful incentive to build unreliable wind and solar facilities with battery backup to maximize utility profits. This places the interests of the utility in direct competition with those of the ratepayers, who would benefit most from the company investing in reliable power plants that last 40 to 80 years.

This situation could be remedied if IOUs were allowed to recoup only the portion of their costs based on the reliability of the asset in question.

Property taxes

Property taxes increase most under the Walz Proposal because compared to the current grid and LCD Scenario, there is much more property to tax. While the property taxes assessed on power plants are often a crucial revenue stream for local communities that host power plants, these taxes also effectively increase the cost of producing and providing electricity for everyone.

For example, Xcel Energy saw its property taxes increase exponentially as it built wind, solar and transmission facilities to satisfy Minnesota's original renewable energy mandate, the NGEA.

Property taxes increased from a low of $79 million in 2007 to $192 million projected in the year 2023, an increase of more than 143 percent (see Figure 14).[36]

Additional property tax payments under the Walz Proposal were calculated to be $36 billion, compared to operating the existing power grid.[37] Under the LCD Scenario, additional property taxes would be $14.4 billion, relative to current expenditures, as older, depreciated coal plants are replaced with new nuclear power plants and other reliable carbon-free technologies.

Total Cost

Figure 15 shows the total cost comparison of the Walz Proposal and the LCD Scenario. As you can see, the Walz Proposal is more expensive than the LCD Scenario in every aspect.

Section V: The Levelized Cost of Energy for Different Generating Resources

Almost all studies that examine the cost of renewable energy use a methodology called the Levelized Cost of Energy, or LCOE, to assess the cost of wind and solar compared to different technologies.[38] LCOE estimates reflect the cost of generating electricity from different types of power plants, on a per-unit of electricity basis (generally megawatt hours), over an assumed lifetime and quantity of electricity generated by the plant.

In other words, LCOE estimates are essentially like calculating the cost of your car on a per-mile-driven basis after accounting for expenses like initial capital investment, loan and insurance payments, fuel costs, and maintenance.

> **"LCOE estimates are essentially like calculating the cost of your car on a per-mile-driven basis after accounting for expenses like initial capital investment, loan and insurance payments, fuel costs, and maintenance."**

Wind and solar advocates often misquote LCOE estimates from Lazard or EIA to claim that wind and solar are now lower cost than other sources of energy.[39] However, Lazard and EIA show the cost of operating a single wind or solar facility at its maximum reasonable output; they do not convey the cost of *reliably operating an entire electricity system* with high penetrations of wind and solar, which costs exponentially more.[40]

For example, Lazard and EIA do not account for the expenses incurred to build new transmission lines, the additional property taxes, utility profits, or the cost of providing "backup" electricity with natural gas or battery storage when the wind is not blowing or the sun is not shining, referred to as a "load balancing" cost in this report.[41]

Even more importantly, the LCOE estimates generated by Lazard and EIA do not account for the massive overbuilding and curtailment that must occur to ensure that grids with high reliance on wind, solar, and battery storage meet electricity demand at every hour of every day.[42]

It is important for the reader to understand that the costs associated with load balancing, overbuilding, and curtailment increase dramatically because the amount of wind,

FIGURE 16

LCOE: Existing vs. New Energy Sources

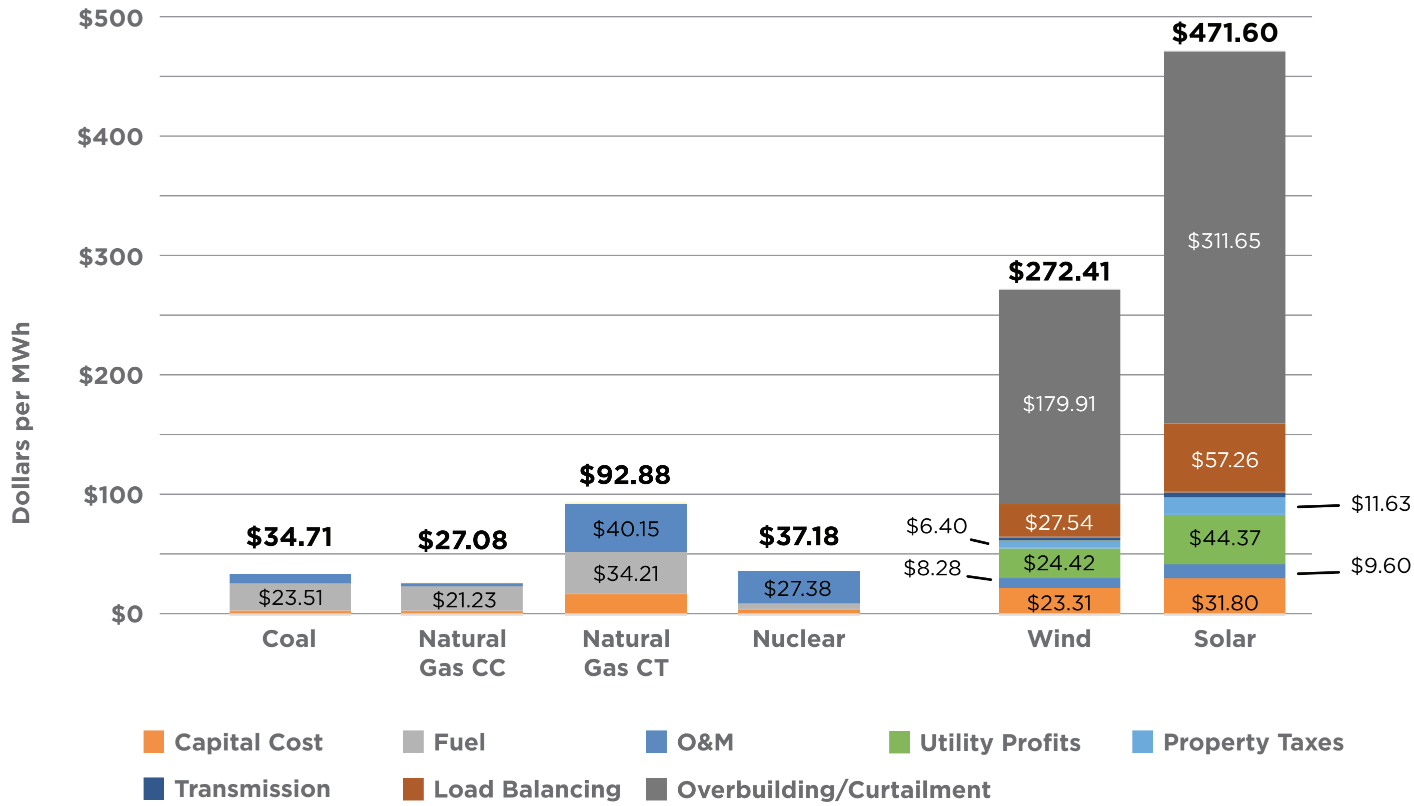


Figure 16. New solar facilities are the most expensive form of new electricity generation built under the Walz Proposal. Once costs such as property taxes, transmission, utility returns, battery storage, and overbuilding and curtailment, are accounted for new wind costs $272 per MWh, and new solar costs $472 per MWh.

solar, and battery storage must be "overbuilt" to account for the intermittency of wind and solar, which is why the Walz Proposal has an installed capacity of 100,445 MW by 2040, whereas the LCD Scenario has a capacity of 16,379 MW.

American Experiment's model accounts for all of these additional expenses and attributes them to the cost of wind and solar to get an "All-In" LCOE value for these energy sources. Our All-In LCOE represents the cost of delivering the same reliability value of other generating technologies, allowing for an apples-to-apples comparison of the cost of reliably meeting electricity demand with existing nuclear, natural gas, and coal plants operating in Minnesota, or new plants built under the LCD Scenario and Walz Proposal.

Data from the Federal Energy Regulatory Commission (FERC) show Minnesota's natural gas plants are some of the lowest-cost sources of electricity in the state, generating electricity at a cost of $27 per MWh. Minnesota's nuclear plants generated electricity for $37 per MWh, and coal plants in the state generated electricity for $35 per MWh, on average in 2019 (see Figure 16).

Under the Walz Proposal, these low-cost, reliable coal and natural gas plants would be replaced with wind, solar, and battery storage by 2040. Figure 16 shows the All-In LCOE of

FIGURE 17

LCD Scenario LCOE: Existing vs. New Energy Sources

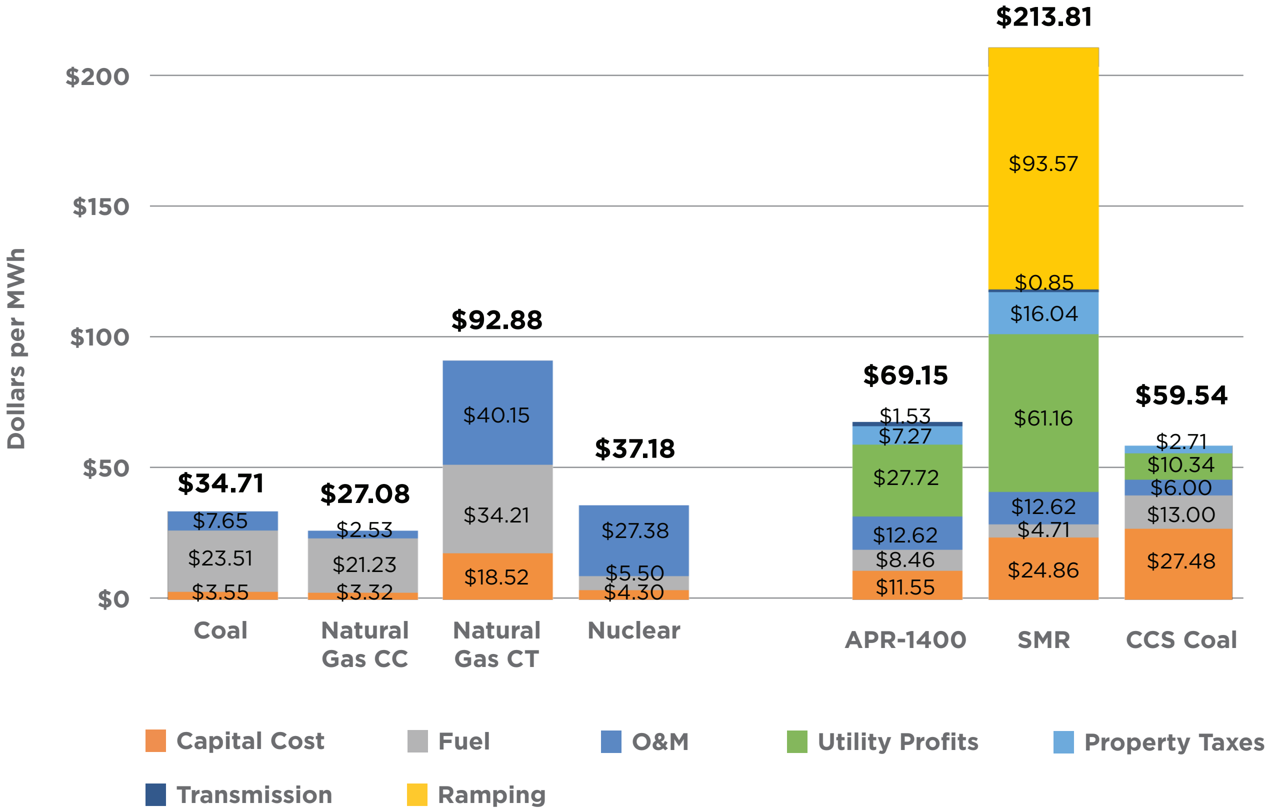


Figure 17. Under the LCD Scenario, CCS coal would become the lowest-cost low-carbon asset serving Minnesota's electricity demands. APR-1400s would become the lowest cost source of new nuclear power.

new wind and solar reaches approximately $272 and $472 per MWh, respectively, on average throughout the model run.

Because curtailment rates reach 72 percent by 2040, overbuilding and curtailment costs are the primary drivers of wind and solar expenses due to the need to build 7.3 times more capacity than would be needed to meet Minnesota's peak demand of 13,690 MW with dispatchable power plants.[43] As a result, the cost of battery storage, overbuilding, and curtailing in Figure 16 can be thought of as a levelized cost of intermittency, or unreliability.

In the LCD Scenario, new SMRs, APR-1400s, and retrofitted coal plants utilizing CCS have higher costs than existing nuclear, natural gas, and coal power plants, but these costs are substantially lower than wind and solar in the Walz Proposal (see Figure 17).

As discussed in Section IV, costs are higher for wind and solar facilities because grids powered with large concentrations of intermittent wind and solar require much more total capacity and transmission to meet electricity demand than systems consisting largely of dispatchable power systems such as traditional fossil fuel plants and nuclear. While the cost of new nuclear SMR power plants is also high, this is because these facilities are utilized as "peaking" energy sources later in the model.[44]

Section VI: Implications for Reliability

Reliability is the most crucial function of the electric grid. Our lives have never been more dependent upon electronic devices, and it is highly unlikely that we will be less dependent upon them in the future.

The Walz Proposal will seriously undermine the reliability of the electric grid by making it more dependent on fluctuations in the weather. This dependency will end in blackouts. In contrast, the LCD Scenario maintains the reliability of Minnesota's electric grid while reducing emissions at a much lower cost.

> **"The Walz Proposal will seriously undermine the reliability of the electric grid by making it more dependent on fluctuations in the weather."**

Reliability in the Walz Proposal

American Experiment's modeling determined the amount of wind, solar, and battery storage capacity needed for the Walz Proposal by using hourly electricity demand data for 2021 from the U.S. Energy Information Administration and real-world wind and solar capacity factors from MISO for the year 2021.

With these inputs, our model determined that the 47,112 MW of wind, 15,390 MW of solar, and 35,449 MW of battery storage built in the Walz Proposal would provide enough electricity to meet demand for every hour of the year in 2021.

Figure 18 shows electricity demand and supply by type for a hypothetical period in the future stretching from January 15, 2040, to February 15, 2040. As you can see, wind, solar, battery storage, and Minnesota's existing nuclear power plants are able to provide enough electricity to meet demand, shown in the black line.

While our model shows there is enough electricity to meet demand for every hour of 2021, it is important to remember that this conclusion is based on just one year's worth of weather-driven wind and solar generation.[45] Given that wind and solar generation is driven by weather patterns, it is important to evaluate whether changes in the weather would result in a situation where electricity supply could not meet demand — a capacity shortfall — resulting in rolling

FIGURE 18

Walz Proposal Hourly Electricity Supply 1/15/2040-2/15/2040: 2021 Demand and Capacity Factors

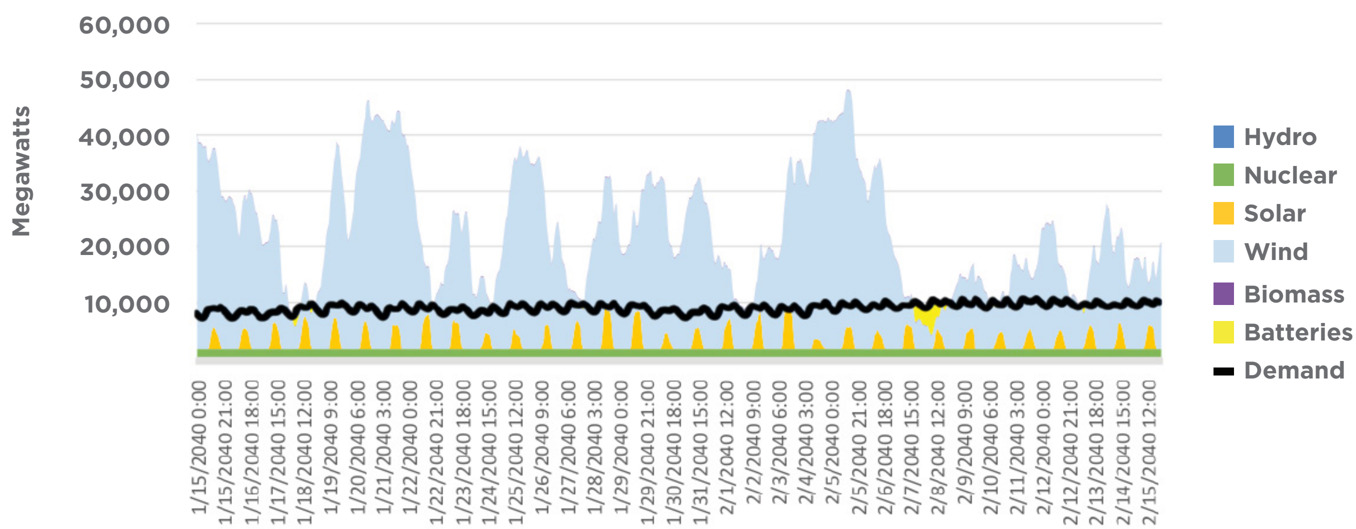


Figure 18. Wind, solar, and battery storage are able to meet electricity demand for every hour from January 15, 2040 through February 15, 2040.

blackouts or brownouts.

To evaluate the impact of annual changes in wind and solar generation — which is a function of the weather—on the reliability of the grid, American Experiment obtained the MISO capacity factors for wind and solar in 2019 and 2020 to see if the amount of installed wind, solar, and battery storage capacity in the Walz Proposal would be enough to meet electricity demand at all hours of the year, regardless of changes in the weather.

It is not.

The reliability of the Walz Proposal with 2019 weather

Using 2019 wind and solar generation data from MISO and comparing it to 2021 hourly electricity demand data, American Experiment determined that there would be 11 hours of capacity shortfalls throughout the year, with a maximum capacity shortfall of more than 2,400 MW.

Figure 19 shows electricity demand and supply during the same hypothetical period in the future stretching from January 15, 2040, to February 15, 2040. As you can see, wind, solar, battery storage, and Minnesota's existing nuclear power plants are ***unable*** to provide enough electricity to meet demand, shown in the black line, resulting in a 6-hour blackout on the night of February 6 into the morning of February 7.

The capacity shortfall stretching from February 6 to February 7 is caused by low wind and solar output and insufficient battery storage capacity to store excess wind generation from previous days — even with more than 140,000 MWhs of storage available. During this period, solar capacity factors were

FIGURE 19

Walz Proposal Hourly Electricity Supply 1/15/2040-2/15/2040: 2021 Demand and 2019 Capacity Factors

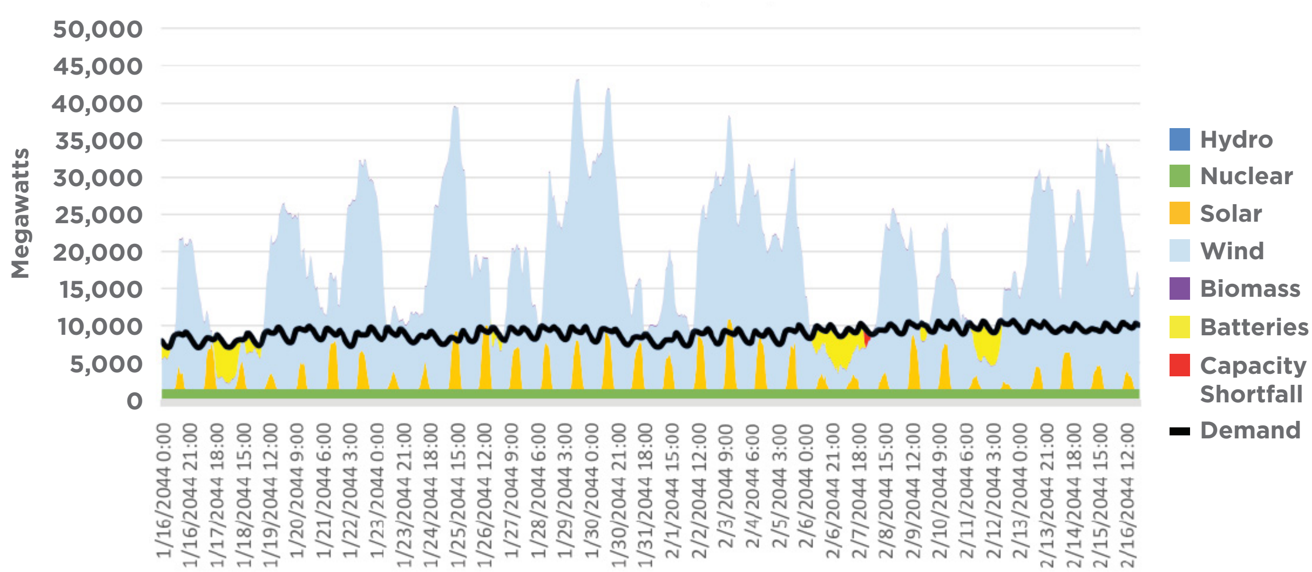


Figure 19. Wind, solar, and battery storage are unable to meet electricity demand for every hour of the year 2021, resulting in a 6-hour capacity shortfall in February, shown in red on the graph.

just eight percent due to the fact that February 2019 was one of the snowiest months in recent records, and wind capacity factors were 33 percent.

The size of the shortfall is significant, with a maximum shortfall of 2,439 MW occurring at midnight on February 7, which is enough to power nearly all of the homes in Minnesota in an average hour.

The reliability of the Walz Proposal with 2020 weather

Using 2020 data for wind and solar generation presents a much more dire situation.

Comparing this wind and solar generation to 2021 hourly electricity demand data, American Experiment determined there would be 71 hours of capacity shortfalls throughout the year, totaling more than 357,000 MWhs of lost generation. Shortfalls would occur in January and July.

Figure 20 shows electricity demand and supply for the hypothetical period stretching from January 15, 2040, to February 15, 2040. As you can see, wind, solar, battery storage, and Minnesota's existing nuclear power plants fail to provide enough electricity to meet demand, shown by the black line, for 55 straight hours stretching from 8 a.m. on January 28 to 2 p.m. on January 30.

The capacity shortfall stretching from January 28 to January 30 is caused by wind output dropping to below 10 percent of its

FIGURE 20

Walz Proposal Hourly Electricity Supply 1/15/2040-2/15/2040: 2021 Demand and 2020 Capacity Factors

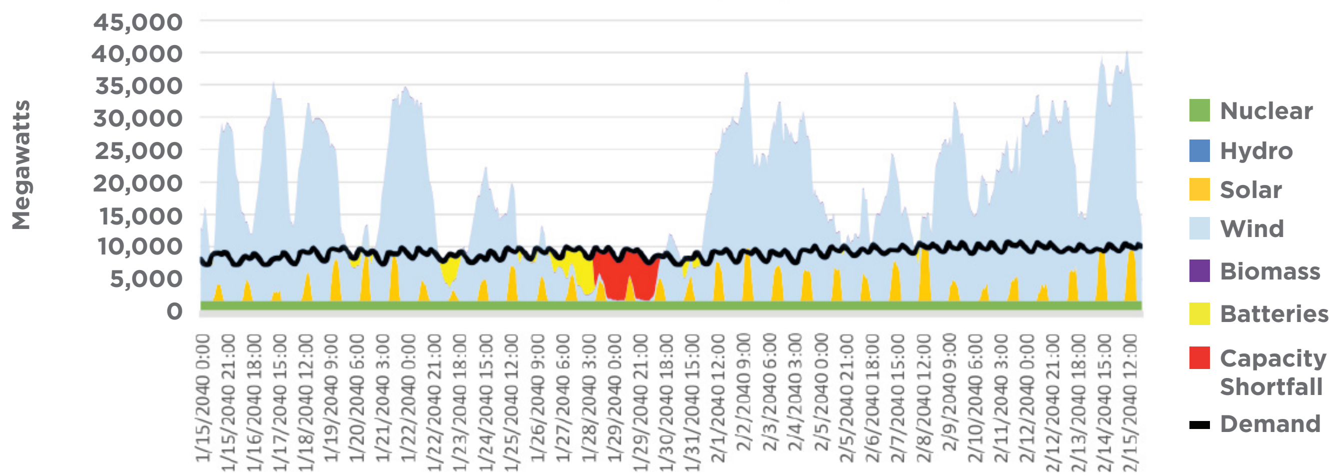


Figure 20. Wind, solar, and battery storage are unable to meet electricity demand for 55 straight hours, shown in red, resulting in a devastating winter blackout.

potential output, or capacity factor, for 82 hours straight. Of those 82 hours, 42 straight hours saw wind capacity factors below 1.5 percent. Additionally, solar capacity factors never exceed 25 percent during the duration of the capacity shortfall.

The size of the shortfall is enormous, with a maximum shortfall of 7,884 MW occurring at 8 p.m. on January 28, which is enough capacity to power the entire state, based on the average hourly consumption in 2020.

Relatively short blackouts ranging from four to six hours are economically damaging, but long sustained blackouts are absolutely devastating. A 55-hour blackout in January would be nothing short of catastrophic in Minnesota.

Furnaces would stop working because the blower fans that circulate the warm air are powered by electricity. Water pipes would freeze, and hundreds, if not thousands, of people would die from carbon monoxide poisoning when they attempt to keep warm by bringing charcoal grills inside or sitting in running cars in their garages, as occurred in Texas during the blackouts of 2021.[46]

In a year with weather like 2020, the Walz Proposal would result in a disaster like the situation in Texas in February 2021, when 246 people died.[47] On top of the high human cost, such a long blackout in Minnesota would also be economically devastating.

Using a rough metric of dollars of state gross domestic product (GDP) per MWh of electricity consumed, the average MWh of electricity consumption supports nearly $5,650 in economic activity.[48] Therefore, the 313,000 MWhs not consumed during the 55-hour blackout would result in $1.77 billion in lost economic productivity, which does not even begin to account for the repairs that would

FIGURE 21

LCD Scenario Hourly Electricity Supply 1/15/2040-2/15/2040

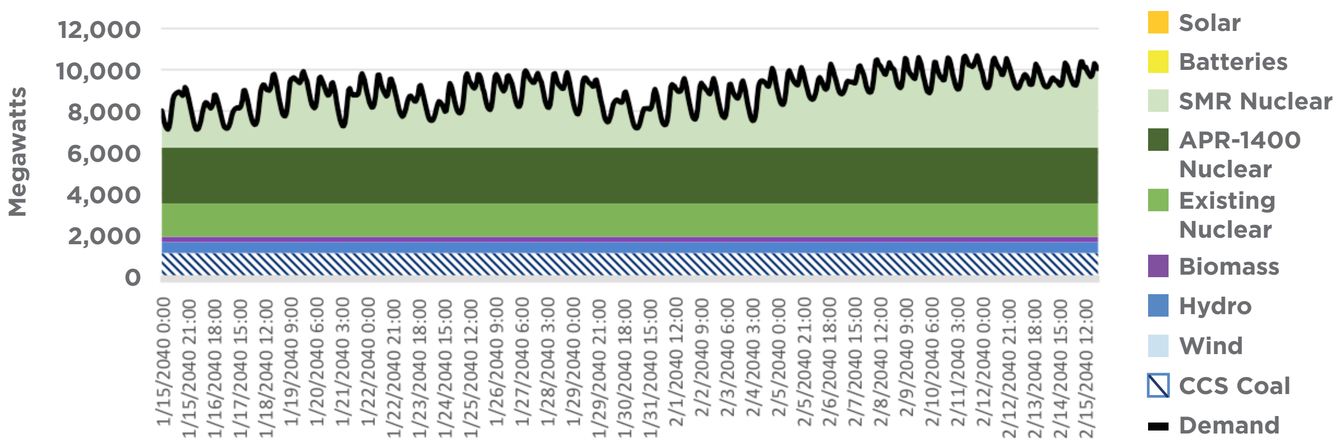


Figure 21. The LCD Scenario would maintain the reliability of Minnesota's electric grid by utilizing reliable sources of electricity.

need to be made to fix the damages caused by the blackout.

Preventing these blackouts by increasing the amount of wind, solar, and battery storage capacity serving Minnesota's electricity demand would bring the total cost of the Walz Proposal to $521 billion, which would cost the average Minnesota household nearly $6,500 per year in additional electricity expenses. Even after spending these additional funds, it is possible that fluctuations in weather from year to year could still cause rolling blackouts.

LCD Scenario

While the Walz Proposal would result in rolling blackouts in two (2019 and 2020) of the last three years, the LCD Scenario would maintain a reliable grid and increase the amount of dispatchable capacity in the state, resulting in zero hours of capacity shortfalls.

Figure 21 shows there is enough dispatchable capacity on the Minnesota electric grid in the LCD Scenario to reliably meet electricity demand for every hour during the period from January 15, 2040, through February 15, 2040, regardless of weather conditions.

In the LCD Scenario, SMRs, hydroelectric plants, and battery storage increase and decrease their output to perfectly match electricity demand. APR-1400s and coal plants with CCS act as baseload power plants, providing steady, reliable power around the clock.

The fact that the LCD Scenario utilizes reliable, dispatchable power plants saves $224 billion compared to the Walz Proposal and delivers far superior results for electric reliability. Even so, the average residential customer would see his or her annual electricity expenses increased by more than $2,400 in 2040 to finance the construction of new nuclear power plants and battery storage, and additional expenses for retrofitting coal plants with CCS equipment.

Section VII: High Energy Costs Harm Minnesota Families and the Economy

Proponents of solar panels and wind turbines often argue that increasing the use of these technologies will benefit local economies. They are wrong. Increasing the cost of electricity does not grow the economy, it simply transfers into the electricity sector money that would have been spent elsewhere.

Spending $313 billion on new solar panels, wind turbines, transmission lines, and battery storage facilities under the Walz Proposal will cause significant increases in electricity costs for every electricity customer in Minnesota. The LCD Scenario, with a cost of $89.5 billion, will increase electricity costs to a much lesser degree.

"Spending $313 billion on new solar panels, wind turbines, transmission lines, and battery storage facilities under the Walz Proposal will cause significant increases in electricity costs for every electricity customer in Minnesota."

As discussed earlier in this report, the Walz Proposal would result in average additional costs of $3,888 per customer per year through 2050, whereas the LCD Scenario would increase costs by $1,039 per customer per year.[49] Rising electricity costs mean Minnesotans will have less money for rent or mortgage payments, nutritious food for their families, healthcare for their children, or to put into savings.

Low-income households will be hurt most by rising electricity costs because they spend a higher percentage of their income on energy bills than other Minnesota households.

Data from the U.S. Department of Energy's Low-Income Energy Assistance Data (LEAD) program show a significant number of Minnesota residents already spend between four and six percent of their income on electricity and home heating fuels, such as natural gas, heating oil, propane, or electricity (see Figure 22).[50] The number of Minnesotans paying this much of their income for energy has almost certainly increased since the beginning of 2021, as natural gas and electricity prices have increased.[51,52]

FIGURE 22

Low-Income Energy Affordability (LEAD) Tool

Data (housing only) comes from the U.S. Census Bureau's American Community Survey 2018 Public Use Microdata Samples.

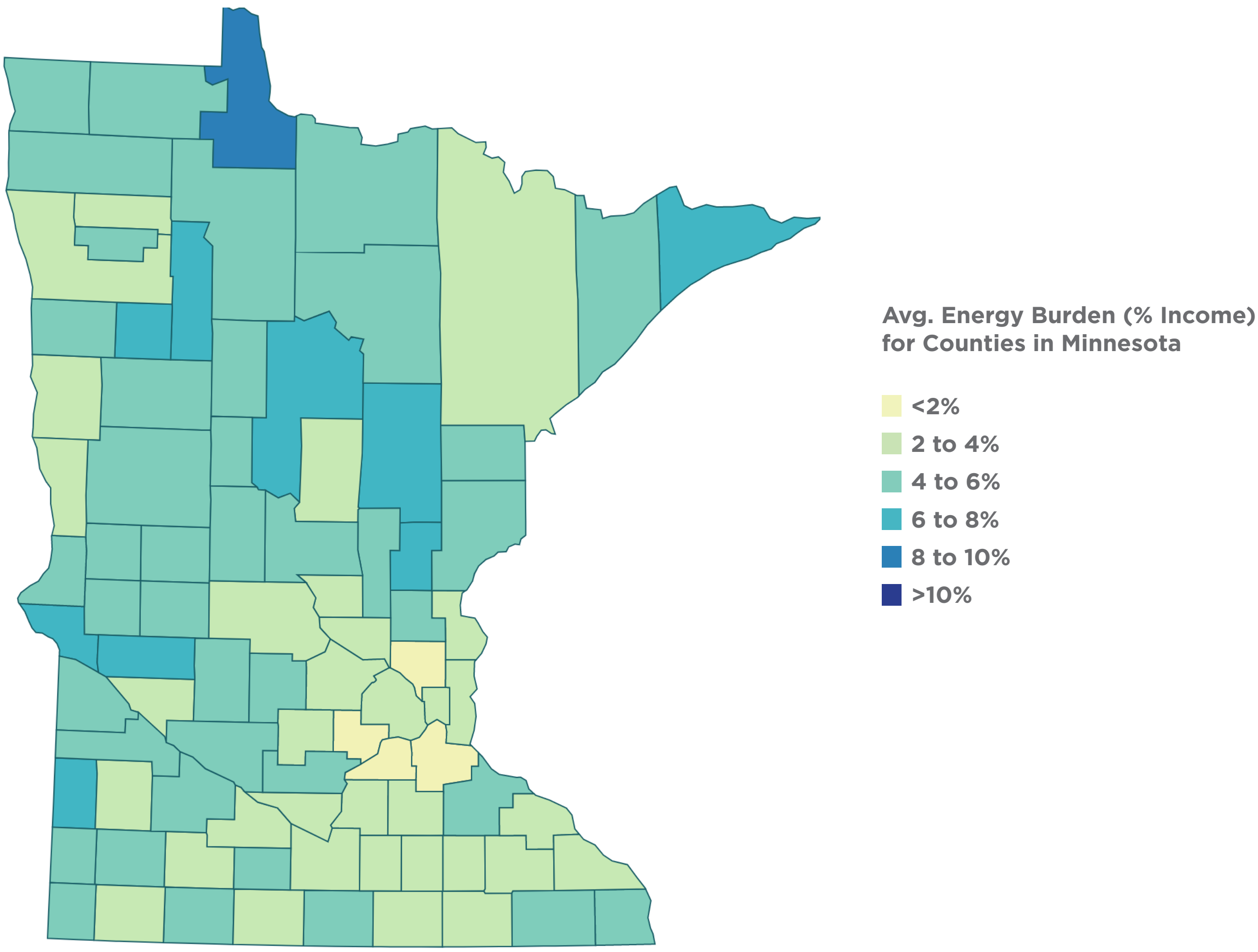


Figure 22. Federal data show Minnesota households living in several counties already pay between four and six percent of their income for energy bills.

By drastically increasing energy costs paid by Minnesota consumers, the Walz Proposal will increase the cost of essential services like refrigerating food and medicine, home heating, and air conditioning. The policy is incredibly regressive because those with the least will lose the most.

Broader economic impacts

Increasing the cost of electricity would harm the state's economy in two primary ways.

First, it would reduce the amount of household income available to families to spend on goods and services, therefore

FIGURE 23

Job Losses Due to Higher Electricity Prices

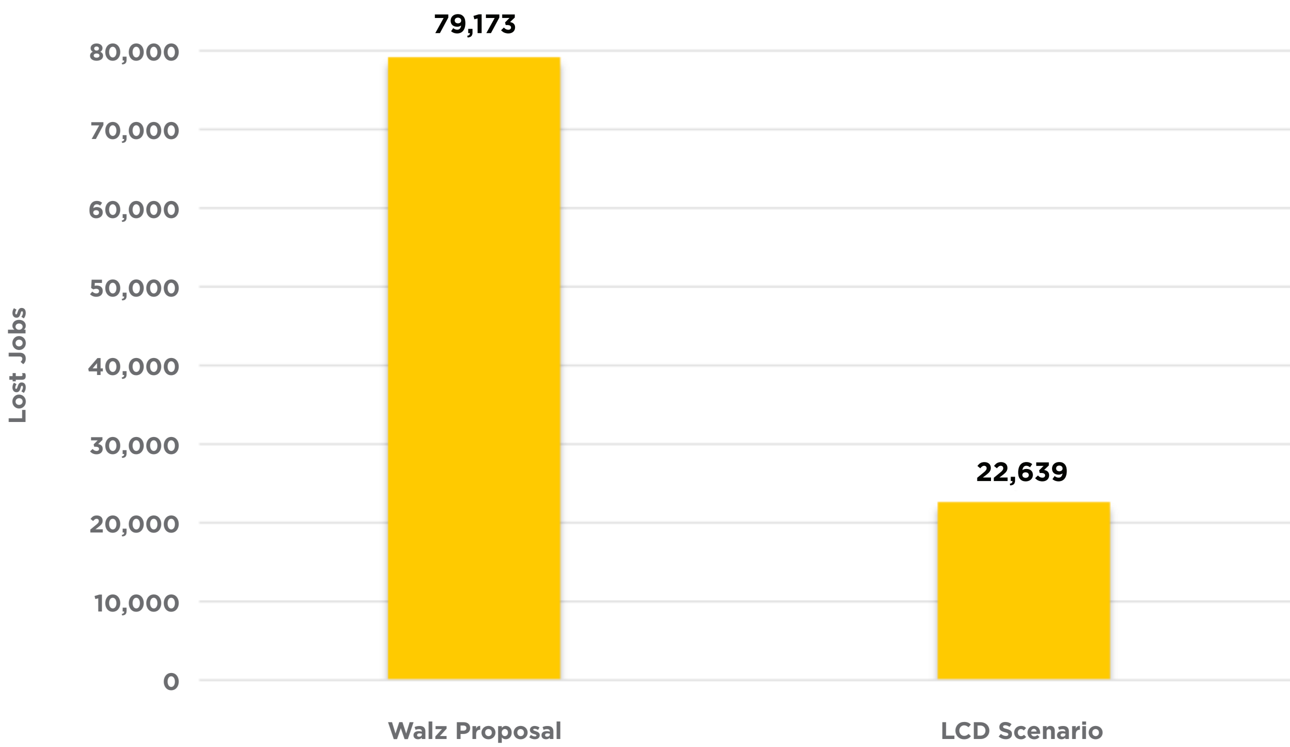


Figure 23. Higher electricity prices act as a tax increase on the entire economy, which in turn reduces employment. The Walz Proposal would kill 79,173 jobs, while the LCD Scenario would reduce employment by 22,639.

reducing demand in other sectors of the economy. For example, the extra money a family spends on electricity may mean fewer meals at local restaurants or delayed repairs to a home or automobile.

Second, it would increase the costs of healthcare, education, food, and durable goods, because electricity is the invisible ingredient in everything. Rising electricity costs force businesses to raise the prices of the goods and services they offer or reduce staffing or other expenses to help offset additional energy costs.

Lost jobs from high energy prices

By increasing energy costs and thereby reducing the income available for spending in other sectors of the economy, the Walz Proposal and LCD Scenario would reduce the ability of Minnesota families to pay for, thus reducing the demand for, other goods and services in the broader economy. This makes it more difficult for businesses to retain employees and raise wages. Most importantly, it makes Minnesota businesses less competitive

FIGURE 24

Average Wages in St. Louis and Hennepin County vs Mining Jobs (2021)

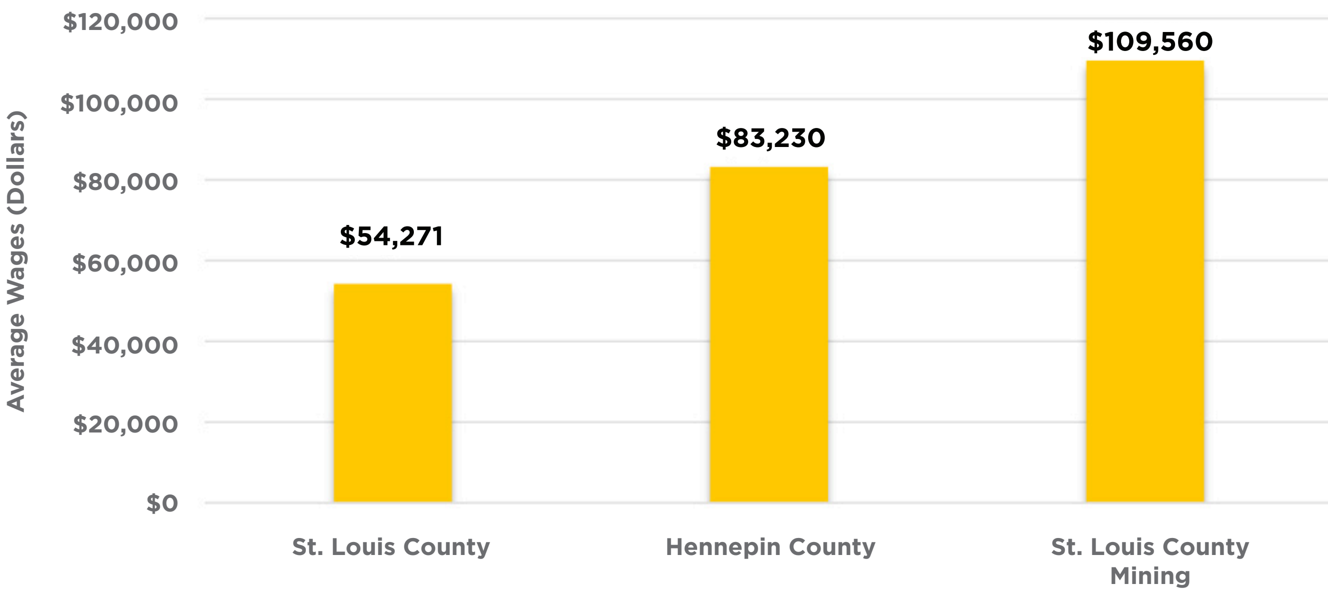


Figure 24. Mining jobs pay twice as much as the average job in St. Louis County, making them a vital cornerstone of the region's economy.

with companies in other states, or nations, with lower energy costs.

Using the economic modeling software IMPLAN, American Experiment calculated the number of jobs that would be lost due to higher electricity prices in the Walz Proposal and LCD Scenario. The Walz Proposal would result in a loss of 79,173 jobs through 2050, the LCD Scenario would result in 22,639 job losses (see Figure 23).

Minnesota's GDP would be $13.27 billion smaller (in 2022 constant dollars) every year through 2050 under the Walz Proposal and $3.8 billion smaller under the LCD Scenario, the equivalent of 3.2 percent of the state's 2021 GDP under the Walz Proposal, and about one percent of Minnesota's 2021 GDP under the LCD scenario.[53]

In the Walz Proposal, prices increase dramatically, and the vast majority of the jobs created are temporary construction jobs at wind and solar installations. High electricity costs disproportionately jeopardize jobs in energy-intensive industries like agriculture, manufacturing, and mining, which compete in a global marketplace.

While the initial building of new wind turbines and solar facilities does create a substantial number of low-wage, temporary jobs — approximately 67 percent of solar jobs are in installation and development — many more permanent, higher-paying jobs are lost due to the higher electricity prices that accompany renewable energy.[54,55]

High electricity prices destroy jobs in manufacturing and mining

Energy-intensive industries such as manufacturing and mining are at the highest risk of becoming uncompetitive due to increasing electricity prices. Industrial electricity users in Minnesota spent $1.5 billion on electricity in 2020, consuming 19.5 million MWhs of electricity, nearly 32.5 percent of Minnesota's total electricity use that year.[56]

Under the Walz Proposal, these expenditures would grow to more than $5 billion by 2040, a 240 percent increase compared to 2020 costs. Industrial electricity expenses would increase by 163 percent under the LCD Scenario.

"Energy-intensive industries such as manufacturing and mining are at the highest risk of becoming uncompetitive due to increasing electricity prices."

Manufacturing

Manufacturing is a staple of Minnesota's economy. Manufacturing jobs are good, family-supporting jobs. According to the National Manufacturers Association, manufacturing accounted for $52 billion in the state's economy in 2019, accounting for 13.6 percent of total GDP. Minnesota manufacturers employed 310,000 people in 2020, with average annual compensation of $80,900 in 2019.[57]

The high wages paid in the manufacturing sector are why each job in manufacturing supports 1.9 indirect and induced jobs (the "multiplier effect") in other sectors of the economy, bringing the total employment impact of manufacturing to more than one million jobs.[58] Because manufacturing has a high multiplier effect, a factory closing in Greater Minnesota has a large, negative ripple effect throughout entire communities.

Unfortunately, this sector is especially sensitive to rising energy costs because manufacturers consume large quantities of electricity. Industrial electricity prices in Minnesota already have increased by 48 percent since the NGEA was signed into law in 2007. The Walz Proposal would increase the average annual electric bill for industrial electricity consumers by $222,000, compared to $62,000 for the LCD Scenario.

Mining

Like manufacturing, mining is an indispensable pillar of Minnesota's economy. Bureau of Labor Statistics (BLS) data show mining employed 3,541 people in St. Louis County, Minnesota in 2021, with annual average wages exceeding $109,560 in 2021.[59,60] Mining jobs are some of the best jobs in the entire state, but they are especially critical for northeastern Minnesota, where average annual wages in St. Louis County are approximately $54,200 (see Figure 24).[61]

Unfortunately, high electricity prices threaten these high-paying jobs because mining operations use enormous quantities of electricity. For example, the Minntac Mine in Mountain Iron is reported to use as much natural gas and electricity as the City of Minneapolis. Statewide, the iron mining industry uses 600 MW of power, enough power plant capacity to power nearly 23 percent of all the homes in Minnesota, in an average hour.[62,63]

American Experiment estimates that electricity costs for iron mines under the Walz Proposal would be 3.4 times higher than current expenses, increasing from $400 million in 2020 to $1.368 billion in 2040, an increase of $965 million. This is the equivalent of 10,490 mining jobs. Electricity expenses would increase by $656 million under the LCD Scenario, the equivalent of 7,130 jobs.

The massive quantities of electricity needed for mining and processing iron ore makes the price of energy a large factor in determining whether a mining operation will be profitable. The Walz Proposal would also harm the mining industry by making electricity less available.

In June 2021, MISO issued an emergency warning that the hot weather, unexpected power plant outages, and high demand were resulting in a shortage of electricity. Minnesota iron ore facilities were called on to reduce production, thereby reducing electricity demand and helping to prevent rolling blackouts, according to the Mesabi Tribune:[64,65]

> *"For the second time in five months, northeastern Minnesota taconite plants have had to cut back on electricity usage.*
>
> *With unusual heat blanketing the Midwest and high demand for electricity expected, the Midcontinent Independent System Operator (MISO) on Thursday asked large users across the Midwest to reduce electrical consumption.*
>
> *Northeastern Minnesota taconite plants idled processing equipment to help reduce electricity demand.*
>
> *"We were notified by Minnesota Power that a temporary power reduction was needed to balance power requirements due to the hot weather," Amanda Malkowski, United States Steel Corp. spokeswoman said. "We safely shed power by an orderly temporary idling of several Concentrator lines. The curtailment period has ended."*

Reducing the number of hours a taconite facility can run, thereby reducing its productivity, will make it more difficult for Minnesota mining facilities to compete in a global marketplace. This places the 11,600 jobs that are supported by Minnesota's mining industry — and the families that rely upon them — in jeopardy.

These factors will also be true for Minnesota's fledgling copper-nickel, cobalt, platinum group metal, and ilmenite mining industries, which could support up to 14,850 new direct, indirect, and induced jobs in Minnesota.[66]

If we don't mine these resources in Minnesota due in part to high electricity prices or faltering reliability, we will obtain them from somewhere else, making the United States more dependent on foreign countries like China, the Democratic Republic of the Congo, and Russia for the metals and minerals we use every day.[67]

These nations are decidedly less democratic than the United States, and they have fewer protections for workers and the environment. They use mining techniques that are less efficient and have a higher negative environmental impact.

Instead of incentivizing the offshoring of our critical industries, we should seek to bolster those industries by providing the most reliable, affordable electricity possible while taking cost-effective measures to curb emissions.

Section VIII: Emissions Reductions

Given the large cost of reducing carbon dioxide emissions from both the Walz Proposal and the LCD Scenario, it makes sense to ask two questions: How much future global warming would these policies prevent, and are these measures worth the cost?

Temperature impacts of reduced emissions

Both the Walz Proposal and the LCD Scenario reduce carbon dioxide emissions by at least 98 percent compared to 2021 levels of 37 million metric tons.

To understand the global-temperature impact of reducing emissions by 37 million metric tons, it helps to examine the temperature impact of the Clean Power Plan (CPP), which was widely considered to be the Obama administration's signature climate change initiative.

> **"Using MAGICC, the Obama administration estimated the CPP would have reduced future warming by only 0.019° C by 2100, an amount too small to be accurately measured with even the most sophisticated scientific equipment."**

The Obama administration claimed the CPP would have reduced annual CO_2 emissions nationally by 730 million metric tons (804.7 million short tons) by 2030. The Obama administration's Environmental Protection Agency used a climate model called the Model for the Assessment of Greenhouse-Gas Induced Climate Change (MAGICC) to determine the CPPs temperature impact.

Using MAGICC, the Obama administration estimated the CPP would have reduced future warming by only 0.019° C by 2100, an amount too small to be accurately measured with even the most sophisticated scientific equipment. The 37 million metric tons of CO_2 no longer emitted from power plants serving Minnesota would account for 5 percent of the 730 million metric tons averted by the CPP.

From this figure, we can extrapolate that the Walz Proposal and LCD Scenario would

FIGURE 25

Social Cost of Carbon (Obama and Trump Estimates) vs. Cost of Reducing CO_2 Emissions (LCD Scenario and Walz Proposal)

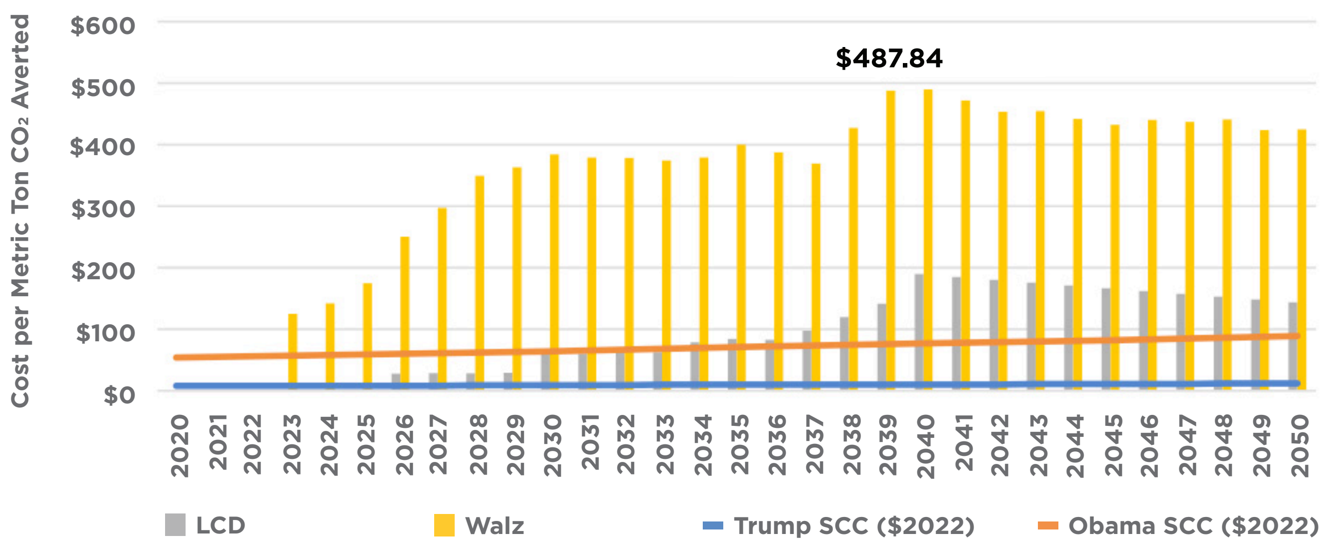


Figure 25. The cost of reducing emissions under the Walz Proposal vastly exceed the Obama SCC estimates in every year studied, and exceed the Trump administration estimates to a far greater extent.

avert 5 percent of the 0.019° C by 2100, for a potential future temperature reduction of 0.00096° C by 2100, meaning the reductions will have no measurable impact on future global temperatures.

Assessing the costs and benefits of reducing emissions

When evaluating energy policies aimed at reducing greenhouse gas emissions, it is important to weigh the cost of reducing emissions against the expected benefits of doing so. If the costs of reducing emissions exceed the expected benefits, the policy does not make sense to enact.

To conduct this cost benefit analysis, policymakers often use a tool called the Social Cost of Carbon (SCC) to estimate the economic costs, or damages, of emitting one additional ton of carbon dioxide into the atmosphere in terms of changing temperatures, and thus the benefits of reducing emissions.[68] While the SCC has serious shortcomings, it can help illustrate when the costs of a proposed policy obviously outweigh the benefits.[69]

Figure 25 shows the cost of reducing each ton of carbon dioxide in the year 2040 under the Walz Proposal and the LCD Scenario and compares it to the SCC estimates established by both the Obama and Trump administrations.

Figure 25 shows that the cost of reducing

FIGURE 26

Annual CO_2 Emissions: Walz Proposal vs. LCD Scenario

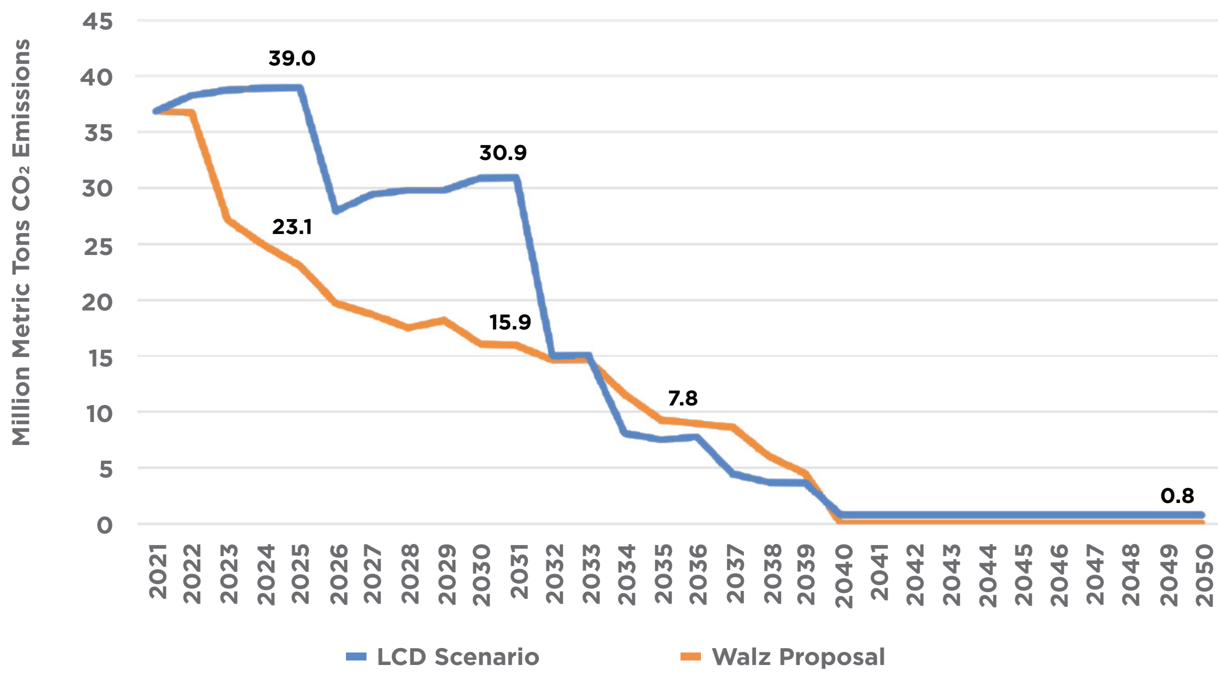


Figure 26. Both scenarios achieve dramatic reductions in carbon dioxide emissions by 2040.

carbon dioxide emissions in both the Walz Proposal and the LCD Scenario exceed the Trump administration SCC estimates for every year. Additionally, while the cost of reducing CO_2 emissions in the Walz Proposal also exceeds Obama SCC estimates in every year, the LCD Scenario exceeds Obama SCC estimates after 2033. The average cost of reducing emissions for both scenarios exceeds both SCC estimates. This means the cost of reducing carbon dioxide emissions under these plans far exceed the benefits of doing so.

Figure 26 shows the CO_2 emissions for the Walz Proposal and LCD Scenario.

These conclusions have important ramifications for energy policy.

First, they show that using wind and solar to meet the requirements set out by the Walz administration would cost far more than using nuclear power, CCS technologies, and battery storage under the LCD Scenario.

Second, and more importantly, they show that the benefits of reducing carbon dioxide emissions are less than the cost of both scenarios, which means it is better to do nothing than to implement them.

In short, Minnesota cannot save the planet by implementing the Walz Proposal, but we can seriously undermine the reliability and affordability of our electric grid.

Conclusion

Compliance with the Walz Proposal in Minnesota would cost $313.2 billion through 2050. This means Minnesota families would see their electric bills increase by an average of nearly $1,650 per year. Commercial businesses would see their costs increase by $9,900 per year. Industrial customers, like manufacturers and mining operations, would see their electric bills increase by an average of almost $222,400 per year. In comparison, the LCD Scenario would increase costs for consumers by $89.5 billion through 2050, which is $224 billion less than the cost of the Walz Proposal while maintaining grid reliability.

"In the end, the idea that we can run our electric grid on wind turbines, solar panels, and batteries is a dangerous and unserious one."

Walz Proposal costs are driven by a massive buildout of solar panels, wind turbines, and transmission lines, in addition to the costs associated with higher property taxes, utility profits, and the cost of building battery storage facilities to provide power when the sun is not shining, or the wind is not blowing. LCD Scenario costs are driven by nuclear plant refurbishing, building new nuclear plants and battery storage facilities in Minnesota, and retrofitting existing coal plants in North Dakota to reduce carbon dioxide emissions.

In the end, the idea that we can run our electric grid on wind turbines, solar panels, and batteries is a dangerous and unserious one. If policymakers who claim that climate change is an existential crisis truly believe this, they should immediately support the legalization of nuclear power plants in Minnesota. Otherwise, it is impossible to take them seriously.

Acknowledgements

We thank Brent Bennett, Ph.D. of the Texas Public Policy Foundation for his assistance on this report, particularly with respect to determining the capacity of battery storage necessary to meet Walz Proposal requirements. We also thank Diane Bast for editing.

Appendix

Electricity consumption assumptions

Electricity consumption is kept constant at 71.4 million MWhs throughout the course of this model run based on data from Minnesota's EIA electricity state profile. Electricity use in each customer class — residential, commercial, and industrial — is also held constant.

This assumption is made for two reasons. One, this analysis is intended to show the difference in cost between operating the electric system in Minnesota today compared to what it would cost to generate the same number of MWhs of electricity under the Walz Proposal and LCD scenarios. Doing this is especially insightful when new capacity is not being built to meet expected growth in electricity demand but rather to comply with government mandates like the Walz Proposal.

Two, load-growth projections are subject to a wide variety of assumptions, such as energy efficiency measures that reduce electricity demand, electric vehicle adoption, and the electrification of other sectors of the economy, which would increase demand for electricity.

These factors are difficult to predict accurately, and the assumptions used for load growth or energy efficiency can have major implications for cost. Therefore, the most straightforward analysis looks at these issues assuming all other factors remain equal.

Time horizon studied

This analysis studies the impact of the Walz Proposal and LCD scenario on electricity prices from 2021 to 2050, rather than 2040, to determine the long-term cost of implementing the Walz Proposal and LCD scenario.

This time horizon is examined because like a mortgage, electricity customers pay off the cost of the plant each year, meaning decisions made today will affect the cost of electricity for decades to come. As such, the total costs highlighted by this study do not represent the total costs incurred by each of the scenarios studied, but rather the total cost that ratepayers would pay off through 2050.

Hourly load, capacity factors, and peak demand assumptions

Hourly load shapes were determined using MISO region 1 generation numbers obtained from EIA and multiplying by the share (77 percent) that is served by Minnesota. This is the best available data for hourly load shape profiles for the state of Minnesota. The peak demand for Minnesota is estimated to be 13,690 MW. These are the best available data for estimating peak demand in the state of Minnesota. These inputs were entered into a model provided by the Texas Public Policy Foundation to assess hourly load shapes, capacity shortfalls, and calculate storage capacity needs.

Capacity factors used for wind and solar facilities were determined using wind and solar generation data obtained from EIA's electric grid monitor, and installed capacity values for wind and solar from MISO.[70]

Plant retirement schedules

Our model uses the Integrated Resource Plans (IRPs) from Xcel Energy, Minnesota Power, and Otter Tail Power Company as templates for our analysis, specifically as it pertains to dates for power plant retirements.[71]

However, plans submitted by these utility companies do not satisfy the carbon-free requirements of the Walz Proposal extending out to 2040. To meet full compliance, this analysis assumes all carbon-dioxide emitting plants will be shut down by 2040 and replaced by wind, solar, and battery storage in the Walz Proposal, and CCS coal, nuclear, and battery storage in the LCD Scenario.

Plant construction by type

This analysis assumes no new carbon-dioxide emitting power plants will be built in Minnesota. Under the Walz Proposal, Minnesota would add wind, solar, and battery storage capacity to meet the governor's proposal by 2040. This analysis does not account for wind installations in neighboring states that are owned or operated by Minnesota electric companies. However, given the short, 20-year lifespan of wind facilities, this has a minimal impact on the costs incurred in the Walz Proposal.

In the LCD scenario, only carbon-free power plants are added, including new nuclear power plants (APR-1400 and SMRs), battery storage, and two existing North Dakota coal plants are retrofitted with CCS equipment.

Load modifying resources

Our model does not allow for the use of Load Modifying Resources (LMRs) or demand response (DR) in determining how much reliable capacity will be needed to meet peak electricity demand in the Walz Proposal.

Instead, battery capacity and excess wind and solar capacity is built to provide enough power to supply Minnesota's electricity needs under the Walz Proposal at all times based on a test year using historical generation (77 percent of the 2021 hourly load data from MISO Region 1), and hourly capacity factors for wind and solar for MISO.[72] Battery storage capacity was assumed to be perfectly efficient and fully charged at the start of the test year.

We acknowledge that voluntary LMRs and DRs can play a role in optimizing system cost and reliability. However, we believe that DR resources are being inappropriately used by many wind and solar special interest groups to manipulate their models to unrealistically reduce the amount of capacity needed to meet peak demand, and thus artificially suppress the cost of their proposals.

In this way, these groups are essentially fudging the numbers on the amount of capacity needed to meet current electricity demand and not providing an apples-to-apples comparison of the cost. Their proposals will effectively place more responsibility on behalf of the customer to keep the grid online.

To test this theory, American Experiment allowed the availability of LMRs up to 2,000 MW, or 14.6 percent of the system, to determine the impact on the cost of meeting the Walz Proposal.

This resulted in a $79.4 billion reduction in the cost of the proposal from 2021 through 2050 — now totaling $234 billion — by eliminating a substantial portion of the overbuilding required to meet demand during peak hours and periods of low wind and solar output. As a result, using LMRs would

FIGURE 27
Utility Profits: Walz vs. LCD

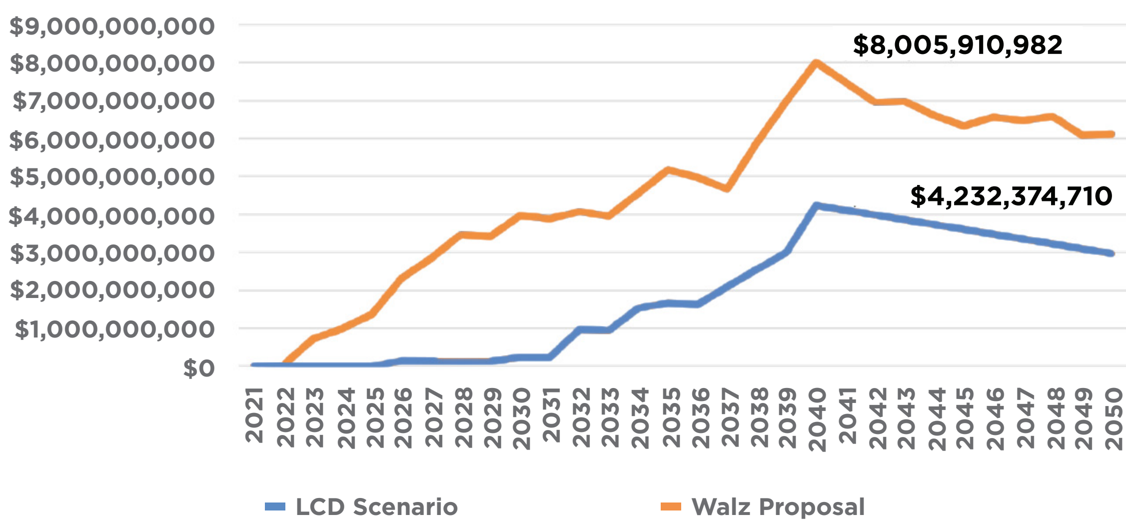


Figure 27. Annual utility profits under the Walz Proposal and LCD Scenario are massive, with profits hitting $8 billion in the Walz Proposal and $4.2 billion in the LCD Scenario in 2040.

reduce the cost of the Walz Proposal by $986 per year on average for each electricity customer.

While LMR advocates argue that these resources bring costs down, this argument only looks at one side of the ledger because it assumes that the power that is no longer being consumed **produces no *value***, which is incorrect.

For example, the 2,000 MW of LMRs would be used to reduce electricity consumption by 1.6 million MWhs on an annual basis. Dividing the annual savings of $2.7 billion ($79.4 billion/29 years) by the 1.6 million in MWhs in reduced consumption results in a savings of $1,700 per MWh. Using our metric of $5,580 of GDP per MWh of electricity consumed, reducing these MWhs would lower the state's GDP by $9 billion annually, resulting in a net loss of $6.2 billion for the state.

Utility returns

The amount of profit a utility makes on capital assets is called the Rate of Return (RoR) on the Rate Base for both the Walz Proposal and the LCD Scenario.

For the purposes of our study, the capital structure used is that of Xcel Energy: 47.65 percent debt and 52.35 percent equity, a return on debt of 4.8 percent, and return on equity of 10.2 percent.[73]

Utility profits are much higher in the Walz Proposal than the LCD Scenario because utility companies are earning a government-approved profit on much more new electricity generation and storage capacity (see Figure 27).

Transmission

For transmission costs, distance per mile costs were estimated from the 2021 Midcontinent Independent Systems Operator Transmission Cost Estimation Guide.[74] This analysis uses the Minnesota average cost estimates of double circuit 230 kV, 345 kV, and HVDC lines.

For the LCD Scenario, we assume a needed transmission costs of $25,102.88 per MW of new nuclear capacity installed, based on cost information from a nuclear plant currently under construction in the United States, the Vogtle nuclear plant. In an August 31, 2018, filing to the Georgia Public Service Commission, Georgia Power stated the cost of interconnection and transmission for the 2,430 MW Vogtle nuclear plant would be $61 million, or $25,102.88 per MW installed.[75] These transmission investments were amortized over 30 years.

We assume all transmission expenses are paid by Minnesota ratepayers.

Property taxes

Additional property tax payments for utilities were calculated to be two percent of the undepreciated cost of generation assets installed to comply with the Walz Proposal and LCD scenario, based on Minnesota property tax rates.

Wind and solar degradation

According to the Lawrence Berkeley National Laboratory, output from a typical US wind farm shrinks by about 13 percent over 17 years, with most of this decline taking place after the project turns ten years old. According to the National Renewable Energy Laboratory, solar panels lose one percent of their generation capacity each year and last roughly 25 years, which causes the cost per megawatt hour (MWh) of electricity to increase each year.[76] However, our study does not take wind or solar degradation into account.

Annual average additional cost per customer

The annual average additional cost per customer was calculated by dividing the average yearly expense of the Walz Proposal and the LCD Scenario by the number of electricity customers in Minnesota.[77]

This methodology is used because rising electricity prices increase the costs of all goods and services. Businesses will attempt to pass these additional costs onto consumers, effectively increasing the cost of everything. Therefore, this method helps convey the total cost of the Walz Proposal and LCD Scenario for Minnesota households in a way that is more representative than calculating the costs associated with higher residential electric bills.

Annual average cost per rate class customer

The annual average additional cost per residential, commercial, and industrial rate class customer was calculated by applying the overall cost per KWh of Walz Proposal and LCD Scenario compliance during the time horizon of the study to rate classes based on historical rate factors in the state of Minnesota. Rate factors are determined by the historical rate ratio (rate factor) of each customer class.

For example, electricity prices for residential, commercial, and industrial rate classes in Minnesota were 13.17, 10.43, and 7.67 cents per KWh in 2020, respectively. Based on general electricity prices 10.57 cents per KWh, residential, commercial, and industrial rates had rate factors of 1.25, .99, and .73, respectively. This means that, for example, residential customers have historically seen electricity prices 25 percent above general rates. This model continues these rate factors to assess rate impacts for each rate class.

Impact on electricity rates

The table below shows annual additional electricity rates by customer class using the cost of the Walz Proposal and LCD Scenarios and adjusting for the rate factor described above in cents per KWh.

	Total		Residential		Commercial		Industrial	
	LCD	**Walz**	**LCD**	**Walz**	**LCD**	**Walz**	**LCD**	**Walz**
2022	0.03	0.10	0.03	0.12	0.03	0.09	0.02	0.07
2023	0.02	1.70	0.01	2.12	0.01	1.68	0.01	1.24
2024	0.01	2.29	0.00	2.97	0.00	2.35	0.00	1.73
2025	0.00	3.11	-0.02	4.22	-0.01	3.34	-0.01	2.46
2026	0.35	5.58	0.43	7.51	0.34	5.95	0.25	4.37
2027	0.29	6.87	0.37	9.42	0.29	7.46	0.22	5.49
2028	0.27	8.41	0.35	11.81	0.28	9.36	0.20	6.88
2029	0.28	8.09	0.36	11.85	0.29	9.39	0.21	6.90
2030	0.50	9.51	0.63	13.95	0.50	11.05	0.37	8.13
2031	0.50	9.22	0.63	13.86	0.50	10.97	0.36	8.07
2032	1.95	9.72	2.44	14.69	1.93	11.63	1.42	8.56
2033	1.92	9.51	2.39	14.52	1.89	11.50	1.39	8.45
2034	3.17	11.31	3.96	16.75	3.13	13.27	2.30	9.76
2035	3.46	13.30	4.32	19.27	3.42	15.26	2.52	11.22
2036	3.37	12.85	4.21	18.89	3.33	14.96	2.45	11.00
2037	4.43	12.18	5.53	18.22	4.38	14.43	3.22	10.61
2038	5.56	16.05	6.93	23.01	5.49	18.22	4.04	13.40
2039	6.58	19.60	8.20	27.57	6.50	21.83	4.78	16.05
2040	9.59	22.34	11.96	31.53	9.47	24.97	6.96	18.36
2041	9.34	20.88	11.65	30.37	9.23	24.05	6.78	17.69
2042	9.11	19.55	11.36	29.20	9.00	23.12	6.62	17.01
2043	8.88	19.49	11.08	29.27	8.77	23.18	6.45	17.05
2044	8.65	18.86	10.79	28.44	8.54	22.52	6.28	16.56
2045	8.42	18.56	10.50	27.83	8.32	22.04	6.12	16.21
2046	8.19	19.29	10.21	28.34	8.09	22.45	5.95	16.51
2047	7.96	19.49	9.93	28.14	7.86	22.28	5.78	16.39
2048	7.73	20.03	9.64	28.39	7.63	22.48	5.61	16.53
2049	7.50	19.44	9.35	27.28	7.41	21.60	5.45	15.88
2050	7.27	19.81	9.06	27.35	7.18	21.66	5.28	15.93

Assumptions for Levelized Cost of Energy (LCOE) calculations

The main factors influencing LCOE estimates are capital costs for power plants, annual capacity factors, fuel costs, heat rates, variable operation and maintenance (O&M) costs, fixed O&M costs, the number of years the power plant is in service, and how much electricity the plant generates during that time (which is based on the capacity (MW) of the facility and the capacity factor).

LCOE values for existing energy sources were derived from FERC Form 1 data submitted by Xcel Energy, Minnesota Power, and Otter Tail Power. Data utilized in FERC Form 1 filings include capacity factors, capital costs, and production expenses.

These LCOE values are inserted into the model and adjusted annually based on annual capacity factors for existing resources for the rest of Minnesota. This method is used because while FERC Form 1 data is the best available source for LCOE cost assumptions for existing resources, it does not account for all power sources in Minnesota. This report adjusts LCOE values for the three IOUs in Minnesota for the rest of the power plants within the state.

LCOE values for new power plants were calculated using data values presented in the Assumptions to the Annual Energy Outlook Electricity Market Module (EMM) and are based on the cost of operating each energy source during the model. The cost of repowering power facilities that need it at the end of their useful lives is accounted for in each value. These values are described in greater detail below.

Capital costs, and fixed and variable operation and maintenance costs

Capital costs and expenses for fixed and variable O&M for new wind, solar, battery storage, and SMR resources were obtained from the EMM. Region 3 capital costs were used, and national fixed and variable O&M costs were obtained from Table 3 in the EMM report.[78]

APR-1400 capital costs were obtained from the Science Council, with EMM assumptions light water reactors for heat rates, fixed, and variable O&M.[79]

This study makes several assumptions about CCS technology. Capital costs for CCS retrofits are assumed to be $1.4 million per MW, based on the projected cost estimates of $1 billion to retrofit the 705 MW Milton R. Young coal-fired power plant in North Dakota.[80]

CCS equipment is estimated to become operational in 2026, which is generally consistent with the projected implementation timeline for the Milton R. Young station.

All capital and operating costs are held constant throughout the model run.

Unit lifespans

Different power plant types have different useful lifespans. Our analysis takes these lifespans into account for our Levelized Cost of Energy analysis.

Wind turbines last 20 years. Federal LCOE estimates seek to compare the cost of generating units over a 30-year time horizon.[81] This is problematic for wind energy LCOE estimates because the National Renewable Energy Laboratory reports the useful life of a wind turbine is only 20 years before it must be repowered. Our analysis corrects for this error by using a 20-year lifespan for wind projects before they are repowered and need additional financing.

Solar panels last 25 years. Our analysis uses a 25-year lifespan for solar because this is the typical warranty period for solar panels. These facilities are rebuilt after they have reached the end of their useful lifetimes.

Battery storage lasts 20 years. Battery storage facilities are expected to last for 20 years. Battery facilities, like wind and solar, are rebuilt after reaching the end of their useful lifetimes.

New nuclear plants are licensed for 40 years. Capital costs for new nuclear plants were amortized over 40-year periods, rather than 30, because this is the amount of time nuclear plants are initially licensed for by the Nuclear Regulatory Commission. This corrects for EIA LCOE calculations that attribute 30-year lifespans for all energy technologies, which, in the case of nuclear power, artificially inflate the cost of electricity during the initial production years of the facility.

Many nuclear power plants have already had their initial 40-year licenses extended by 20 years, and in 2019, the Nuclear Regulatory Commission approved a second extension — up to 80 years — for the Turkey Point Power Plant in Florida, suggesting a long useful lifespan for new nuclear power plants.[82] However, license extensions are beyond the span of this analysis.

Fuel cost assumptions

Fuel costs for existing nuclear, natural gas, and coal facilities were estimated using FERC Form 1 data for existing facilities. Fuel costs used for new power plants are derived from EIA data for delivered fuel costs to Minnesota power plants.[83] We hold these values constant throughout the entirety of the report.

Nuclear fuel costs. Existing nuclear plants had a fuel cost of $5.50 per MWh according to FERC Form 1 data. Fuel costs for new nuclear plants were assumed to be $8.46 per MWh, which was the latest available price for Minnesota power plants provided by EIA.[84]

Natural gas fuel costs. Existing natural gas prices were assumed to be $21.23 per MWh and $34.21 per MWh for CC and CT plants, respectively, based on data obtained from 2019 FERC Form 1 filings. We held this fuel cost constant through 2050. However, Henry Hub natural gas prices reached nearly $9 per million BTU in early September 2022. As a result, our assumptions for natural gas prices will almost certainly be too low, and our estimates on the cost of natural gas generation are overly generous for natural gas plants.

Coal fuel costs. Existing coal fuel cost assumptions of $23.51 per MWh were based on 2019 FERC Form 1 filings.

Capacity factors for generation resources

Capacity factors for existing coal, natural gas, and nuclear facilities in 2019 were obtained from FERC Form 1 filings and EIA's state electricity profile for Minnesota. Average coal capacity factors were 49 percent, natural gas CT was 4.66 percent, natural gas CC was 52.7, and nuclear was 97.2 percent.

New facilities had an estimated capacity factor of 40 percent for wind, 20 percent for solar, 90 percent for APR-1400s, 50.1 percent for SMRs, 62.4 percent for Coal CCS.

Levelized cost of transmission, property taxes, and transmission lines

This report calculated the additional levelized transmission, property tax, and utility profit expenses resulting from each new power source during the course of the model and according to the additional capacity in MW installed and generation in MWh of that given source. Capacity installed is used to determine capital costs and additional expenses (transmission, property taxes, and utility profits) of each electricity source over the course of its useful lifespan.[85]

The Levelized Cost of Intermittency (LCOI)

This report also calculated and quantified the levelized cost of intermittency (LCOI) for wind and solar energy on the entire energy system. These intermittency costs stem from the need to build backup natural gas or battery storage facilities to provide power during periods of low wind and solar output, which we call "load balancing costs," and the need to "overbuild and curtail" wind and solar facilities to limit the need for battery storage. It is important to note that these costs are highly system specific to the mix of resources being built and operated in any given area.

Load balancing costs

We calculate load balancing costs by determining the total cost of building and operating new battery storage facilities to meet electricity demand during the time horizon studied in the Walz Proposal.[86] These costs are then attributed to the LCOE values of wind and solar by dividing the cost of load balancing by the generation of new wind and solar facilities (capacity-weighted).

Attributing load balancing costs to wind and solar allows for a more equal comparison of the expenses incurred to meet electricity demand between non-dispatchable energy sources, which require a backup generation source to maintain reliability, and dispatchable energy sources like coal, natural gas, and nuclear facilities that do not require backup generation.

The key determinant of the load balancing cost is whether natural gas or battery storage is used as the "firming" resource. While natural gas provides relatively affordable firm capacity, battery storage is often prohibitively expensive. For the Walz Proposal, no carbon dioxide-emitting technologies would be allowed after 2040, so no new natural gas was allowed in the model and battery storage was used as the backup source.

To understand why intermittency costs are required, Figure 28 shows the generation mix by source during the hypothetical week of February 7, 2040, through February 10, 2040. Low generation from wind and solar resources necessitates the use of battery storage to meet electricity demand. Because wind and solar cannot offer stand-alone reliability, the cost of battery storage must be attributed to these resources to accurately convey the true cost of using them.

FIGURE 28

Walz Proposal Hourly Generation Mix February 7, 2040 to February 10, 2040

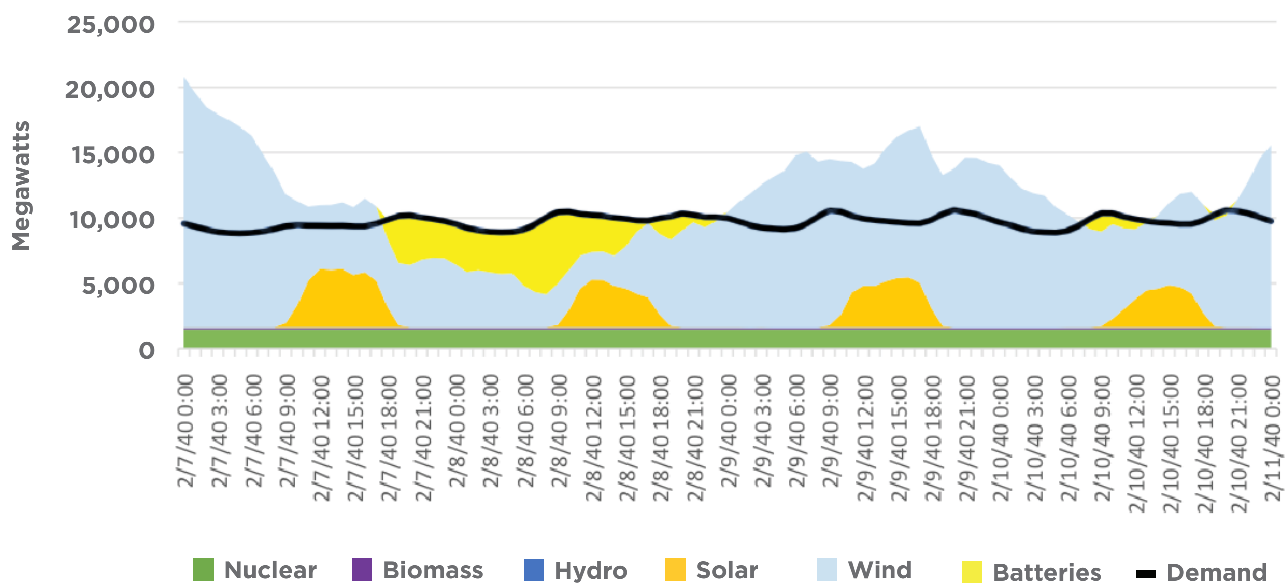


Figure 28. The costs of battery storage are attributed to solar and wind as a "load balancing" cost because the batteries would not be needed if it were possible to "turn up" the wind turbines and solar panels to meet electricity demand.

Overbuilding and curtailment costs

The cost of battery storage for meeting electricity demand is prohibitively high, so many wind and solar advocates argue that it is better to overbuild renewables, often by a factor of five to eight compared to the dispatchable thermal capacity on the grid, to meet peak demand during periods of low wind and solar output. These intermittent resources would then be curtailed when wind and solar output improves.

As wind and solar penetration increase, a greater portion of their output will be curtailed for each additional unit of capacity installed.[87]

This "overbuilding" and curtailing vastly increases the amount of installed capacity needed on the grid to meet electricity demand during periods of low wind and solar output. The subsequent curtailment during periods of high wind and solar availability effectively lowers the capacity factor of all wind and solar facilities, which greatly increases the cost per MWh produced.

For example, future curtailment values in the Walz Proposal will increase substantially. Annual curtailment levels for this model were estimated based on hourly load forecasts and were found to reach up to 72 percent of total wind and solar generation by the end of the model (see Figure 29).

FIGURE 29

Curtailment vs. Renewable Percentage

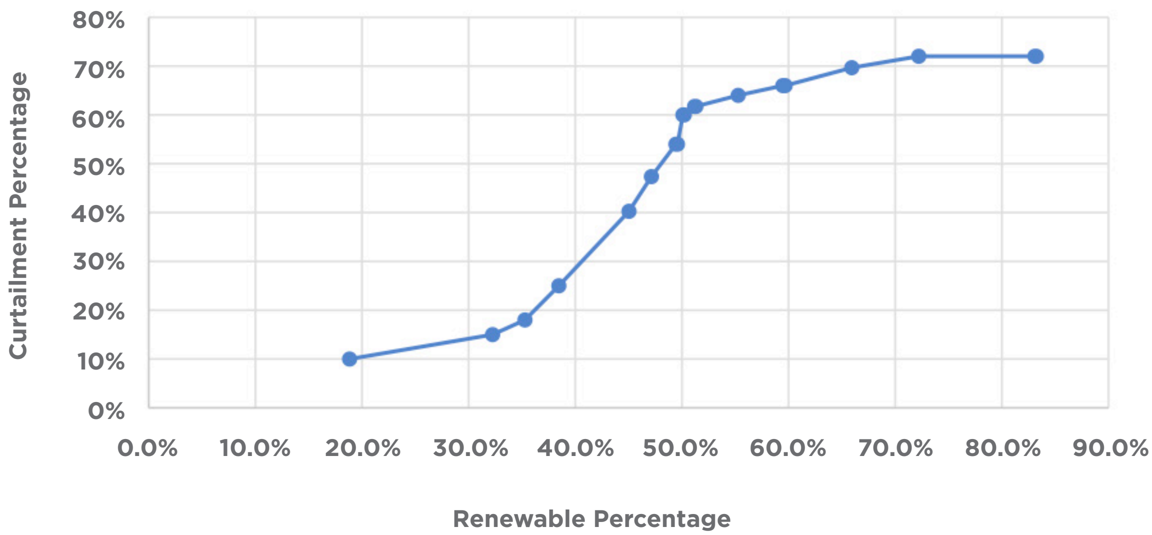


Figure 29: Curtailment increases most severely during the 35 to 50 percent phase due to the need to massively overbuild, caused by the lack of adequate dispatchable and battery storage resources.

FIGURE 30

Annual Cost of Overbuilding and Curtailment

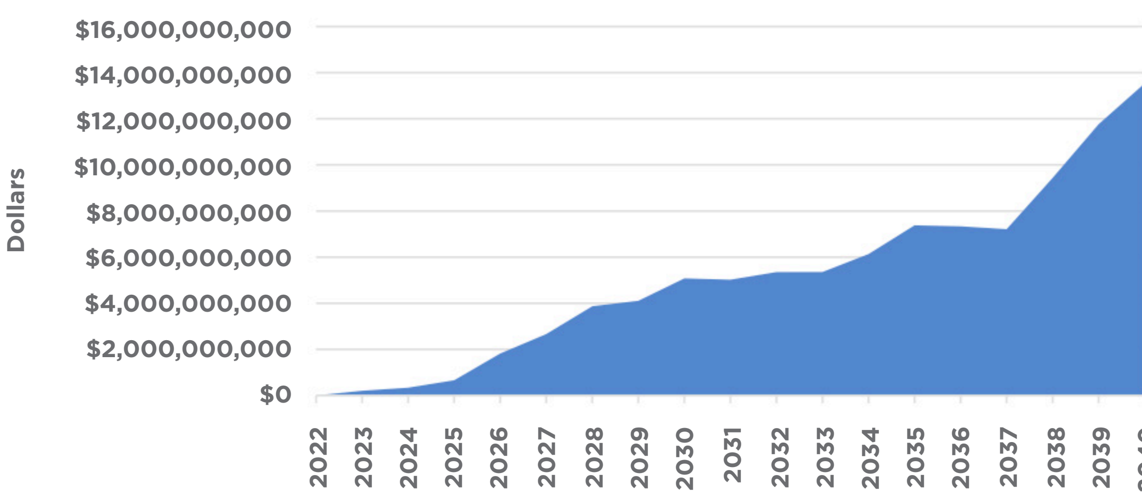


Figure 30. The costs of overbuilding and curtailing excess wind and solar generation grow over time as more of these intermittent resources are added to the grid. These costs reach almost $14 billion in 2040.

Rising rates of curtailment stemming from the overbuilding of the grid effectively lower the capacity factor of all generating resources on the grid, thereby increasing the levelized cost of energy, which is a calculation of power plant expenses divided by the generation of the plant. As curtailment rises, wind and solar facilities are forced to recover their costs over fewer MWhs, resulting in huge increases in the overbuilding and curtailment costs as the percentage of electricity demand served by wind, solar, and battery storage increases (see Figure 30).

The annual cost of each energy resource

Metrics like LCOE show the average cost of a power plant through the course of its financial payback period. These average cost estimates can be a helpful rule-of-thumb for comparing the cost of different energy resources, but in the real world, the costs of new power plants are frontloaded, and the cost of producing electricity from a power plant declines as it pays off its initial capital investment, and utility profits fall as the plant is depreciated.

This has important implications for electricity consumers in the future, as the short useful lifespans of wind and solar facilities require the building and rebuilding of wind turbines and solar panels to maintain the same level of electricity generation, whereas nuclear, coal, and natural gas plants become more affordable over time.

Wind

Figure 31 shows the annual cost of a wind facility operating at its full potential capacity with additional costs incurred because of utility profits, property taxes, transmission, load balancing, and overbuilding and curtailment costs. New wind costs begin at $78.36 per MWh in 2022 and rise throughout the model run to a high of $318.87 per MWh in 2039.

The cost of wind energy fluctuates after 2043 between $290 to $297 per MWh as wind facilities reach the end of their useful lives and must be rebuilt, beginning the sequence of repaying the debt on the turbines all over again.

Solar

Figure 32 shows the annual cost of a solar facility operating at its full potential capacity with additional costs incurred because of utility profits, property taxes, transmission, load balancing, and overbuilding and curtailment costs. Costs begin at $121.23 per MWh in 2022 and rise throughout the model run to a high of $568.19 per MWh in 2039.

The cost of solar energy fluctuates after 2047 between $470 to $480 per MWh as the solar facilities reach the end of their useful lives and must be rebuilt, beginning the sequence of repaying the debt on the panels all over again.

FIGURE 31

Wind Energy Average Annual Cost Dollars Per MWh

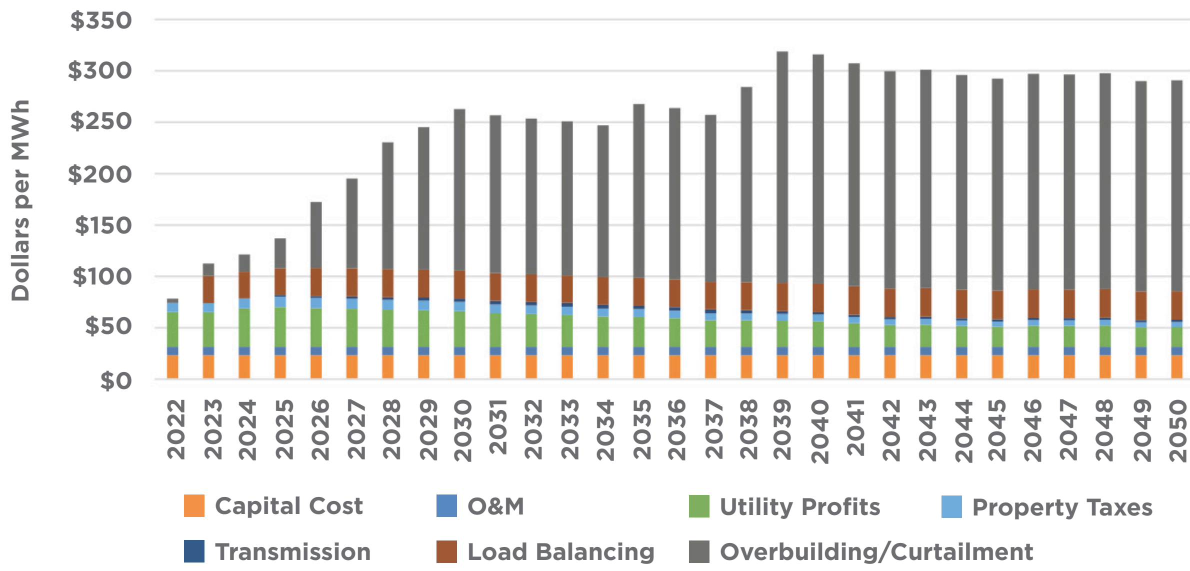


Figure 31. Wind costs increase dramatically after 2024 as wind is expected to meet greater percentages of electricity demand. This graph demonstrates that while it may be "cheap" to add each incremental MWh of wind electricity, meeting the current electricity demand with wind is very expensive.

FIGURE 32

Solar Energy Average Annual Cost Dollars Per MWh

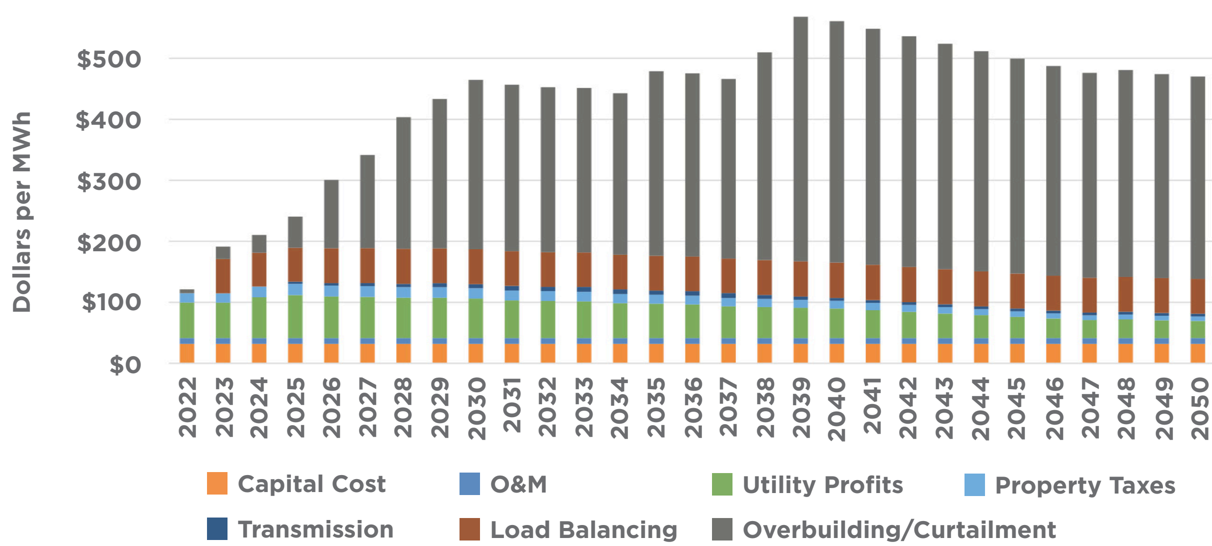


Figure 32. Solar costs exceed $500 per MWh in 2040. Solar costs are higher than wind costs because solar panels produce less electricity on an annual average basis than wind turbines, meaning these facilities recoup their costs over fewer MWhs.

FIGURE 33

APR-1400 Annual Cost Dollars Per MWh

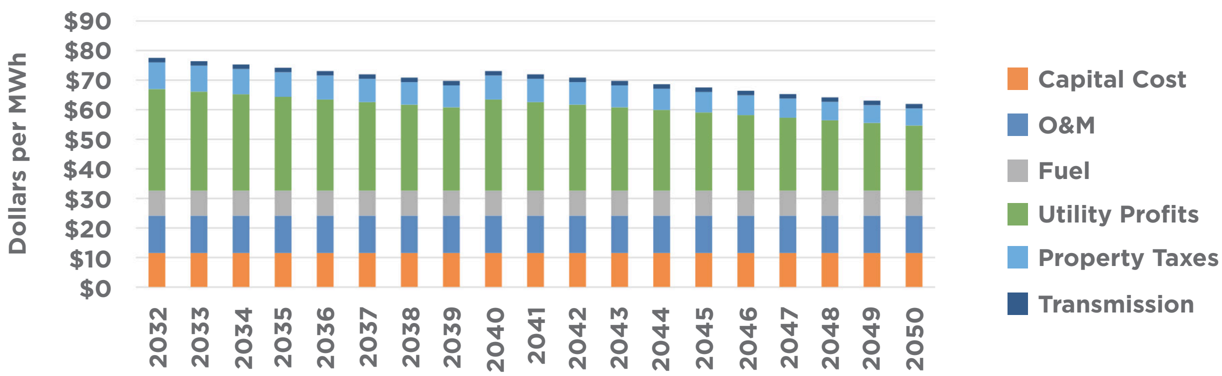


Figure 33. APR-1400s get more affordable as time goes on and the utility profits decline as the plant depreciates. These costs would continue to decline past 2050.

APR-1400

Figure 33 shows the annual cost of an APR-1400 operating at its full potential capacity with additional costs incurred because of utility profits, property taxes, and transmission costs. Costs begin at $77.53 in 2032, the first year an APR-1400 begins operating in or model, and ends at $61.96 in 2050. These costs would continue to decline as the plant depreciates.

SMR

Figure 34 shows the annual cost of an SMR operating at its full potential capacity with additional costs incurred because of utility profits, property taxes, transmission, and due to the fact that SMRs are used for ramping up generation during periods of high demand, which means the plant is used less frequently than they could be. Costs begin at $140.82 per MWh in 2032, decline to a low $134.83 per MWh by 2036, reach a high of $287.26 per MWh by 2040, and end at $219.84 in 2050. These costs would continue to decline as the plant depreciates

As you can see, the cost of SMR technology is highly dependent on what it's being used for. Costs are much lower when it is being used as a baseload resource from 2032 to 2037 compared to a peaking resource from 2038 onward.

Coal CCS

Figure 35 shows the annual cost of a coal plant with CCS operating at its full potential capacity with additional costs incurred because of utility profits, property taxes, and transmission costs. Costs begin at $68.75 per MWh in 2026, the first year a coal plant with CCS begins operating in our model, and ends at $50.32 in 2050.

These cost calculations assume a parasitic load of 30 percent for CCS equipment, which is at the higher end for some estimates assuming a 25 percent parasitic load.

FIGURE 34

SMR Average Annual Cost Dollars Per MWh

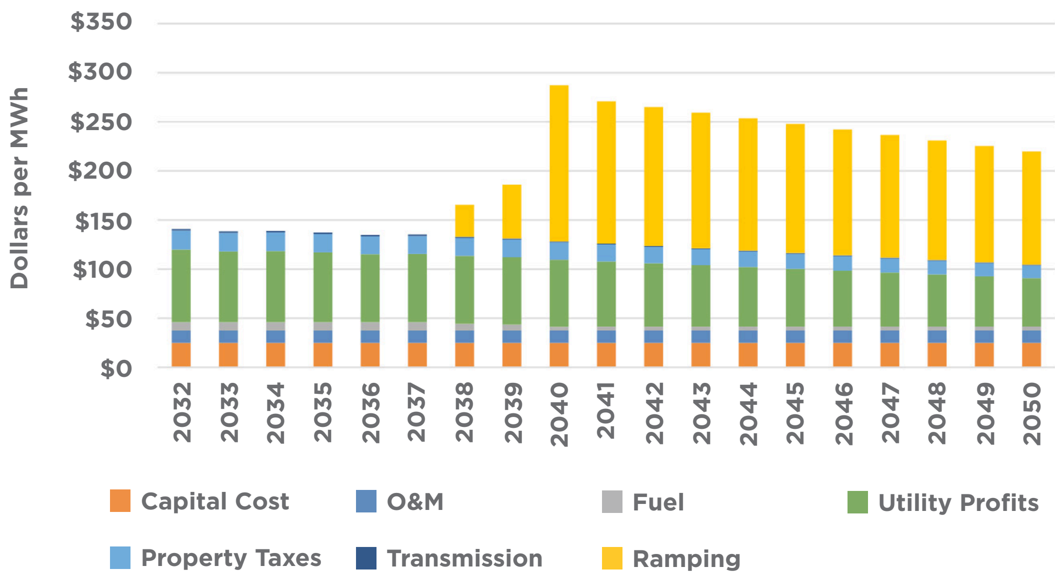
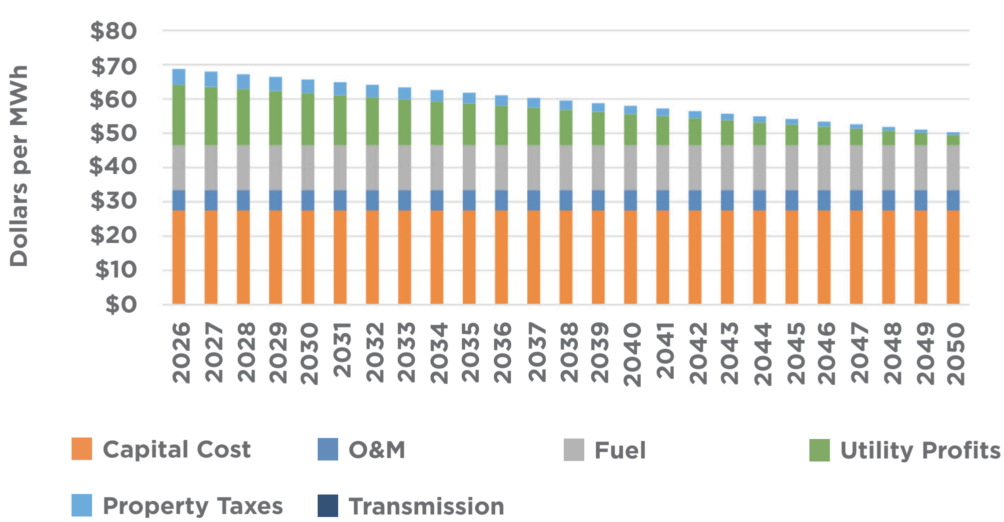


Figure 34. SMRs begin producing power in 2032 at a cost under $150 per MWh. In our model, these costs increase over time as these smaller reactors are used less to follow load, which is shown in the ramping cost. Costs increase because the reactors are being used less frequently.

FIGURE 35

CCS Coal Average Annual Cost Per MWh



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