Energy and Emissions Benefits From Minnesota Energy Efficiency Investments

Improving the Analytical Approach to How Minnesota Values Energy Efficiency

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Executive Summary

Minnesota is undergoing a significant energy transition, and utilities are moving away from coal- and gas-fired generation to a more diverse and less carbon-intensive portfolio with higher levels of energy efficiency and wind and solar resources. Minnesota utilities are expected to invest in higher levels of newer technologies and strategies such as energy storage, customer-owned distributed generation resources, and demand response. As the transition progresses, traditional paradigms and approaches to valuing energy efficiency must evolve. Utilities use avoided cost analysis to determine the types of energy efficiency programs and measures they will offer and the overall level of energy efficiency they will pursue. As the generation mix changes, the avoided cost and emissions benefits of energy efficiency programs and measures changes.

The Union of Concerned Scientists (UCS) analyzed several methods of calculating the avoided energy costs and the emissions benefits provided by energy efficiency and proposes options for consideration in Minnesota. One traditional method of calculating the avoided costs of energy efficiency relies on utilities' own dispatch models and designations of marginal energy sources. However, these models regularly deem zero-marginal-cost renewable energy resources as being "marginal" even as a number of costly coal or natural gas plants are operating and should be considered the marginal resources instead. Under this method, renewable energy resources are given a zero marginal energy and emissions value, which implicitly de-emphasizes efficiency's role in displacing expensive and carbon-intensive fossil-fuel generation and underestimates the benefits and cost effectiveness of energy efficiency. The methodological bias becomes more apparent and more significant as utilities integrate higher levels of renewable energy resources into the generation mix. The more often the "avoided" resource includes these low-cost, carbon-free renewable generation sources, the less value is assigned to energy efficiency and, consequently, the less incentive the utility has to invest in it.

Traditional avoided-cost analyses also suffer from a lack of transparency. In many cases, the bulk of avoided-cost data provided by utilities is filed under trade secret protection and generated using proprietary software and data. Stakeholder review, therefore, is limited to the high-level description provided by utilities for the underlying drivers of increases or decreases in avoided costs compared to previous years.

This analysis demonstrated ways that current shortcomings of the existing avoided-cost calculation process can be rectified.

Alternative Methods for Calculating Avoided Costs

We present three potential methods for calculating the avoided costs of energy efficiency using publicly available data and provide the resulting value of energy efficiency for the different method options:

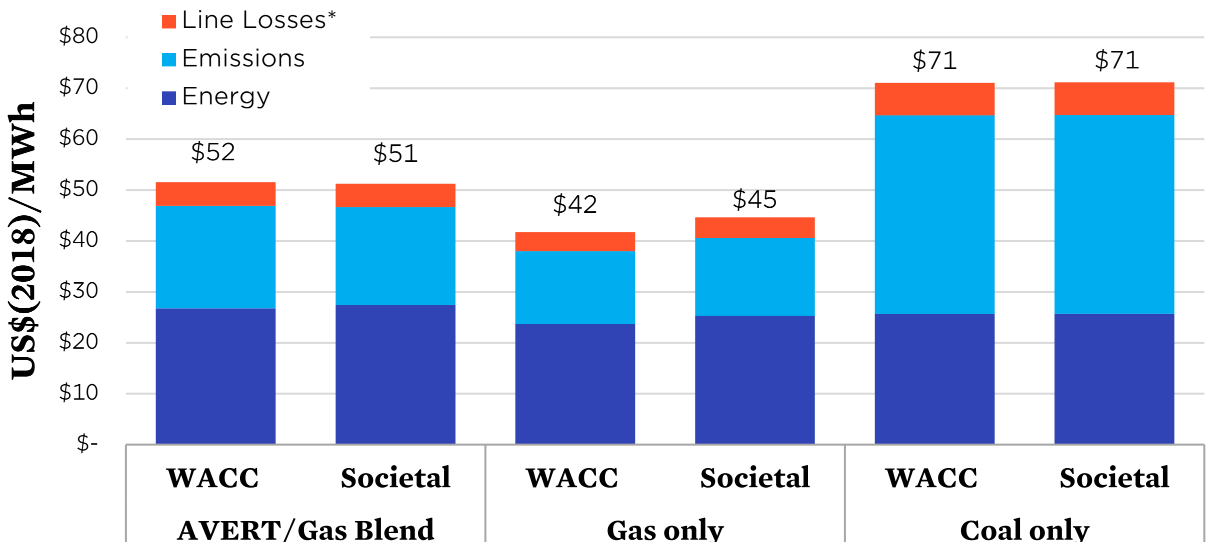
1. *Coal proxy method*: an analysis of the avoided costs of energy efficiency that displaces existing coal-fired power plants
2. *Gas proxy method*: an analysis of the avoided costs of energy efficiency that displaces natural gas–produced electricity
3. *AVERT/gas blend method*: an avoided cost analysis using the AVERT model, developed on behalf of the Environmental Protection Agency (EPA).

Results

All three methods produced a reasonably similar avoided energy cost for energy efficiency measures, ranging from $24 to $27 per megawatt-hour (MWh). Differences among the models are mainly related to avoided emissions, which range from $14 per MWh in the gas-only case to $39 per MWh in the coal-only case. The value generated by the AVERT/gas blend method sits between the other two because its results reflect the displacement of a mix of both gas- and coal-fired power plants.

For each of the three methods, the analysis calculates the levelized values of avoided costs using two different discount rates: the weighted average cost of capital (WACC) and a societal discount rate. For the AVERT/gas blend method and the gas proxy method, we levelized the values over a 30-year time frame. We used a five-year time frame for the coal proxy method analysis, given that most of the coal in Minnesota and elsewhere is expected to be phased out in less than 30 years. The results displayed in *Figure ES-1* use a reference case carbon dioxide (CO_2) cost (the median value for CO_2 externalities as laid out in the 2018 Minnesota Public Utilities Commission Order)[1] and Xcel Energy's base case natural gas price.[2]

Figure ES-1. Summary of Avoided Energy and Emissions from Efficiency by Method



**Line losses are displayed separately for clarity, since some utilities embed avoided line losses in the avoided energy value while others do not. The weighted average cost of capital (WACC) is a proportionately weighted average of the costs of different types of financing (debt and equity) to a company. The societal discount rate is a mechanism to place a present value on costs and benefits that will accrue in the future associated with the time preferences of society (as opposed to individual companies).*

Conclusions and Recommendations

Energy efficiency, like all resources, should be integrated into the grid as efficiently as possible, which means that it should displace the most expensive, and often the most polluting, resources operating on the grid. Determining the avoided energy and emissions of energy efficiency through using utilities' dispatch models may not provide an accurate valuation, and may incorrectly place low-cost, carbon-free resources on the margin even as high-cost, emitting resources continue to operate. Current methods can and have led to false conclusions that efficiency cannot displace those high-cost, emitting resources. Similarly, the use of market-based locational marginal pricing as a proxy value for avoided energy—a practice often used by utilities instead of the utility dispatch model method—also continues to undervalue energy efficiency. Using the locational marginal pricing in this way is inappropriate because it assumes that higher cost units that operate under current market rules cannot be displaced by energy efficiency, when in fact they can and should.

Utility regulators need to adopt an avoided-cost methodology that accurately reflects the value of energy efficiency measures given the current (and evolving) generation mix and that is transparent, accessible, and auditable. To the extent that other methods are available and are robust and transparent, the use of dispatch modeling should be avoided—but if it is used, superfluous constraints like "must run" designations should be removed.

This analysis found that the use of a new natural gas combined cycle plant might be an appropriate proxy value for avoided energy, given that it is the most common new, emitting resource currently being proposed by many utilities, including the Minnesota utilities analyzed here. However, the use of this proxy value likely still underestimates avoided costs of both energy and emissions and may be inconsistent with assumptions that a natural gas combustion turbine is the avoided capacity resource. Assumptions (whether they are implied or explicit) that wind or solar constitute the avoidable resource are inappropriate because they will produce an unrealistically low value for the avoided cost of energy efficiency. Assuming wind and solar are on the margin in a real-time market—which means that the avoided energy and emissions values in that hour are zero—ignores opportunities to improve system operations.

Based on our analysis, we make the following recommendations:

Utility regulators should adopt an avoided-cost methodology that is transparent, accessible, and auditable. The dispatch/optimization modeling that is currently conducted by utilities is difficult to audit, not generally available to the public, and not transparent. This type of modeling also has many pre-established assumptions about how the electric grid operates that may or may not accurately reflect today's economic and operational reality. Therefore, dispatch/optimization modeling runs counter to one of the six principles of cost-effectiveness analyses in the National Standard Practice Manual—transparency—and it should be avoided.

If a dispatch model is used, superfluous constraints like "must run" designations should be removed. When utilities or other entities use dispatch/optimization models as part of avoided-cost studies, the models should be scrutinized to remove any inherent assumptions that might lead to bias. For instance, in some cases, utilities will designate company-owned resources as "must run" when conducting modeling with optimization software, a designation that forces the models to select those resources to serve load, even if lower-cost resources are available. The models are unable to displace "must run" resources with other existing resources, energy efficiency, or new resources that may represent lower-cost options. Therefore, setting company-owned resources in a status of "must run" in utility optimization software should be avoided, because doing so may present results that are not fully optimized.

Chapter 1
Introduction and Purpose

Many states are undergoing a significant energy transition, with utilities transitioning from a predominantly coal-fired generation fleet of large, central plants to a more diverse and less carbon-intensive fleet with high levels of wind and solar resources, supplemented mostly by natural gas–fired power plants. In addition to the shift in generation resources, utilities are being expected to invest in higher levels of alternative energy resources, such as energy efficiency, energy storage, customer-owned distributed generation resources, and demand response.

The Union of Concerned Scientists (UCS) conducted a study to analyze current methods of calculating the avoided energy and emissions costs provided by energy efficiency in Minnesota and to propose options that most appropriately reflect the avoided-cost benefits of energy efficiency. Avoided-cost analysis is used by utilities to assign value to energy efficiency, small-scale renewables, and most distributed resources. It includes emissions benefits of those resources' displacement of more expensive and more polluting generation such as coal, gas, and oil as well as the benefits associated with avoided construction of new generation capacity, avoided construction of transmission and distribution infrastructure, and avoided line losses from more polluting electricity generation. These benefits are then compared to energy efficiency–related costs in cost-effectiveness tests, which determines the types of utility-funded energy efficiency programs and measures, as well as the overall level of energy efficiency, that utilities pursue.

A Need for Updates to Efficiency Cost-Benefit Analyses

In 2018, Synapse Energy Economics prepared a study for the Minnesota Department of Commerce's Division of Energy Resources recommending updates to the state's efficiency cost-benefit analysis to better reflect the National Standard Practice Manual (Malone, Woolf, and Goldberg 2018). Its recommendations are far-reaching and propose the inclusion of many benefits that our study does not attempt to monetize, including, but not limited to capacity, transmission and distribution costs, wholesale price suppression effects, avoided costs of complying with the renewable portfolio standard, and reduced risk. The Synapse report also discussed the importance of the methodological approach of calculating these various benefits. This UCS report attempts to address some of those methodological issues for two well-established benefits: energy and emissions.

As states increasingly integrate low-cost, zero-emission resources into the electricity mix, some have argued that those resources (mainly wind and solar) have become "marginal" and would be avoided by energy efficiency. Such claims are only partially true. It is true that states with mandates to procure renewable energy as a percentage of overall electricity sales will be obligated to procure less renewable energy if electricity sales decline as a result of efficiency. It is also true that if electricity demand were met with 100 percent renewable energy, the reduced demand from increased amounts of energy efficiency would translate into less use of renewable energy. However, the existing grid is still heavily reliant on fossil fuel resources, including coal, and so we are far from these scenarios. Energy efficiency, therefore, has an important role in creating a cleaner, lower-cost grid by displacing more expensive, more polluting resources, and should be optimized to do so.

More Accurately Valuing Energy Efficiency's Ability to Decrease Emissions

The traditional method of calculating the avoided costs of energy efficiency relies on the utilities' own dispatch models and designations of marginal energy sources. Energy efficiency is presumed to displace the marginal energy source (the highest-price and therefore the price-setting source), which historically was a polluting one but today is frequently solar or wind. For models employing utilities' dispatch order, then, energy efficiency is assumed to be displacing renewable energy resources, which are given a zero marginal energy and emissions value. This practice greatly undervalues efficiency's role in displacing expensive and carbon-intensive fossil-fuel generation.

For example, imagine that in one hypothetical year wind energy is curtailed in 10 percent of operating hours. One might reason that reducing demand through energy efficiency in those same hours would lead to even more wind curtailment, leading to a conclusion that the efficiency provides no avoided emissions or avoided energy cost. This logic might even produce the odd result that energy efficiency is imposing an energy *cost* because the market price in those hours is sometimes negative. Under the current method of accounting for the benefits of energy efficiency, the calculated avoided costs are 10 percent lower than they should be, because in the hours that wind was on the margin and curtailed, the method assumes a zero dollar value for avoided energy and emissions even though other, more expensive emitting resources could have been curtailed and those costs avoided.

The methodological bias becomes more apparent and more distorting as utilities integrate increasing amounts of renewable energy resources into the generation mix—i.e., as wind and solar are increasingly seen as the marginal resource avoided. The more often that these low-cost, carbon-free renewable resources are portrayed as the marginal resource, the less value is assigned to energy efficiency because the costs and pollution being avoided are much less.

In addition to inaccuracies in the current method of calculating avoided costs, the method is rather opaque. This runs counter to best practices of energy efficiency valuation and screening as identified in the National Standard Practice Manual (Woolf et al. 2017) and as outlined in a report commissioned by the Minnesota Department of Commerce and written by Synapse Energy Economics (Malone, Woolf, and Goldberg 2018). The Synapse report stated that the calculation of avoided cost should be a transparent process that is easily replicable and accessible. However, the majority of avoided-cost data provided by utilities in Minnesota are filed under trade secret protection and are not visible to public stakeholders. Therefore, unless stakeholders become intervening parties and sign confidentiality agreements, stakeholder review is limited to the stakeholder reactions to the high-level description provided by utilities for the underlying drivers of increases or decreases in avoided costs compared to previous years.

A Need to Identify an Avoided-Cost Methodology that Fits States' Realities and Goals

The methodology used by states to calculate avoided costs going forward will have a significant influence on the speed at which fossil fuel resources are retired, as well as on the size, cost, and carbon profile of replacement resources. Given the significant shifts in the electricity industry and the important role of avoided-cost calculations, it is important to reexamine how the avoided costs of energy efficiency are calculated and to develop new methodological options that better fit the realities of states' evolving electric grids and support a clean, timely, and cost-effective transition of the electricity system.[3] This study uses a combination of regional and national data, as well as inputs specific to Xcel Energy's upper Midwest territory for its Minnesota example; however, it relies primarily on publicly available data, making the methods replicable for all utilities in all states.[4]

The study examines three alternative methods for calculating the avoided costs of energy efficiency:

1. *Coal proxy method*: an analysis of the avoided costs of energy efficiency that displaces existing coal-fired power plants
2. *Gas proxy method*: an analysis of the avoided costs of energy efficiency that displaces natural gas-fired generation
3. *AVERT/gas blend method*: an avoided cost analysis using the AVERT (AVoided Emissions and geneRation Tool) model, developed on behalf of the Environmental Protection Agency (EPA). The AVERT model simulates the impacts of energy efficiency on individual generators of multiple types.

Before exploring these alternative methods in chapters 4 through 6, we first set out the theories underlying avoided-cost analyses and the Minnesota context in which they are applied (Chapter 2), followed by a discussion of the traditional methods for calculating avoided costs (Chapter 3).

Chapter 2
Avoided-Cost Theory and the Minnesota Context

What Is an Avoided-Cost Study?

An avoided-cost study examines the benefits that energy efficiency and small-scale renewable energy have for the electric power system. These benefits are enumerated and quantified by calculating the costs that the utility system would incur if those resources had not been provided. Such benefits include the amount of energy no longer needed (in megawatt-hours (MWh)), capacity no longer required (in megawatts (MW)), avoided transmission and distribution system investments, and avoided emissions costs, as well as a range of other non-cost-related benefits.[5]

Efficiency Is a Preferred Resource in Minnesota

Minnesota policymakers have long recognized energy efficiency as a cornerstone of the state's energy policy. Minnesota's utility-funded energy efficiency programs date back to the early 1980s.[6] State policy has consistently recognized that energy efficiency results in long-lasting benefits to the environment, the economy, the utility system, and utility customers through reduced carbon emissions, reduced costs to residents and businesses, reduced utility capital costs, and rightsizing of energy loads.

Minnesota law provides that "cost-effective energy savings are preferred over all other energy resources" and that "cost-effective energy savings should be procured *systematically* and *aggressively* to reduce utility costs for businesses and residents, improve the competitiveness and profitability of businesses, create more energy-related jobs, reduce the economic burden of fuel imports, and reduce pollution and emissions that cause climate change" (emphasis added).[7]

The primary means of achieving this statutory directive are the Minnesota Conservation Improvement Program and the state's energy efficiency resource standard, which requires utilities to meet 1.5 percent of energy needs through energy savings.[8] Minnesota's Conservation Improvement Program, energy efficiency programs, and policy framework have evolved to meet the changing energy landscape and public policy imperatives of the time. Since the beginning of the Conservation Improvement Program 38 years ago, the statute has been amended 36 times.

The policy objectives underlying this program—strengthening the state's economy and creating economic opportunity, reducing energy costs for Minnesota businesses and residents, and protecting and improving the environment—are long term and forward-looking. Similarly, energy efficiency is a long-term, cumulative resource in that many energy efficiency improvements have useful lifetimes of 20 years or more and contribute energy savings each year over the lifetime of the measure (CEE, Optimal Energy, and Seventh Wave 2018).

Minnesota Policy Recognizes the Costs of Carbon Emissions and Other Pollutants

The Minnesota Public Utilities Commission (PUC) is required by state law to "quantify and establish a range of environmental costs associated with each method of electricity generation" and to require utilities to use these costs "when evaluating and selecting resource options in all proceedings before the Commission, including resource plan and certificate of need proceedings."[9] This directive has been in state law since the early 1990s and compels Minnesota utilities to account for the publicly borne costs of pollution from power plants when making energy resource decisions, including what levels of energy efficiency to pursue.

The purpose of quantifying environmental externalities is to include those societal costs, among other factors, in PUC decisions to approve Minnesota utilities' purchase or construction of new generation sources—including whether existing facilities should be repowered or retired.[10] Carbon dioxide (CO_2) is the largest component of Minnesota's environmental externality costs. Accordingly, Minnesota has established a goal to reduce statewide greenhouse gas emissions to 20 percent of 2005 levels by 2050.[11, 12]

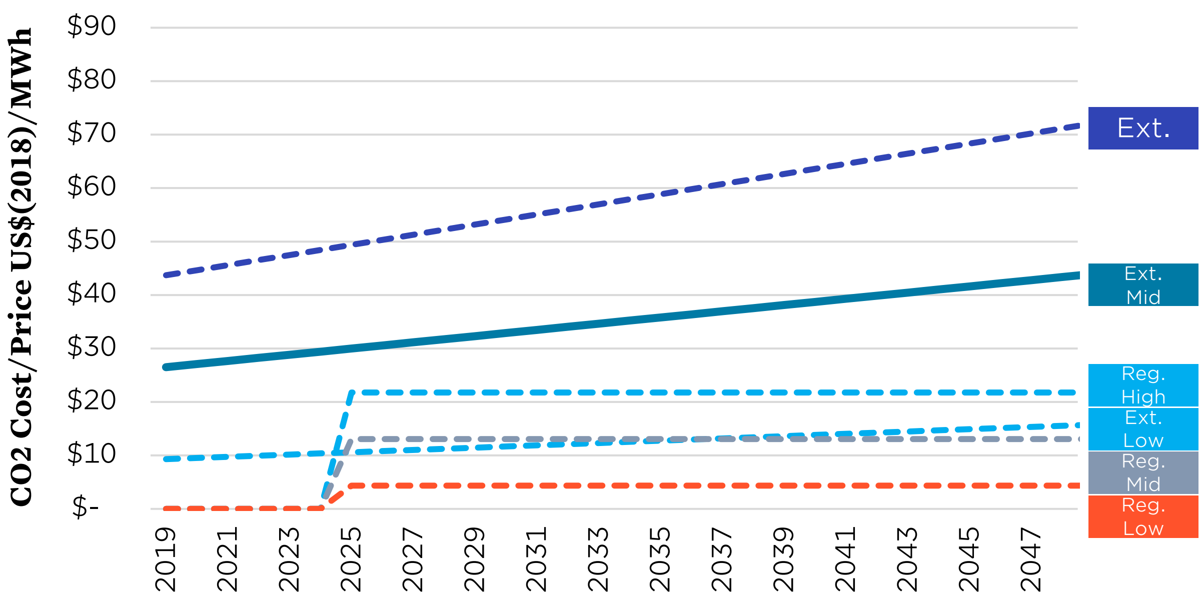
On January 3, 2018, the PUC issued an order updating the environmental cost values to be used by Minnesota utilities in their analyses. The PUC's order relied on the "damage-cost" method of estimating environmental cost values for emissions, which attempts to place an economic value on the net damage to the environment caused by power plant emissions.[13] This method typically excludes difficult-to-monetize benefits, such as reduced ecosystem changes or human health effects with insufficient data, and tends to underestimate those benefits that can be monetized (Stanton, Ackerman, and Daniel 2014). As a result, it is generally regarded as a conservative value that typically underestimates the social costs of pollutants (EESC 2013).

The PUC established a range of environmental costs for carbon. The low end of the range reflects the global damage of the last (marginal) short ton of CO_2 emitted, calculated through the year 2100, with a 5.0 percent discount rate. The high end of the range reflects the global damage of the last (marginal) short ton emitted, calculated through the year 2300, with a 3.0 percent discount rate.[14] The PUC also adopted a range of values for the environmental costs associated with particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x), and sulfur dioxide (SO_2). The PUC directed utilities to analyze potential resources under a range of assumptions with respect to environmental values.[15] The latest directive for criteria pollutants (NO_X, SO_2, and $PM_{2.5}$) is to use the metropolitan fringe value,[16] which reflects the externality cost of pollution when the source is located near but not within a densely formed population center. Criteria pollutants (and other localized pollutants) typically have the greatest effect when emitted from sources that are close to densely population centers. That effect is reflected by the costs of pollution being highest when emitted in urban centers and lowest when emitted 200 or more miles away from urban centers. Figure 1 details the range of externality values for NOx, SO_2, and $PM_{2.5}$ for pollution emitted in urban centers, metro fringes, rural areas, and areas more than 200 miles away from an urban population. Figure 2 displays both the externality values and assumed regulatory costs for CO_2 emissions.

Figure 1. Externality Costs of Select Pollutants in Minnesota (US$(2018)/ton)

SOURCE: Minnesota Public Utilities Commission. Values are provided for single year and held constant (in constant dollars) throughout the study period. All results in this report reflect calculations based on the metro fringe value. All values in US$(2018).

Figure 2. Externality and Compliance Costs of Carbon Dioxide in Minnesota (US$(2018)/ton)



SOURCES: Minnesota Department of Commerce for the externality values; Xcel Energy for the compliance cost values.

Xcel Energy's regulatory compliance costs are set to $5, $15, and $25 per ton (set in constant US$(2025)) for the low, mid, and high scenarios. This analysis's reference case value is set to the median value of the externality high and low values, as approved by the Minnesota Department of Commerce's 2019 decision for natural gas utilities.[17]

The above combination of policy directives and regulatory decisions clearly shows that Minnesota recognizes the costly impacts of emissions resulting from energy production and is committed to reducing those emissions to contain and mitigate the associated costs to society.

Chapter 3
Methods of Calculating Avoided Costs

There are several methods for calculating avoided costs. In addition to using locational marginal price (LMP) as a proxy there are four other ways to model the avoided costs of a resource like energy efficiency. These are referred to below as the system cost differential method, the proxy unit method, the peaker method, and a blended method.

This chapter begins by exploring the concept of marginal resources and why using LMP as a proxy may not be valid. It then explores the other four methods and discusses their relative advantages and disadvantages.

Locational Marginal Pricing

Avoided costs are calculated on a marginal basis, and a resource like energy efficiency will not impact all generating resources or even the "average" resource. Rather, incremental reductions in load will affect resources that are used to serve incremental load.

Energy system planning and operations are designed to function such that the marginal resources are typically more expensive than the average resources. This is achieved through merit order dispatch and locational marginal pricing. The grid operators are meant to run power plants based on merit order, opting first for resources with the lowest marginal cost and moving on to those with higher marginal cost. As demand increases, prices increase. Since price is correlated with the efficiency of the individual power plants, the most efficient power plants of any given fuel type should be called on first and the least efficient plants of that same fuel type called last.

LMP is used in the competitive market structure that Minnesota participates in—run by the regional grid operator, the Midcontinent Independent System Operator—and the construct includes day-ahead and real-time energy markets. In this regional grid, the cost to buy and sell power at specific points in the power grid at a specific time is set by the LMP. Many utilities either use LMP or have offered LMP as a way to determine the value of avoided energy.[18] Because markets are expected to dispatch generating units in merit order, and because the last unit called upon sets the price for all the units, LMPs are often thought of as representing the price of the most expensive unit on the system. However, that is not always the case.

Price formation—the equation and calculation of the marginal price—is a function of market rules and reflects market preferences. For example, some markets have rules that bear an inherent bias in favor of fossil fuels (Mays, Morton, and O'Neill 2019). Some markets have rules that benefit inflexible resources such as coal and nuclear while other markets are proposing rules that would favor flexible resources like demand response and battery storage (Goggin et al. 2018). All markets offer "make-whole payments," system costs that are not reflected in the market price. Power plants can also opt to run as "self-commit," further discussed below, which has the effect of bypassing the market process and can result in plants operating even when the market LMP is considerably lower than the production costs of the plant. These variations in market rules cast shadows of doubt on the presumption that LMP represents marginal system costs.

Self-committing is when the plant owner (i.e., the utility) schedules in advance whether or when a unit will commit to turn on or off, at what output level it will operate, and for how long it runs. Self-committed units will often turn on and operate at minimum level (i.e., the lowest amount of power a unit can generate when turned on) and "allow" the market to dispatch the unit up or back down to the minimum operating level. Many of Minnesota's coal plants self-schedule or self-commit in the Midcontinent Independent System Operator's energy market (Daniel et. al 2020; Daniel 2018).[19] The practice of utility self-committing for coal plants can force power plants with lower costs and lower emissions rates, and even carbon-free resources, to be considered the marginal energy unit. Thus, rather than curtailing expensive, carbon-intensive units, utilities limit the inexpensive, carbon-free resources. At the same time, through the traditional avoided-cost approach, energy efficiency is also assigned the avoided marginal energy and emissions benefit associated with the low-cost renewable resources, thereby undervaluing the energy efficiency.

In other words, the way in which coal plants are currently being operated tends to unfairly penalize energy efficiency in avoided-cost calculations. Using market prices and costs as a proxy for marginal cost presupposes that these higher cost units, such as coal plants, cannot be avoided, when in fact they can and should be displaced by energy efficiency.

SYSTEM COST DIFFERENTIAL METHOD

The system cost differential method—also sometimes referred to as the differential revenue requirement method—calculates the difference in a utility's total costs to provide electricity to customers under two scenarios, one with a preselected amount of energy efficiency and one without that amount.[20] By calculating the difference in total costs under the two scenarios, the total avoided cost is inferred.

This method is considered by some to be the most accurate method, as it takes advantage of complex computer software's ability to replicate the way the grid operators should optimize the system. The sophisticated modeling allows software to replicate the "least cost" planning process and merit-order dispatch that utilities, regional transmission organizations, and/or independent system operators are presumably conducting. In some ways, the calculating of a delta in system costs mirrors the LMP proxy method, because the modeling software dispatches resources and calculates costs based on the same algorithms that underpin LMP calculations. Energy optimization models that are used by utilities forecast LMP out into the future, and so in that way the differential system costs method can be thought of as a forward going market proxy method.

However, this method's greatest strength—the powerful software that conducts complex optimization calculations—is also its greatest weakness. The software used is often proprietary, making it less transparent. These models are also less accessible because they require specialized training to run and typically require expensive licensing fees. The modeling opacity can allow the model operator to obfuscate the costs to run high-cost coal units by setting them as "must run," effectively replicating the practice of self-committing described above. Setting units as "must run" prevents energy efficiency from displacing them and artificially reduces the calculated benefits of energy efficiency.[21]

It is also worth noting that many of the models used for this method can only calculate one or two of the components of avoided costs. Production cost models can calculate avoided energy costs, but they can only calculate avoided capacity within the limits of the software capacity expansion capabilities. Most production cost models can calculate emissions so that the differential can be used to calculate avoided emissions. But many of these models are unable to calculate transmission and distribution costs, and so avoided transmission and distribution costs must be calculated exogenously.

PROXY UNIT METHOD

The proxy unit method for calculating avoided costs sets some hypothetical unit as being avoidable by procurement of an alternative resource, like efficiency. With this method, the hypothetical costs of the future plant are avoided and thus become the avoided costs, with the fixed and capital costs translating into capacity value and the productions costs translating into the avoided energy value. This method is relatively simple and straightforward.

The proxy unit method presumes that some new power plant will be avoided, with the logic being that reduced load will remove the need to build a new power plant in the future. While this assumption is reasonable, new power plants tend to be lower cost and more efficient than the power plants currently operating. Consequently, the results may bear a bias toward an underestimation of avoided costs, particularly avoided energy and emissions costs. Historically, the proxy unit method has resulted in a new natural gas combined cycle (NGCC) unit being selected as the "proxy unit" because new gas units are often much more efficient than units that operate on the margin. Because a new NGCC unit is likely to be more efficient than most of the fleet of gas plants already built, the new NGCC unit will have lower emissions rates and a lower cost to produce energy. As a result, using an NGCC unit as the proxy unit could still be underestimating the energy and emissions benefits of efficiency.

PEAKER UNIT METHOD

The peaker method for calculating avoided costs is a variation of the proxy method in which the assumed proxy plant is a peaker plant (a plant or unit that is designed to only serve peak load) as the unit most likely to be avoidable. Historically, a peaker plant would most likely be a natural gas or oil combustion turbine. Under current economic realities, however, natural gas combustion turbines or batteries are far more realistic resources to be used for peaking capacity, with new oil combustion turbine capacity being exceedingly rare and usually isolated to specific jurisdictions like Hawaii, Puerto Rico, and New England. In 2018, only 2.5 percent of combustion turbine capacity was fueled by oil nationally (EIA 2020b). The Energy Information Administration reported earlier this year that only 0.01 percent of proposed new capacity is from petroleum fuels (e.g., diesel and fuel oil), while batteries make up 3.29 percent of proposed new capacity.[22]

Under the peaker method, the energy value would be equivalent to the production costs of the peaker plant, while the capacity value would be based on the fixed costs of the peaker plant. The capacity value will vary by jurisdiction based on assumed heat rate, fuel costs, construction costs, and other site-specific values.

The peaker method is relatively simple, and, like the system cost differential method, that strength can also be a weakness. The electricity system is hardly so simple as to assume that a single power plant would be displaced by a distributed and dispersed resource like energy efficiency. Peaker plants tend to operate only in peak hours or days. While some efficiency measures target those same hours, most measures aim for year-round savings. Peaker plants also tend to have higher energy costs and lower fixed costs, which can translate into an overestimation of energy costs and an underestimation of capacity costs.

BLENDED METHOD

Here we lay out a fourth method that serves as a hybrid of the above methods by blending the sophistication and complexity of more robust methods alongside the transparency and straightforwardness of the simpler methods. Rather than using proprietary computer software, this method uses widely available programs like Microsoft Excel® and is populated predominantly by publicly available data.[23]

The blended method, described in greater detail below, uses the EPA's AVERT (AVoided Emissions and geneRation Tool) tool. AVERT predicts unit operations based on statistical analysis of historical power plant operations. In short, AVERT applies historical patterns of behavior to simulate the output of individual generators as they are impacted by energy efficiency or renewables.

The AVERT tool provides a reliable sense of the various resources that are currently built that are likely to be displaced by incremental increases in energy efficiency. However, the AVERT model is not designed to make projections about which resources would be displaced by efficiency in the distant future (i.e., more than five years from the present). For example, the AVERT model might indicate that a coal-fired power plant is displaced by efficiency measures. However, if that coal plant is slated for retirement in a few years, it would be unreasonable to assume that efficiency would displace that unit in perpetuity. Thus, the blended method uses the AVERT results for the near term and a proxy unit for the long term.

Chapter 4
Avoided Energy and Emissions from Coal (Coal Proxy Method)

Background

Coal-fired power plants were once thought of as baseload (inframarginal) resources. Changing market dynamics, however, have shifted many coal plants from inframarginal to marginal (mid-merit) resources, which means that the plants are not economic all hours of all days and should only be dispatched when energy demand and prices reach a certain threshold in a particular day. Therefore, methods for calculating avoided costs that preclude a coal plant from being designated as marginal may be misrepresenting the actual avoidable system costs. Coal plants are generally not selected in avoided-cost studies as being the proxy plant; however, this chapter explores what the avoided costs would look like if power plant operators turned down the coal plants as they turned up the energy efficiency savings.

In 2019, investor-owned utilities operated four coal plants in Minnesota.[24] Many of the units at these coal plants operated more than 90 percent of the time, as reflected in Table 1. Coal Plant Operations.

Table 1. Coal Plant Operations

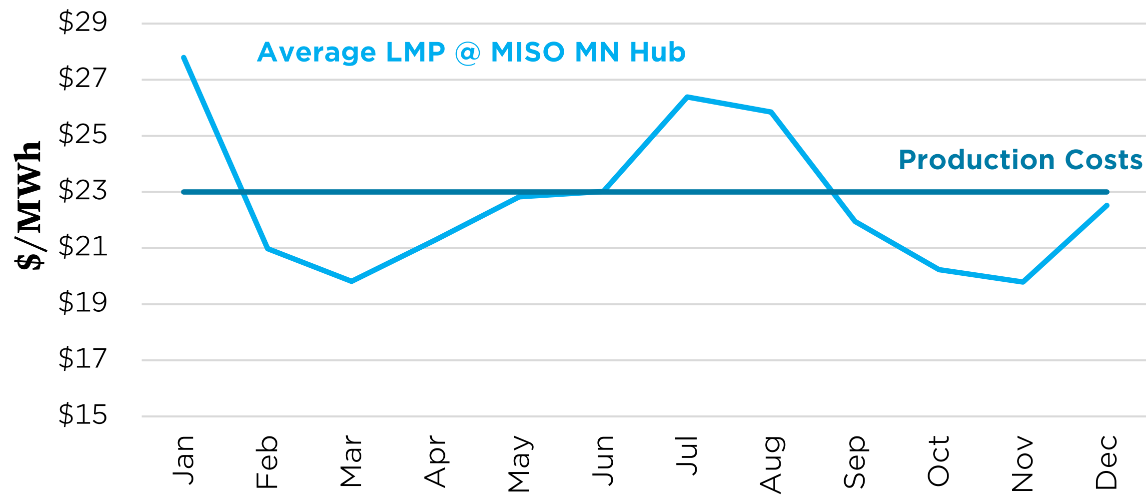
Power Plant	Unit Key	Unit Nameplate Capacity (MW)	Operating Time (hours)	Prod. Cost	Capacity Factor	% of 2017 Operating	% of 2017 Economic
ALLETE, Inc.							
Clay Boswell	8687	75	8529	$24.15	73%	97%	29%
Clay Boswell	8690	558	8222	$22.85	77%	94%	35%
Clay Boswell	8688	75	8524	$23.84	70%	97%	30%
Clay Boswell	8689	365	8036	$23.33	72%	92%	33%
Otter Tail Corporation							
Hoot Lake	7537	54	3602	$46.75	26%	41%	1%
Hoot Lake	7538	75	2836	$46.75	21%	32%	1%
Xcel Energy Inc.							
Allen S. King	8215	598	6945	$24.82	65%	79%	27%
Sherco	8298	765	8134	$24.16	70%	93%	26%
Sherco	8297	765	8440	$24.31	68%	96%	25%
Sherco	8299	939	5942	$22.98	47%	68%	31%

SOURCES: Form EIA-860, Form EIA-923, and FERC Form 1 via S&P Global Market Intelligence. Note: The column on the far right ("% of 2017 economic") displays the percentage of hours over the course of the year in which the market clearing price exceeded a unit's production cost such that the unit is considered to be operating economically and reflects the percent of hours over the course of the year where the plant was on and operating.

When those coal plants operate, the plant owners and operators burn fuel, use chemicals for environmental controls, and consume water. These costs are avoidable if the coal plant output is reduced, as are the emissions associated with generation from the coal plants during those hours. Hence, they should be included as an avoidable cost.

Any avoided-cost analysis that looks only at the market clearing price fails to quantify the true avoidable costs of operating coal plants. For example, the units at the Boswell Energy Center operated 92 to 97 percent of the time at a cost of $23 to $24 per MWh. However, the market clearing price was only at or above that range 30 percent of the time (on an hourly basis), meaning that market prices are often several dollars below the production costs of the plants. Figure 3 illustrates the situation that Boswell and many of the coal plants in Minnesota face.

Figure 3. Market Price Fluctuation Versus Coal Plant Production Costs

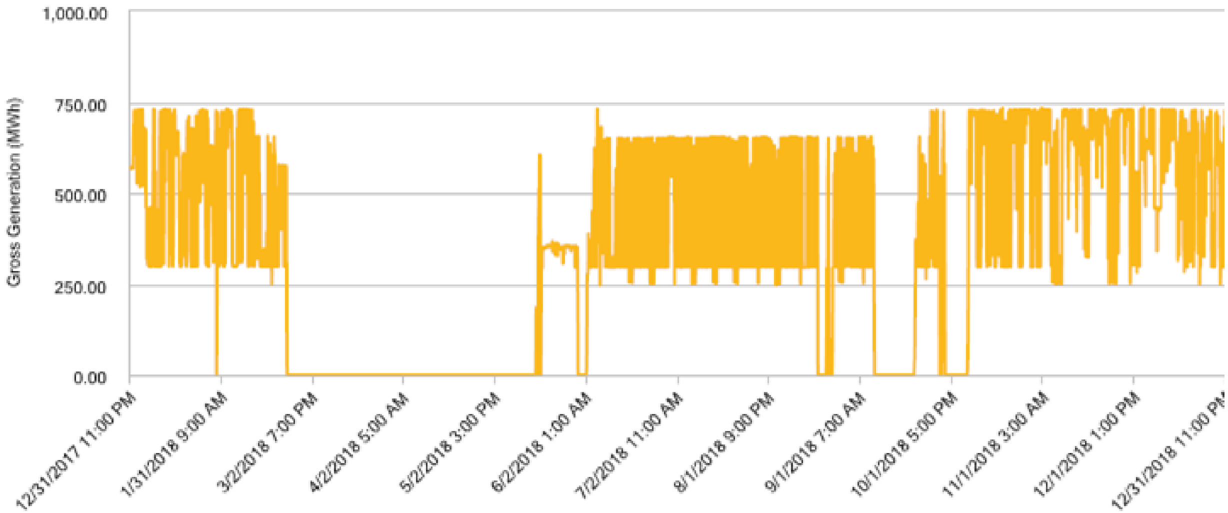


SOURCE: Market prices from S&P Global Market Intelligence.

How the operators of coal plants elect to run their coal plants is a major factor in determining the extent to which fuel costs, variable operations and maintenance (O&M) costs, and emissions can be avoided from coal plants. If coal plant operators continue to run coal-fired power plants as self-committed/"must run," then the avoided costs calculated herein may never come to fruition—but that is a consequence of utility decisionmaking. The utilities in Minnesota have traditionally chosen not to allow the market to dispatch their units. The utilities are, in effect, choosing to operate their power plants sub-optimally.

The three Sherco units make for a good illustrative example. The Sherco units operated 68 to 96 percent of the time but had annual capacity factors of 47 to 70 percent. While operating, the output from those units ranged from 33 percent to nearly 97 percent of nameplate capacity.[25] Sometimes all three units were operating at economic minimum,[26] which, based on hourly data, appears to be about 60 to 66 percent of nameplate capacity. Figure 4 shows the hourly operational data for Sherco Unit 1.

Figure 4. Hourly Operations of Sherco Unit 1



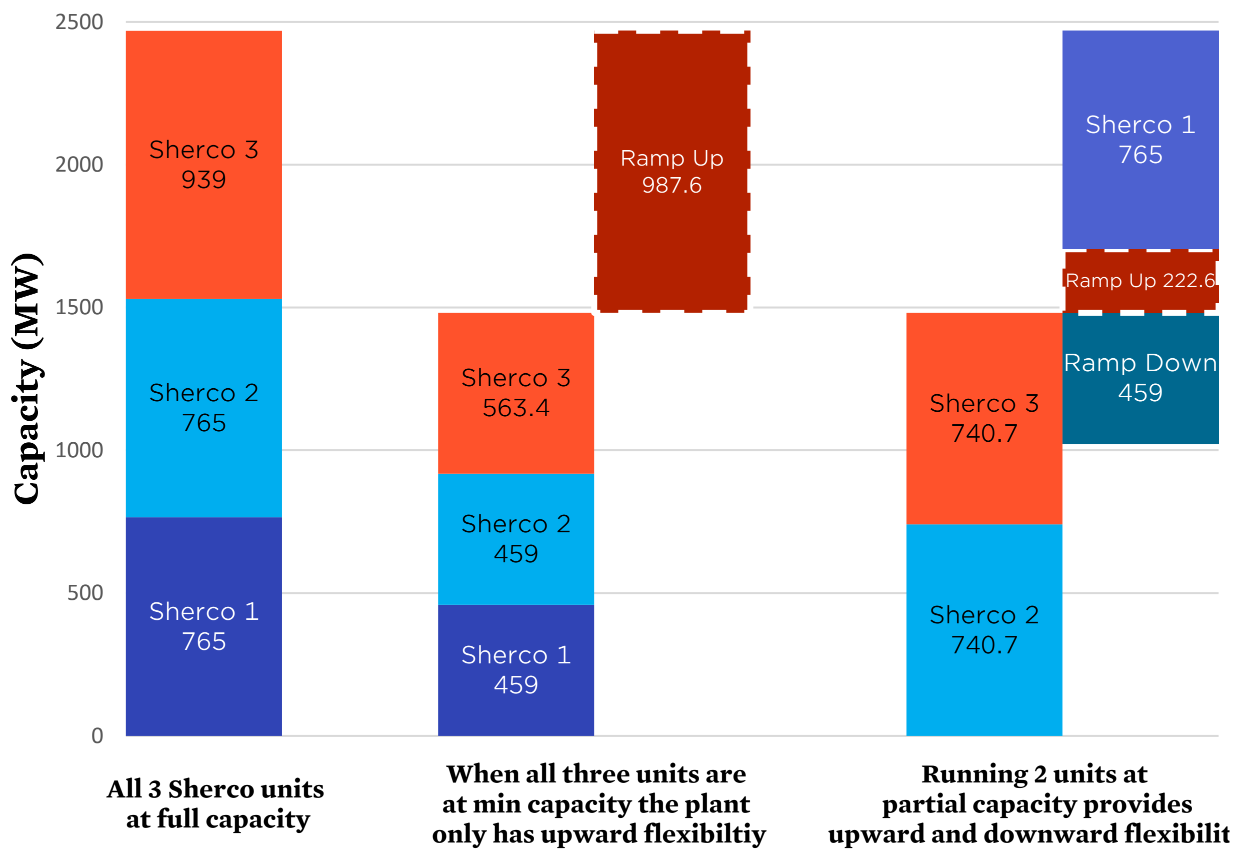
SOURCE: S&P Global Market Intelligence. These public data are also available directly from the EPA's Continuous Emission Monitoring System dataset.

When a unit is operating at its economic minimum, the operator would rather not lower the unit's output any further and would prefer to either curtail some other resource, or, if absolutely necessary, turn off the power plant entirely. Sherco Unit 1 operates for long periods of time at the economic minimum and at an economic loss. Many utilities assert that when a power plant is operating at economic minimum, the unit cannot turn down its operations any further and, therefore, the costs associated with operating at the economic minimum are not avoidable and should not be included in an avoided-cost analysis.

There are several solutions to the above problem. One of the most straightforward is for the owner-operator to turn off one or more units and continue to operate the remaining units at the minimum level. Market prices illustrate that these other units are likely not needed, because if they were, the market prices would probably be higher.

Another approach is for the owner of the coal units to elect to operate the plants more flexibly than just turning off and reducing operations to the minimum level. A plant like Sherco could do this, illustrated in Figure 5, by operating all three units at 60 percent of nameplate capacity—the three units produce 1,481 MW and have 988 MW of upward flexibility and no downward flexibility. That is, there exists 988 MW of headroom between the level of output they are operating at and their maximum output levels. If Units 2 and 3 or Units 1 and 3 operated at 740.5 MW, they would produce the same 1,481 MW but have the ability to ramp up or down (in addition, the remaining Sherco unit could be kept on standby). Given the existing market conditions, the units could operate more economically with that downward flexibility. This precise framework may not be the optimal configuration—another permutation could prove to be better. Regardless, changing market dynamics mandate that power plant owners consider changing plant operations.

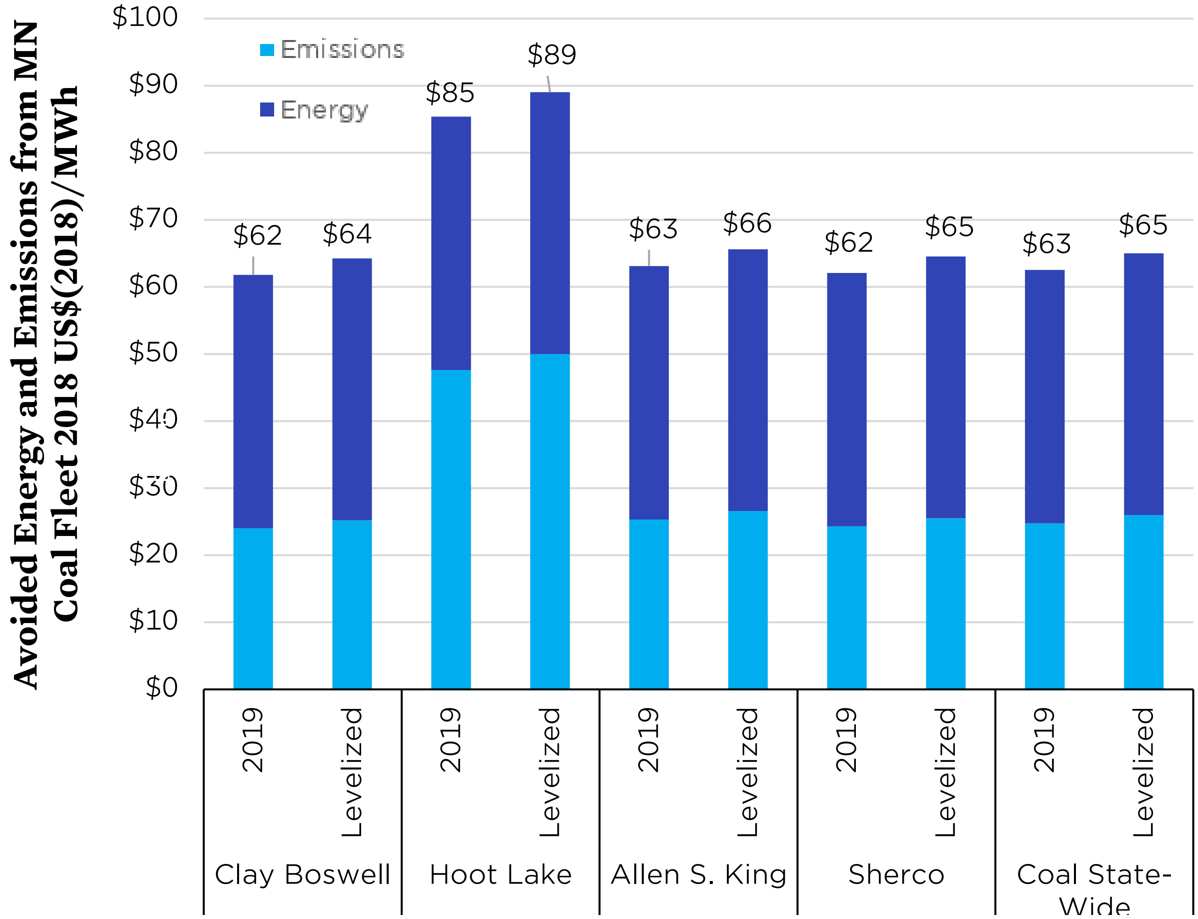
Figure 5. Illustrative Example of How to Increase Operational Flexibility of Coal Fleet



Results: Avoided Fuel, Variable O&M, and Emissions of Coal

To illustrate the potential for meaningful savings if Minnesota utilities were less reliant on coal plants, we calculated the avoided costs of fuel, variable O&M, and emissions of individual coal plants and coal plants statewide in Minnesota if output from the Minnesota coal fleet were reduced. This was calculated using the reported fuel and variable O&M data from S&P Global Market Intelligence for 2018. Fuel costs were escalated in constant dollars based on Xcel Energy's coal price projections. Variable O&M costs were held constant in constant dollars. In the results shown in Figure 6, the 2019 value includes estimated fuel and variable O&M costs for 2019. The levelized value represents a five-year levelized value with the societal discount rate. Fuel and variable O&M costs are escalated based on generic coal escalation and median externality costs.

Figure 6. Results for Avoided Energy and Emissions Costs Associated with the Minnesota Coal Fleet ($/MWh)



SOURCE: UCS calculations using S&P Global Market Intelligence data. Data include only energy and emissions and exclude line losses (which would equate to about a 10 percent adder). Values are in US$(2018).

Note: The statewide values are weighted averages based on the total energy generated by all coal plants. For example, while Hoot Lake has much higher costs, the plant is the smallest and least-operated plant; accordingly, it is weighted less than the other coal plants in calculating statewide values.

Chapter 5
Avoided Energy and Emissions from Gas-Fired Power Plants (Gas Proxy Method)

Background

The use of a natural gas plant as a proxy for calculating avoided costs is commonplace in the utility industry. It has been used to approximate both the avoided costs of energy efficiency as well as the avoided costs associated with buying electricity from a qualified facility under the federal Public Utilities Regulatory Policies Act. As discussed earlier, energy efficiency helps defer or avoid the need to buy or build generation resources such as gas plants; the energy and emissions that would have been produced by that gas plant in the absence of specific energy efficiency measures are also avoided.

In general, there are two types of gas plants that a utility could build: a natural gas combined cycle (NGCC) or a natural gas combustion turbine (NGCT) plant. NGCCs typically have higher capital costs but lower operating costs. In an avoided-cost study, those would translate to energy efficiency having a higher avoided capacity value but lower avoided energy value. NGCTs have lower capital costs but are less efficient and therefore have higher operating costs. Correspondingly, in an avoided-cost study using a NGCT those would translate to energy efficiency having a higher avoided energy value but a lower avoided capacity value.

In our analysis, we selected an NGCC as the proxy plant, given that three of the four proposals for new gas procurement in Minnesota are associated with this type of plant (89 percent on a capacity basis). Because NGCCs are more efficient than NGCTs, using an NGCC offers conservative calculations of avoided energy and emissions.

Xcel Energy and other utilities in Minnesota currently have plans to either buy or build gas plants, as seen Table 2.

Table 2. Planned Gas Plant Transactions (Builds or Buys) for Minnesota Investor-owned Utilities

Plant Name	Gas Plant Type	Owner Operator	Purchase or Construction	Date	Size (MW)	Additional information
Becker Gas Plant	NGCC	Xcel Energy	Construction	2026	750	Authorized via legislation in 2017
Nemadji Trail Energy Center	NGCC	Minnesota Power	Construction	2025	525	Co-owned by Dairyland Power Cooperative and the Minnesota Power affiliate South Shore Energy
Mankato Energy Center (MEC)	NGCC	Xcel Energy*	Purchase	2020	577	MEC unit II was commissioned in 2019. Xcel Energy maintains a power purchase agreement for the energy/capacity.
Astoria Station	NGCT	Otter Tail Power	Construction	2021	245	To be built in Deuel County, South Dakota

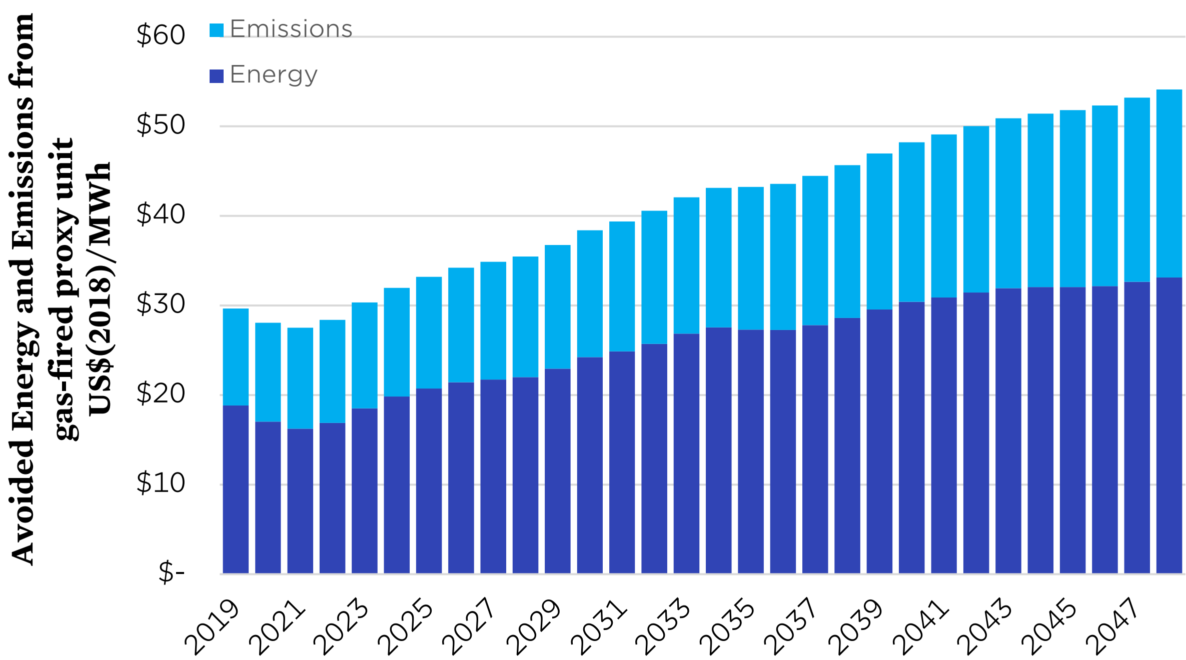
** Xcel Energy acquired the Mankato Energy Center in January 2020 through a nonregulated affiliate company. On April 6, 2020, Xcel announced plans to sell the plant to Southwest Generation in a transaction expected to close in the third quarter of 2020.*

SOURCE: Various sources aggregated by authors.

Results

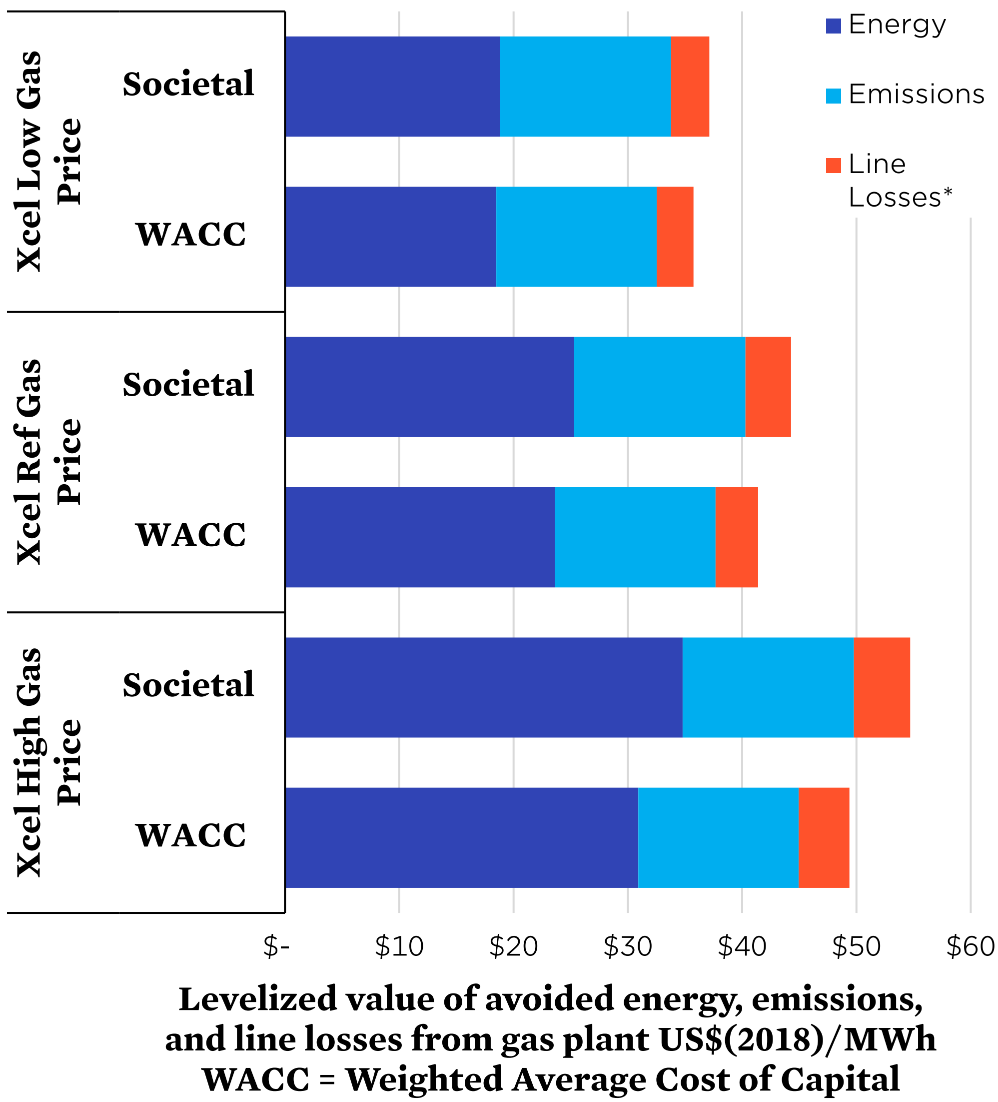
Over the 30-year study period (2019–2049), the annual avoided cost of energy efficiency ranges between $27 and $54 per MWh. The reference case scenario uses Xcel Energy's "base" gas price and a median CO_2 externality cost as approved by the Minnesota PUC. In the first two years, the avoided costs from energy decline due to expected declines in gas prices. Over the same time period, increases in the CO_2 externality cost do not outpace the declines in the gas price, resulting in a decline in overall avoided costs. Avoided costs then begin to steadily rise as gas prices start to increase, driving the value of avoided fuel/energy through the study period. Avoided emissions values are driven by the assumed CO_2 price, which also increases over time. Both emissions and energy are also affected by the assumption of changes in heat rate (the thermal efficiency) of the plants over time. Figure 7 shows the annual avoided energy and emissions values of foregoing an NGCC proxy plant, assuming a base case gas price, and Figure 8 displays the net present value of that same stream of benefits over a range of assumed gas prices.

Figure 7. 30-year Projection of the Value of Avoided Energy and Emissions from NGCC Proxy Unit (US$(2018)/MWh)



Note: Line losses excluded.

Figure 8. Levelized Avoided Energy and Emissions from a NGCC Plant under Different Gas Price Assumptions



The analysis calculated values using two discount rates for the gas-only scenario and looked at two sensitivities, using the low and high gas prices provided by Xcel Energy. The lowest value for energy efficiency was produced by the high discount rate and low gas price—$36 per MWh. The highest value for energy efficiency was produced by the low discount rate and the high gas price and was roughly $55 per MWh. See Table 3 for detailed results.

Table 3. Levelized Results for Gas Proxy Method with Xcel Energy Gas Price and Discount Rate Sensitivities ($/MWh)

Levelized Results — Gas Only					Total	
Scenario	**DR**	**Energy**	**Emissions**	**Line Losses**	**without line losses**	**with line losses**
High Gas Price	WACC	$31	$14	$4	$45	$49
	Societal	$35	$15	$5	$50	$55
Ref Gas Price	WACC	$24	$14	$4	$38	$41
	Societal	$25	$15	$4	$40	$44
Low Gas Price	WACC	$18	$14	$3	$33	$36
	Societal	$19	$15	$3	$34	$37

SOURCE: UCS calculations using gas prices derived from Xcel Energy. Values may not add due to rounding.

Chapter 6
Avoided Energy and Emissions from AVERT/Gas Blend Method

Background

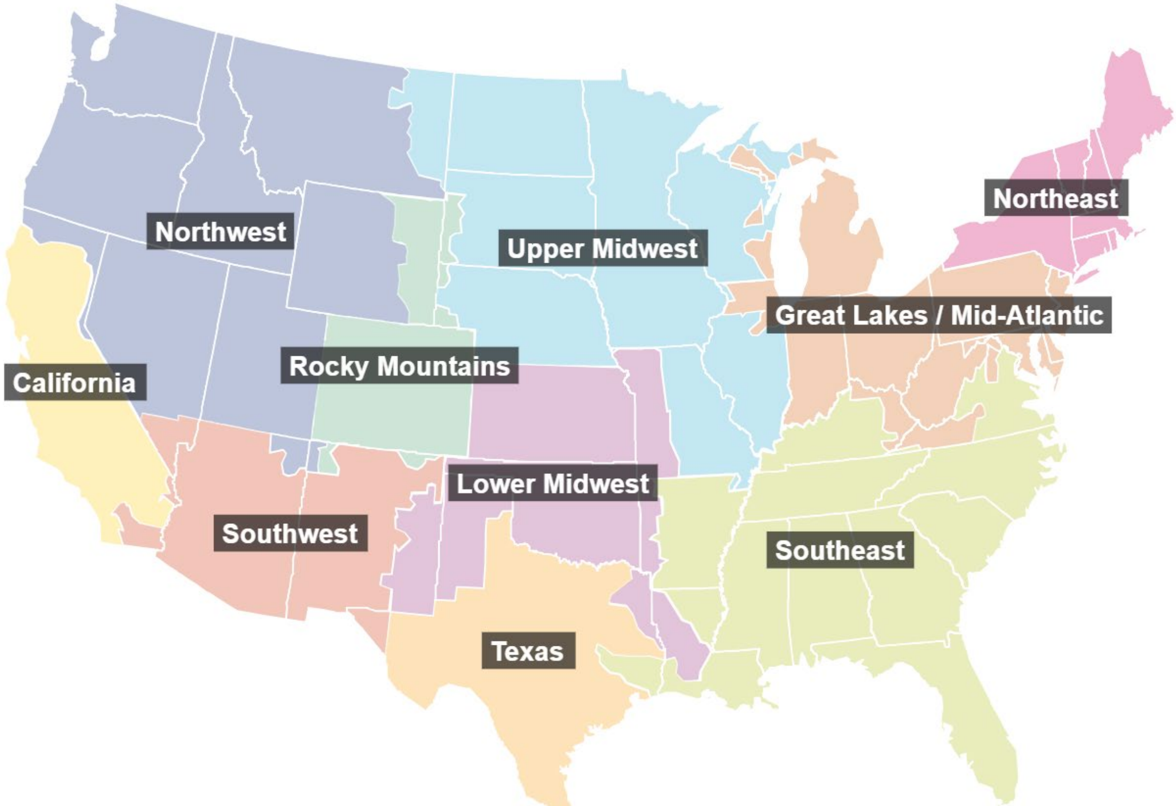
AVERT is an analytical tool developed by Synapse Energy Economics on behalf of the EPA.[27] The EPA has stated that the tool can be used by state air quality agencies or energy offices, by public utilities commissions, and by other organizations interested in calculating the emission benefits of energy efficiency and renewable energy policies or programs.

AVERT is a “behavioral simulator” model. It does not factor in production costs of individual generators; rather, AVERT predicts unit operations statistically. AVERT uses historical patterns and applies those patterns of behavior to simulate the output of individual generators. The model is entirely driven by publicly available data. AVERT splits the contiguous 48 states into 10 regions (see Figure 9). This analysis used the upper Midwest dataset, which includes all of Minnesota and many of the surrounding states in the northern portion of the Midcontinent Independent System Operator territory.

Using the AVERT model, we applied a 1 percent reduction in all hours of the year to serve as an approximation of an energy efficiency resource portfolio that is not targeted to achieve reductions in any specific hour or set hours. We applied the 1 percent reduction to the load associated with the entire Upper Midwest region, not just Minnesota, which means that the total number of MWhs reduced is higher than a 1 percent reduction in just Minnesota and that the total dollars in avoided costs and total pounds of pollution reduced in AVERT are much higher than what would be realized by a Minnesota-only 1 percent reduction. However, because we present our results in dollars per MWh and pounds per MWh, the results are averaged out (i.e., normalized). Additionally, AVERT’s default line losses are 6 percent, which this analysis replaced with 0 percent so that the line losses could be calculated exogenously.[28]

The model results indicate that a 1 percent reduction in load for all hours of the year displaces a mix of coal, gas, and oil resources. We then linked that specific fleet of resources to the fuel and variable costs associated with them, using S&P Global Market Intelligence data, which are populated from both publicly available data sources (like Energy Information Administration and Federal Energy Regulatory Commission forms) and with data provided by S&P on a subscription basis. Cost data were matched to corresponding plants or units associated with over 95 percent of the displaced generation. These associated costs were normalized into a weighted average cost per MW, wherein all the fuel and variable O&M costs were divided by the displaced generation.[29]

Figure 9. AVERT Regions



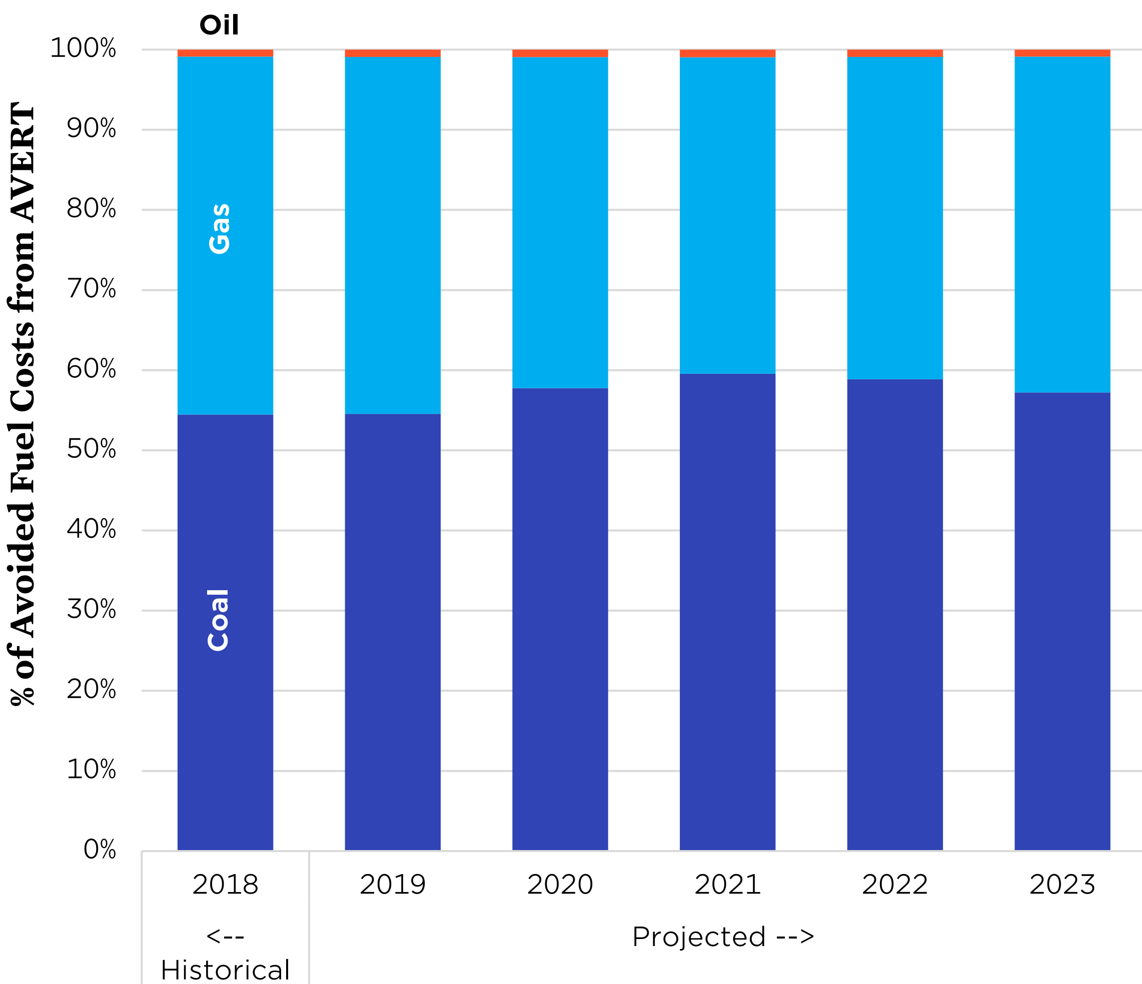
SOURCE: EPA AVERT tool (web edition).

Results: Avoided Fuel, Variable Operations and Management Costs, and Emissions from AVERT

A 1 percent reduction in load for the upper Midwest region displaced a mix of coal and gas, as well as a very small number of oil units. Using data from S&P Global Market Intelligence, this analysis matched the fuel and variable O&M costs with each fossil fuel unit displaced (as calculated by the AVERT model).

In terms of fuel costs, coal is the largest contributor to avoided fuel, followed by gas and then oil. The relative mix of resources is held constant for the entire five-year projection; however, coal and gas prices change over time in the analysis. The result is that avoided coal fuel costs represent 54 to 60 percent of energy costs over the first five years, as shown in Figure 10. Because complete data for 2019 were not available at the time this analysis was conducted, 2019 values reflect projected data.

Figure 10. Projected Mix of Avoided Fuel Costs from AVERT



Notes: Values are based on the percentage of costs, not MWh. Changes over time reflect changes in coal and gas prices.

The avoided fuel costs from oil, gas, and coal were added up and divided by the displaced MW from all fuel types. The same was done for avoided variable O&M. The oil, gas, and coal costs were thus bundled into a weighted average for both avoided fuel and avoided variable O&M value, in terms of MWh. Based on the projection above, the AVERT gas/blend method produced an avoided fuel cost of roughly $26 per MWh. Variable O&M costs were held constant in US$(2018) for the entire study period. Table 4 offers a sample of the underlying model.

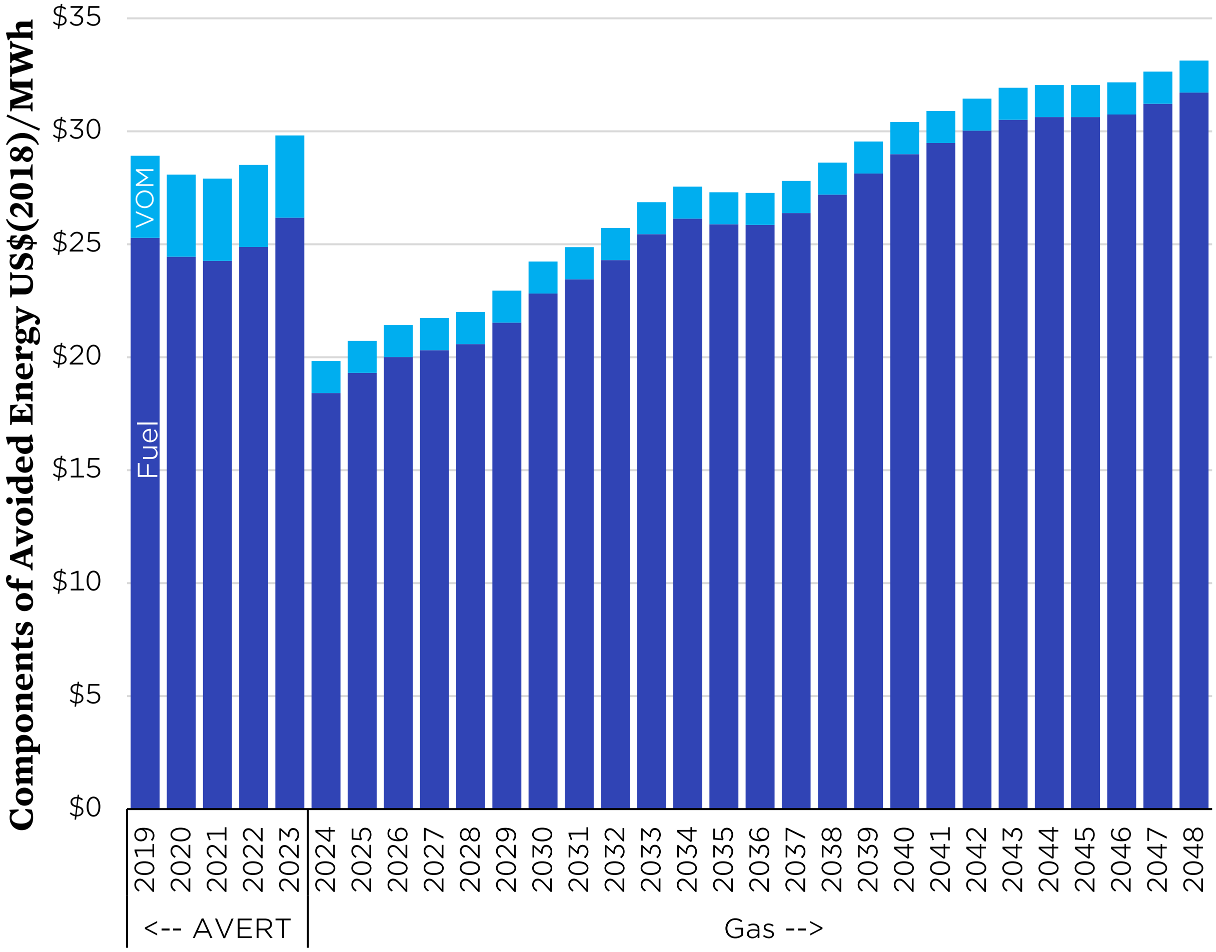
Table 4. AVERT Calculations

Unit	Variable	Assumption/ Calculation	2018 (Historical)	2019 (Projected)	2020 (Projected)
$ Fuel	Coal	**Generic Coal Delivered Price (Xcel)**	$34,297,463	$32,881,513	$33,668,152
$ Fuel	Gas	**Xcel Base**	$28,119,051	$26,845,305	$24,072,069
$ Fuel	Oil	Constant	$546,989	$546,989	$546,989
MWh	All Fuels	Mix	2,384,243	$2,384,243	$2,384,243
$/MWh	All Fuels	Mix	$26.41	$25.28	$24.45
$	VOM	Constant	$8,669,598	8,669,597.53	8,669,597.53
MWh	VOM	Constant	2,384,243	2,384,242.57	2,384,242.57
$/MWh	VOM	Constant	$3.64	$3.64	$3.64
Unit	**Variable**	**Assumption/ Calculation**	**2021 (Projected)**	**2022 (Projected)**	**2023 (Projected)**
$ Fuel	Coal	**Generic Coal Delivered Price (Xcel)**	$34,454,791	$34,926,775	$35,713,414
$ Fuel	Gas	**Xcel Base**	$22,852,660	$23,839,577	$26,147,917
$ Fuel	Oil	Constant	$546,989	$546,989	$546,989
MWh	All Fuels	Mix	$2,384,243	$2,384,243	$2,384,243
$/MWh	All Fuels	Mix	$24.27	$24.88	$26.18
$	VOM	Constant	8,669,597.53	8,669,597.53	8,669,597.53
MWh	VOM	Constant	2,384,242.57	2,384,242.57	2,384,242.57
$/MWh	VOM	Constant	$3.64	$3.64	$3.64

Note: These values do not reflect line losses

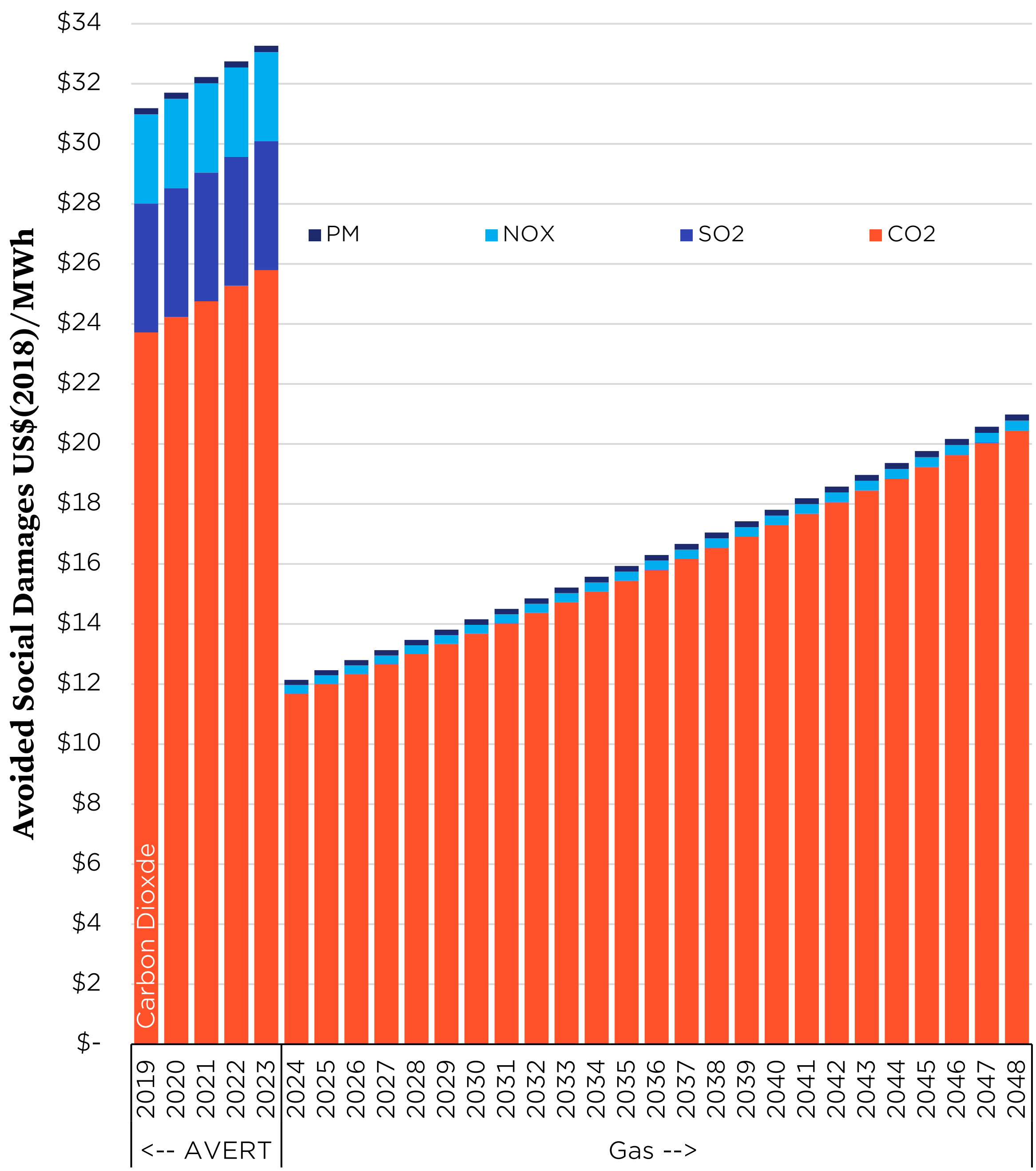
Figure 11 shows the avoided fuel and variable O&M costs from the blended method over the study period. The AVERT model identified coal and gas as being displaced by efficiency. The coal and gas units that are displaced by efficiency are, as one would expect, some of the least efficient of these plants on the system, and therefore have costs that are above average and higher than the costs associated with a brand new, efficient gas plant. Because the displaced coal and gas units have high fuel and variable O&M costs, the results in the early years are relatively high. In year 6, the model switches over to a gas proxy plant. The costs first step down but then rise again as gas prices rise. As a result, at the end of the study period, the avoided-energy value of energy efficiency is higher than the early years.

Figure 11. Avoided Energy Costs (Fuel and Variable O&M) from Energy Efficiency ($/MWh)



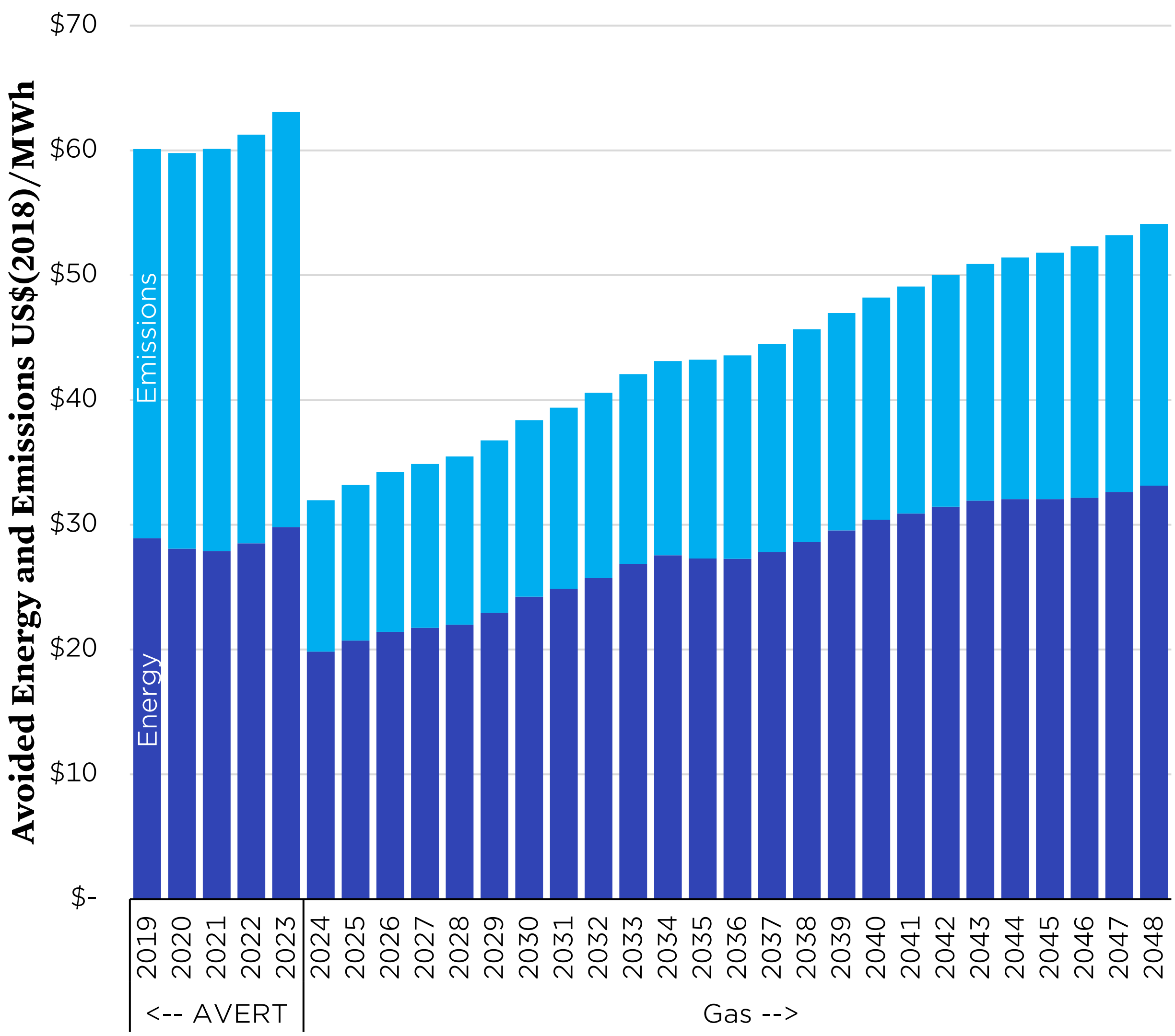
With respect to avoided emissions, the AVERT/gas blend method produces avoided costs over time that show a pattern similar to avoided energy costs. The least-efficient gas and coal plants are displaced initially, as they have higher emission rates than a new NGCC plant. Coal's significant CO_2, NO_X, PM, and SO_2 emissions translate to higher avoided costs when coal is displaced. On the other hand, gas-fired power plants have significantly lower stack emissions; therefore, the avoided costs fall considerably when the model switches over from the AVERT blend of coal and gas to the new, efficient gas proxy unit. Figure 12 breaks out the components of the avoided emissions values over the study period, showing the annual avoided emissions value steadily increasing. This is a function of both increasing externality costs associated with CO_2 emissions and the assumption that gas plants will cycle more often, which will reduce the power plant's efficiency over time.

Figure 12. Avoided Emissions from the AVERT/Gas Blend Method ($/MWh)



When the avoided energy and avoided emissions are stacked, the avoided energy and emission trajectory compounds the above trends, with the total avoided energy plus emissions starting at $60 per MWh and gradually increasing until 2024 when the avoided costs shrink in half, to just over $30 per MWh. These results are displayed in Figure 13. Over the remaining study period, avoided costs continue to consistently increase, a function of reduced gas efficiency, increasing gas prices, and increased externality costs.

Figure 13. Avoided Energy and Emissions Using AVERT/Gas Blend Method



Chapter 7
Conclusions and Recommendations

Discussion

The models showed similarity among avoided energy costs and more divergence among total avoided costs. The three methodological approaches examined in this analysis showed costs falling within a relatively tight range—between $24 and $27 per MWh—as shown by Figure 14. The avoided energy costs produced by the AVERT model were highest because energy efficiency displaced the least efficient existing resources, as opposed to displacing a new NGCC proxy plant. (If an NGCT was assumed, then the avoided energy value would have been higher.)

After accounting for emissions benefits as well as line losses, the overall avoided-cost results differed significantly between the three methods tested, ranging between $41 and $71 per MWh (Table 5). The overall avoided costs that resulted from the coal proxy method were highest, and the results of the gas proxy method were the lowest. The AVERT/gas blend method produced avoided costs that fell between the values produced by the other two methods. Efficiency that displaces gas had an emissions benefit of $14 to $15 per MWh and had more than twice the benefit (roughly $39 per MWh) when it displaced coal.

One reason why the avoided costs were so much higher in the AVERT years as compared to the gas-only years is that the AVERT years included the many inefficient, expensive, and polluting resources still on the grid today. If energy efficiency is to be truly thought of as a resource, it must be optimized into the grid like other resources. When other new resources enter the market, they are adopted and integrated by displacing the most expensive and least efficient resources (in economic merit order), and the same should be true for efficiency.

Figure 14. Comparative Results

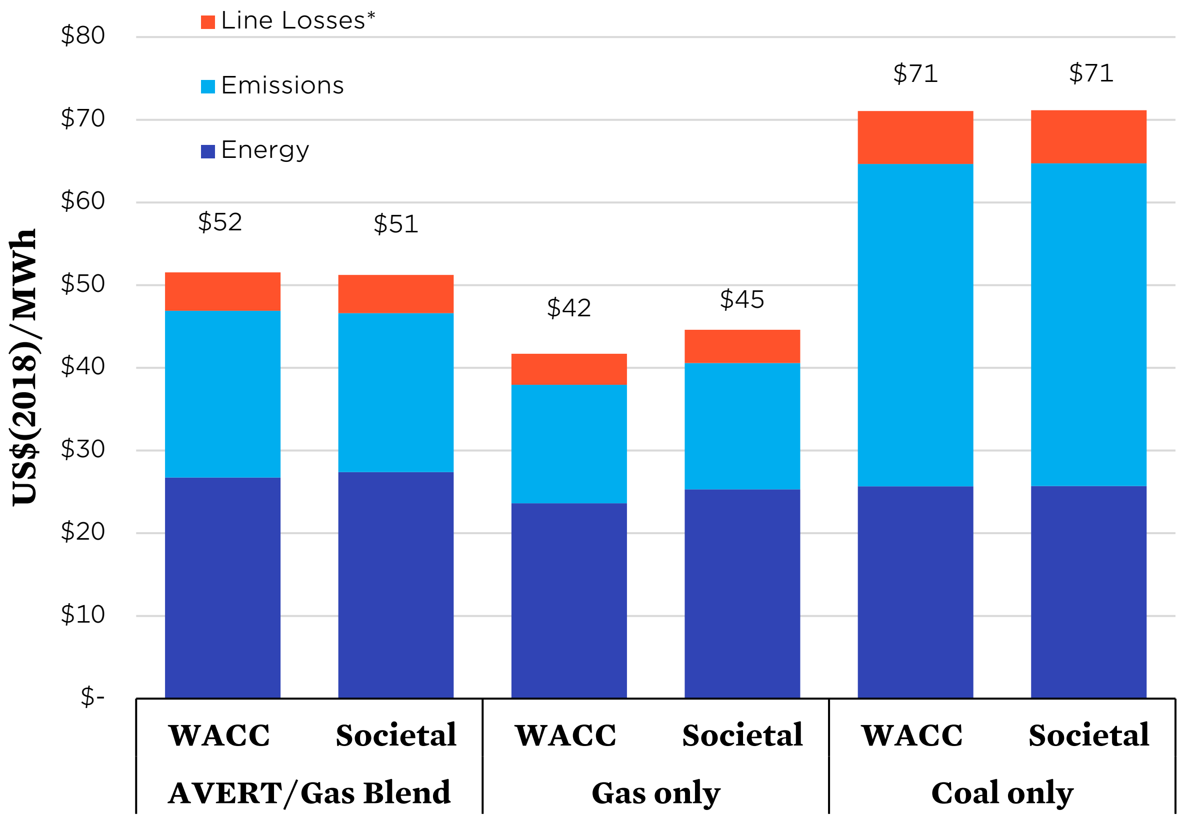


Table 5. Levelized Results for Three Methods under Both the WACC and Societal Discount Rates ($/MWh)

Levelized Results					Total	
Mix	**Discount Rate**	**Energy**	**Emissions**	**Line Losses**	**Without Line Losses**	**With Line Losses**
AVERT/Gas Blend	WACC	$27	$20	$5	$47	$52
	Societal	$27	$19	$5	$47	$51
Gas only	WACC	$24	$14	$4	$38	$42
	Societal	$25	$15	$4	$41	$45
Coal only	WACC	$26	$39	$6	$65	$71
	Societal	$26	$39	$6	$65	$71

Note: Values might not add up due to rounding.

The AVERT/gas blend method results were driven by early-year reductions in coal use. Coal-fired generation was assumed to be eliminated from Minnesota's electricity supply after five years (in 2024). This assumption was a very conservative one. To the extent that Minnesota utilities continue to rely on coal past 2024, it is possible that efficiency will continue to reduce the output of those coal-fired power plants and the avoided energy and emissions costs associated with them.

Conclusions

Since energy efficiency, like all resources, should be integrated into the grid as efficiently as possible, it should displace the most expensive resources operating. Assumptions made in modeling exercises that wind or solar constitute the avoidable resource will produce an unrealistically low result. Stated in other terms, to assume that wind and solar are on the margin in a real-time market—which means that the avoided energy and emissions values in that hour are zero—ignores important opportunities to improve system operations and move toward an increasingly low-carbon grid.

Determining the avoided energy and emissions of energy efficiency through the use of the utility dispatch model to may often provide an inaccurate valuation of the resource, as those models are subject to the utilities' assumed constraints and operating practices and thus may place low-cost, carbon-free resources on the margin even as high-cost, emitting resources continue to operate. Such a scenario assumes that efficiency cannot displace those high-cost, emitting resources—when in fact it can and should.

Similarly, the use of LMPs might show up in an avoided cost explicitly or implicitly in the results produced in a utility dispatch model. The use of LMPs as a proxy value for avoided energy is inappropriate because it assumes that higher-cost units operating under current market rules cannot be displaced by energy efficiency, when they can and should be.

A better model is one that bases avoided-cost analyses on a new NGCC plant, given that it is the most common emitting resource currently being proposed by many utilities, including those in Minnesota.

Recommendations

Based on the above analyses and assessment of the type of avoided-cost analyses that best determines the value of energy efficiency in offsetting costs and emissions, we make the following recommendations.

UTILITY REGULATORS SHOULD ADOPT AN AVOIDED-COST METHODOLOGY THAT IS TRANSPARENT, ACCESSIBLE, AND AUDITABLE.

As noted by Synapse Energy Economics, "[c]ost-effectiveness practices should be completely transparent, and should fully document all relevant inputs, assumptions, methodologies, and results" (Malone, Woolf, and Goldberg 2018). Moreover, as pointed out by the National Efficiency Screening Project, "[t]he monetary impacts of [energy efficiency] resources . . . should be presented in a transparent, detailed, easily reviewable way" (Woolf et al. 2017). Achieving these goals could take the form of any of the methods presented here, using either a proxy plant method (for either coal or gas) or a blended version that uses AVERT in the short run and a proxy plant in the long run.

The dispatch/optimization modeling that is currently conducted by utilities is difficult to audit, not generally available to the public, and not transparent. This type of modeling also has many pre-established assumptions about how the electric grid operates that may or may not accurately reflect today's economic and operational reality. Therefore, dispatch/optimization modeling runs counter to one of the six principles of cost-effectiveness analyses in the National Standard Practice Manual—transparency—and it should be avoided.

IF A DISPATCH MODEL IS USED, SUPERFLUOUS CONSTRAINTS LIKE "MUST RUN" DESIGNATIONS SHOULD BE REMOVED.

When utilities or other entities use dispatch/optimization models as part of avoided-cost studies, the models *should be carefully reviewed and scrutinized to remove any inherent assumptions that might lead to bias*. For instance, in some cases, utilities will designate company-owned resources as "must run" when conducting modeling with optimization software, a designation that forces the models to select those resources to serve load even if lower-cost resources are available. The models are unable to displace "must run" resources with other existing resources, energy efficiency, or new resources that may represent lower-cost options. Therefore, setting company-owned resources in a status of "must run" in utility optimization software should be avoided, because doing so may present results that are not fully optimized.

Technical Appendix 1 Assumptions Underpinning UCS Analysis

Gas Proxy Plant

Energy efficiency helps to defer or entirely avoid the need to buy or build generation resources such as natural gas plants. In doing so, the energy and emissions that would have been produced by that gas plant (if it were not for the energy efficiency) are also avoided. In general, there are two types of gas plants that a utility could build: natural gas combined-cycle (NGCC) plants or natural gas combustion turbines (NGCTs). NGCC plants typically have higher capital costs but lower operating costs than NGCTs. In an avoided-cost study, those NGCC costs would translate to energy efficiency measures having higher avoided capacity value and lower avoided energy and avoided emissions values.

This analysis examined the avoided energy and emissions associated with displacing a gas plant over a 30-year time horizon, using an NGCC as the proxy plant because it produces lower avoided energy and emissions than an NGCT and therefore represents a more conservative estimate for the value of energy efficiency. In addition, two major Minnesota utilities, Minnesota Power and Xcel Energy, have currently identified a need for NGCCs, while only Otter Tail Power has stated plans to build an NGCT (see Table A1-1).

Table A1-1. Planned Gas Plant Transactions (Builds or Buys) for Minnesota Investor-owned Utilities

Plant Name	Gas Plant Type	Owner Operator	Purchase or Construction	Date	Size (MW)	Additional information
Becker Gas Plant	NGCC	Xcel Energy	Construction	2026	750	Authorized via legislation in 2017
Nemadji Trail Energy Center	NGCC	Minnesota Power	Construction	2025	525	Co-owned by Dairyland Power Cooperative and the Minnesota Power affiliate South Shore Energy
Mankato Energy Center (MEC)	NGCC	Xcel Energy*	Purchase	2020	577	MEC unit II was commissioned in 2019. Xcel Energy maintains a power purchase agreement for the energy/capacity
Astoria Station	NGCT	Otter Tail Power	Construction	2021	245	To be built in Deuel County, South Dakota

** Xcel Energy acquired the Mankato Energy Center in January 2020 through a nonregulated affiliate company. On April 6, 2020, Xcel announced plans to sell the plant to Southwest Generation in a transaction expected to close in the third quarter of 2020.*

SOURCE: Various sources aggregated by authors.

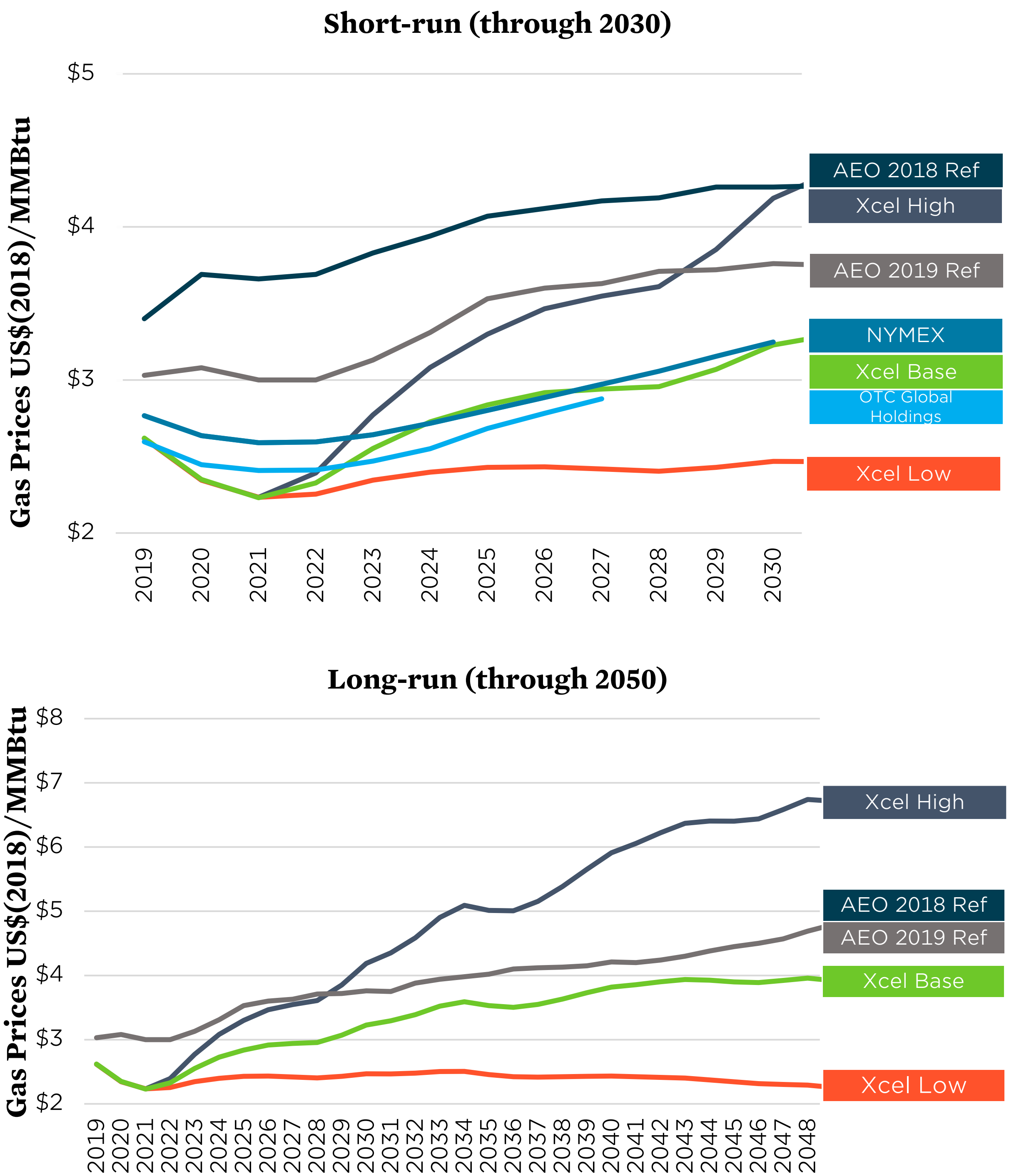
It is worth noting that the avoided capacity value is often assumed to be based on an avoided NGCT. But if an NGCT were to truly be avoided, then any energy from that resource that would have been generated would also be avoided. One cannot generate electricity from a resource that does not exist—and while NGCTs tend to generate very little electricity, if they were to produce zero megawatts of electricity, it is unlikely they would be needed at all. The use of the NGCT assumption produces lower avoided-capacity values but higher avoided-energy values. When a comprehensive avoided-cost study is being performed—one that calculates all the costs and benefits of efficiency measures—internal consistency is key. Therefore, whatever resource the modeler uses as the avoided capacity value (e.g., NGCC or NGCT) should also be used in the calculation of avoided energy and emissions.

Because Xcel Energy is only proposing to build NGCC plants, it would be irrational to assume that the utility will avoid the costs associated with an NGCT when calculating the avoided capacity. Therefore, UCS believes it is reasonable to assume that some energy from an NGCC is going to be avoided from efficiency; however, if that is the case, then the avoided capacity value might better reflect reality if it also assumes the avoided costs associated with an NGCC.

GAS PRICES

This analysis of the avoided costs of Minnesota utilities employs the gas price forecasts being used by Xcel Energy.[30] For reference, Figure A1-1 compares those gas price forecasts to others, including the Energy Information Administration's Annual Energy Outlook 2018 and 2019 projections of gas prices under a range of assumed cases (including the reference case and various side cases).

Figure A1-1. Short-run and Long-run Gas Prices US$(2018)/MMBtu



SOURCE: Gas prices obtained from multiple sources. A 2 percent inflation rate was assumed when adjusting nominal dollars into US$(2018) when no inflation rate was provided. Values reflect prices at the Henry Hub pipeline in Louisiana.

Note: AEO is the Energy Information Administration's Annual Energy Outlook.

Relying only on Xcel Energy's gas prices provides an apples-to-apples comparison of our avoided-cost values to those of Xcel Energy and other Minnesota-based utilities. Also, by using the same gas price forecast as Xcel Energy, the analysis isolates any result variance to assumptions regarding which units are on the margin. The gas-only scenario produces two sensitivities, using Xcel Energy's high and low gas price forecasts.

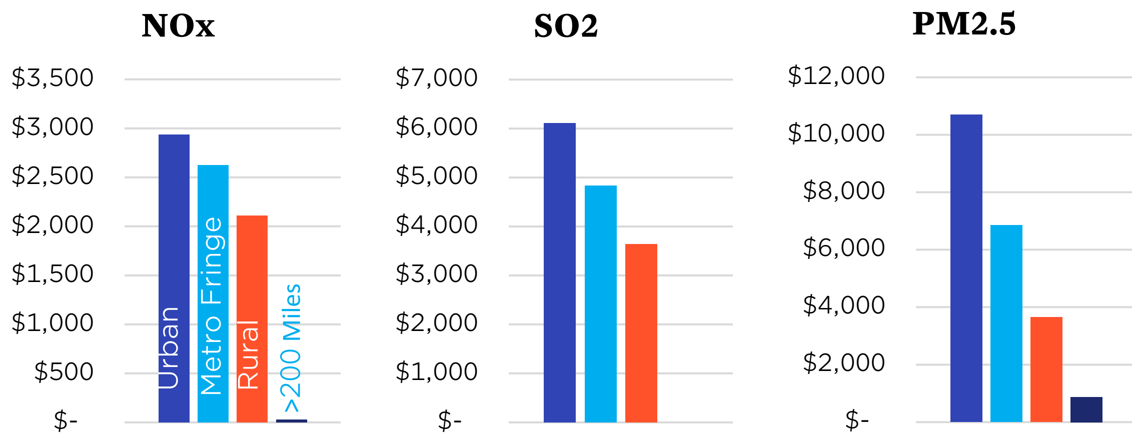
The results in this analysis reflect Xcel Energy's forecast to maintain consistency, and the use of Xcel Energy's gas price in this analysis should not be misconstrued into a position affirming the reasonableness of those gas prices.

Gas prices were used to escalate the fuel costs associated with operating existing resources as identified by AVERT as being displaced by energy efficiency.

Externality and Compliance Costs

For this study, UCS used a reference case for avoided emissions of electricity production based on the Minnesota Public Utilities Commission's (PUC) approved range of externality cost values associated with the pollutants produced as a result of fossil fuel generation of electricity, as well as compliance costs associated with carbon dioxide (CO_2).[31] We based our analysis on the median of the final metropolitan fringe environmental cost values for NO_X, SO_2, and $PM_{2.5}$ (Figure A1-2), and the CO_2 reference reflects a median value of the high and low CO_2 externality costs in the early years (Figure A1-3). The specific value chosen within the PUC's approved range—the median metro fringe value—is consistent with guidance issued by the Minnesota Department of Commerce regarding the externality value that should be used in calculating the cost effectiveness of Minnesota utilities' energy efficiency programs.

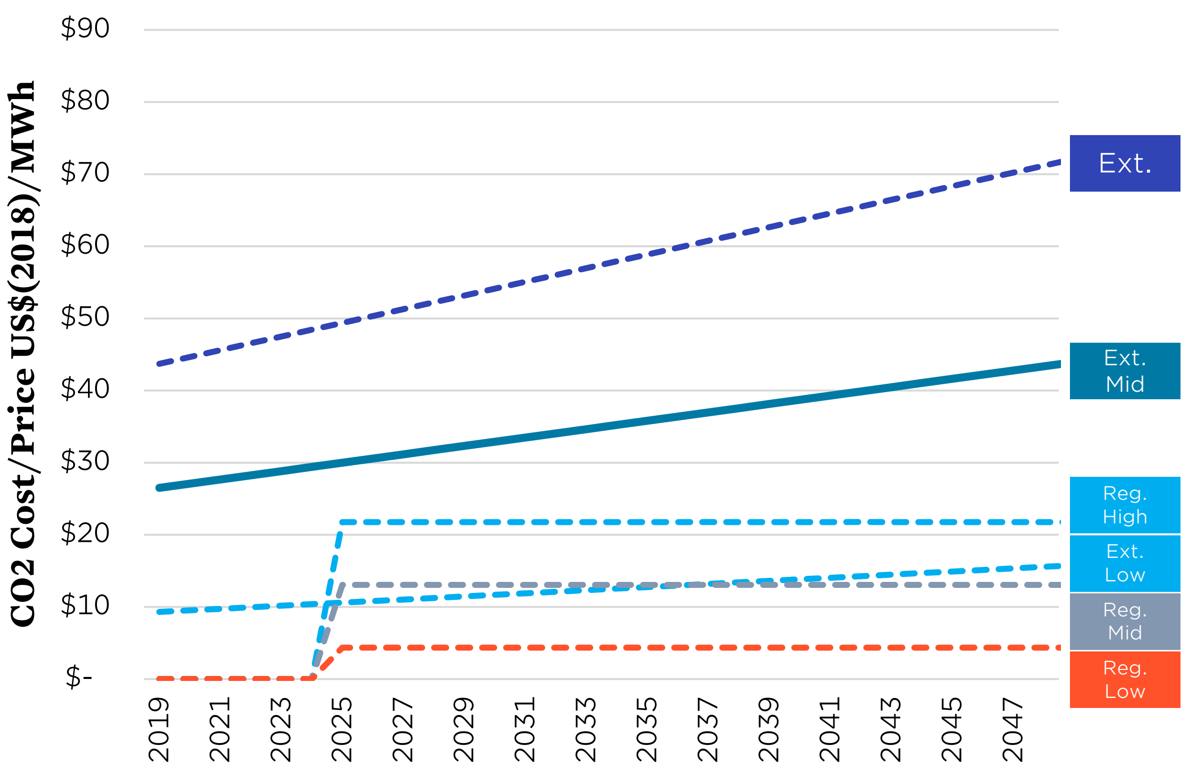
Figure A1-2. Externality Costs of Select Pollutants in Minnesota (US$(2018)/ton)



SOURCE: Minnesota Public Utilities Commission. Values are provided for a single year and are held constant throughout the study period. All results in this report reflect calculations based on the metro fringe value. All values are in US$(2018).

The Minnesota Department of Commerce calculates the non-gas fuel environmental damage factor, defined as the long-term external cost to society and the environment of generating electricity, using (1) the median range of the final metro fringe environmental cost values approved by the Minnesota Public Utilities Commission for carbon dioxide (CO_2), sulfur dioxide (SO_2), fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), nitrogen oxides (NO_x), and lead (Pb); and (2) estimated 2016 emission factor (or factors) for each emission provided by the Environmental Protection Agency and the Minnesota Pollution Control Agency. For CO_2, staff at the Department of Commerce used a median value of $27 per ton in 2020 from the PUC's January 3, 2018, Order Updating Environmental Cost Values.[32]

Figure A1-3. Externality and Compliance Costs of Carbon Dioxide in Minnesota



Note: Although this graph represents the entire outlook of compliance and externality costs of CO2 (as provided by the Minnesota Public Utilities Commission and Xcel Energy), the analysis used a study period of 2019–2049 (inclusive) and did not rely on the values displayed in 2050 or beyond. All values are in US$(2018).

Xcel Energy's regulatory compliance costs are set to $5, $15, and $25 per ton (in US$(2018)) and remain flat in constant dollars.[33] The reference case value for this analysis was set to the median value of the externality high and low values, as recommended by the Department of Commerce 2019 decision.[34]

GAS PLANT HEAT RATE

Heat rate is the amount of energy in British thermal units (Btu) used by an electrical generator or power plant to generate one kilowatt-hour (kWh) of electricity (Table A1-2). The lower the heat rate, the more efficient a plant is operating.

Table A1-2. Proxy Gas Plant Heat Rates

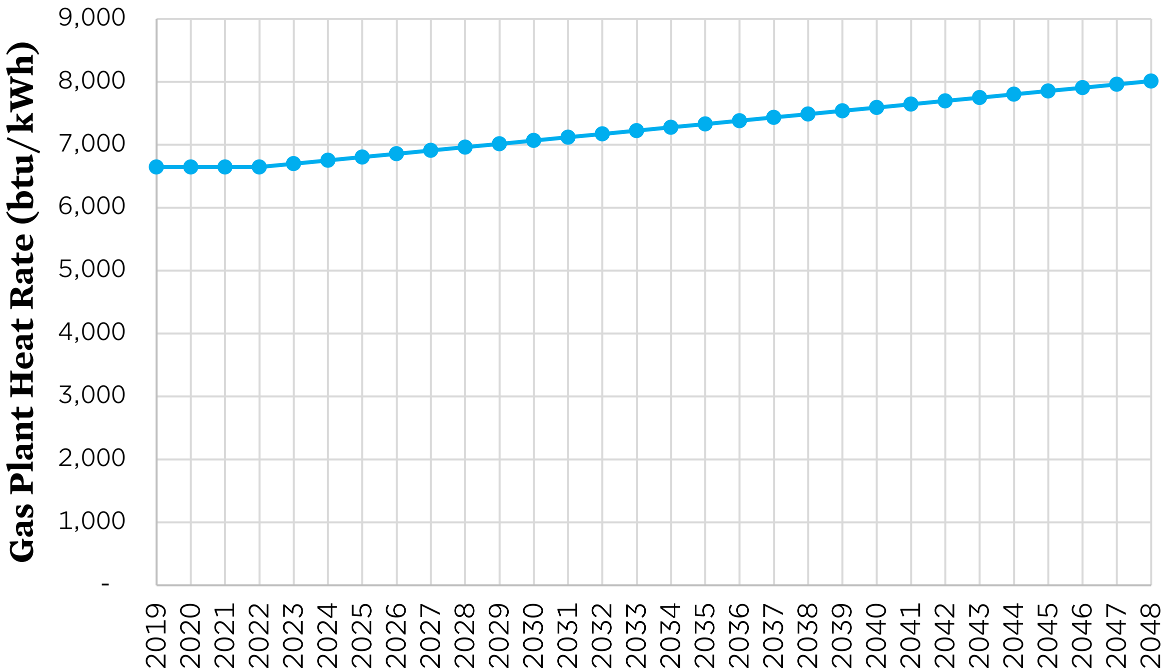
Resource	Sherco CC	Generic CC	Generic CT	Generic CT	Generic CT
Technology	7H	7H	7H	7F	7H
Location Type	Brownfield	Greenfield	Brownfield	Brownfield	Greenfield
Heat Rate with Duct Firing (btu/kWh)	6,494	6,818	N/A	N/A	N/A
Heat Rate 100% Loading (btu/kWh)	6,331	6,647	9,042	9,791	9,042
Heat Rate 75% Loading (btu/kWh)	6,464	6,787	9,474	10,234	9,474
Heat Rate 50% Loading (btu/kWh)	6,876	7,220	10,833	12,006	10,833
Heat Rate 25% Loading (btu/kWh)	7,831	8,222	11,279	12,835	11,279

SOURCE: Xcel Energy in Attachment F (Table 13) of Petition for Approval of the Acquisition of the Mankato Energy Center (MEC), Docket No. IP6949, E002/PA-18-702.

The analysis here assumes that a gas plant has a declining efficiency (that is, an increasing heat rate) over its lifespan. Therefore, the model escalates the heat rate each year linearly (starting in 2022), from the heat rate associated with 100 percent loading to that associated with 25 percent loading. This option reflects the operational expectations of gas plants: that they will need to cycle more and more for renewable integration purposes, and that they will be relied on less in a decarbonizing system.[35]

The heat rate assumption affects both the cost of producing energy and the emissions associated with running a gas plant. The default heat rate assumed in this analysis is shown in Figure A1-4.

Figure A1-4. Heat Rate of Generic New NGCC, Increasing (Reduced Efficiency) Over Time Due to Cycling



SOURCE: UCS calculations, based on data from Xcel Energy in Attachment F of Petition for Approval of the Acquisition of the Mankato Energy Center (MEC), Docket No. IP6949, E002/PA-18-702.

DISCOUNT RATES

Avoided costs are typically presented on either net present value or levelized basis. Either of those calculations requires an assumed discount rate. Minnesota currently employs different discount rates in different circumstances, but most analyses typically use one of two discount rates: the weighted average cost of capital (WACC) or a societal discount rate.

The Minnesota Department of Commerce recommends a societal discount rate of 3 percent and a WACC of 7 percent.[36] Both discount rates are used for this analysis because Minnesota utilities are required to use different cost-effectiveness tests in the evaluation of the cost effectiveness of the Conservation Improvement Program, and both rates are used in the required tests. However, both those values are typically applied to a stream of nominal dollars, whereas this analysis is conducted in real (or constant) dollars. Consequently, the nominal discount rates were converted into a constant discount rate using the equation:

$$i = \frac{i' - f}{1 + f}$$

Wherein, i = the real discount rate, i' = the nominal discount rate, and f = the general inflation rate (2 percent).

This produced real discount rates of 4.9 percent for WACC and 1.0 percent for a societal discount rate. Because the out-year values of avoided energy and emissions are generally greater than the early year values, the lower discount rate generally produces higher values.

Technical Appendix 2
AVERT Model

In this appendix we describe the mechanics of running the AVERT model. For more information on the model, please visit the AVERT webpage on the EPA's website: https://www.epa.gov/statelocalenergy/avoided-emissions-and-generation-tool-avert.

As Synapse Energy Economics describes:

> [T]he model replicates actual unit generation behaviors such as base load, intermediate, and peaking behavior, units that have a must-run designation (i.e.[,] are required to operate for reliability reasons, and often operate at minimum levels to maintain the ability to meet load), as well as forced and maintenance outages. In addition, the model accurately represents the relationship between unit generation and emissions, with characteristics such as a decreasing heat rate (i.e.[,] increasing efficiency) at higher levels of output, higher emissions from units that are just warming up, and seasonally changing emissions for units with seasonal environmental controls (Biewald et al. 2015).

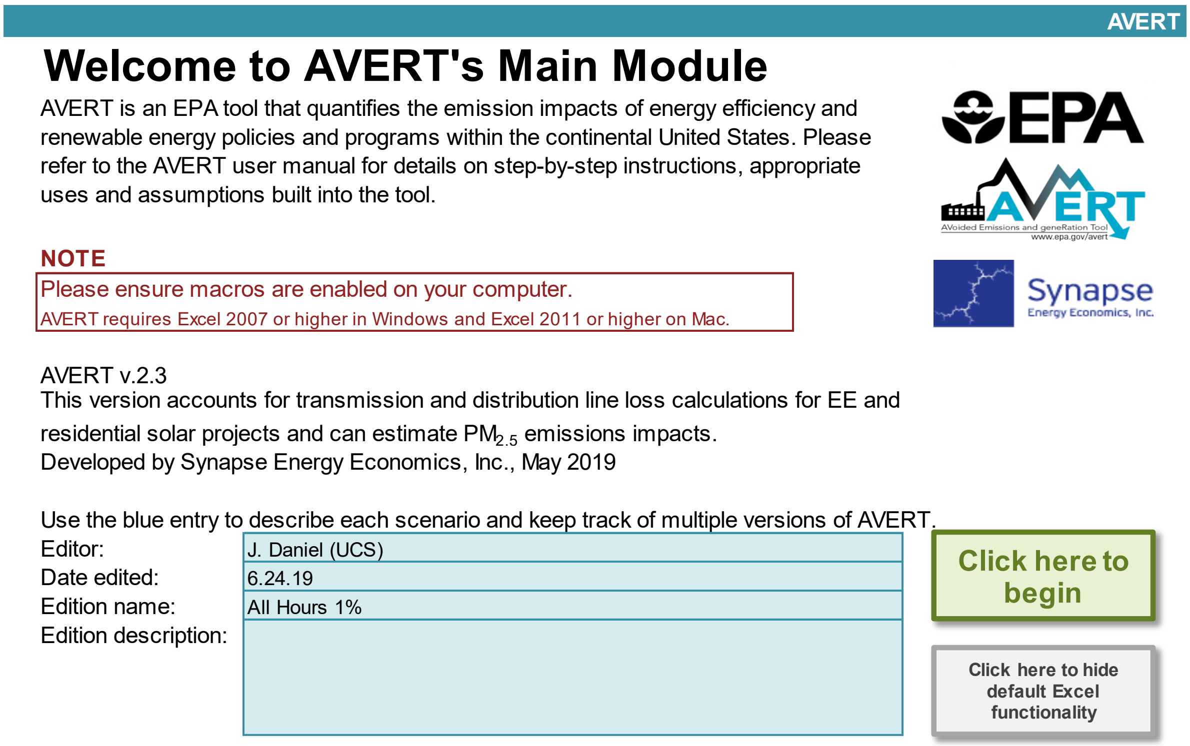
Because the model simulates the impacts of energy efficiency on individual generators, the avoided emissions can be tied directly to the avoided fuel and variable costs of those individual generators, making AVERT a natural fit to calculate the avoided energy and emissions of efficiency in Minnesota. Additional benefits of the tool include that AVERT:

- incorporates a simple user interface that allows both experts and non-experts to use the tool
- is a tool built for the Environmental Protection Agency and underwent extensive external peer review
- is free to the public and fully auditable
- can easily accommodate a variety of load profiles associated with different energy efficiency programs
- is a good middle ground between a simple assumption (e.g., efficiency displacing coal) and more complex, less accessible tools (e.g., production cost simulations).

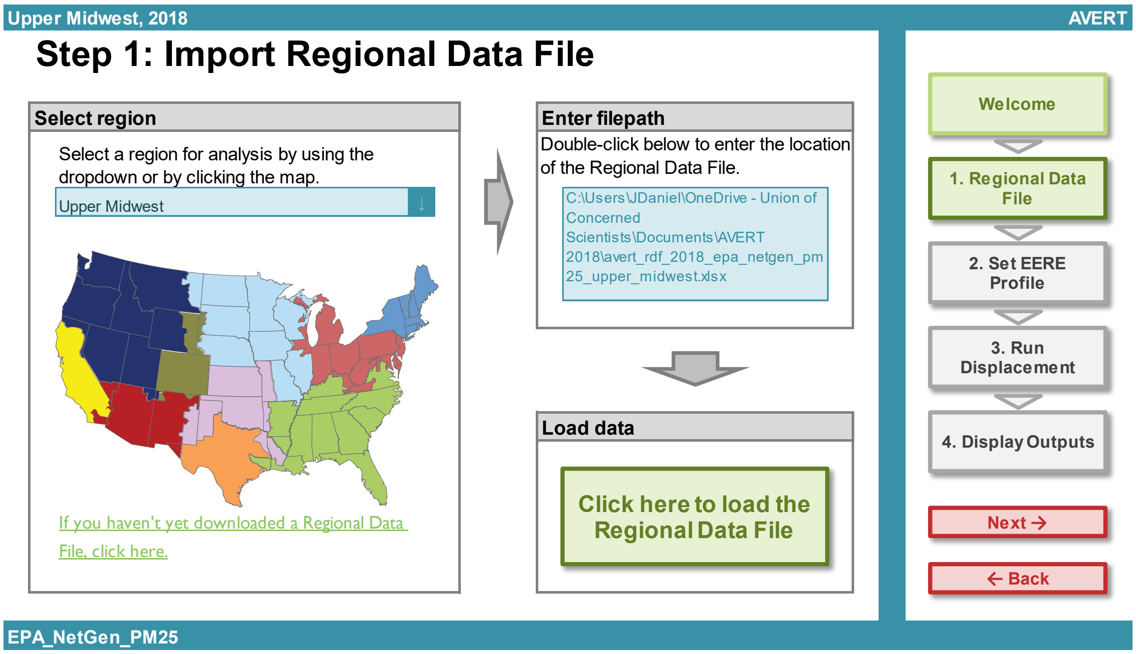
AVERT has been used to quantify avoided emissions by Lawrence Berkeley and Pacific Northwest National Laboratories; the Connecticut Green Bank; universities including Boston University, Illinois State University, North Carolina State University, and the Universities of Chicago, Michigan, Pittsburgh, and Wisconsin; private firms including Advanced Energy, Cadmus, Courtney Strong, ENVIRON, Sustainable Energy Advantage, and Synapse Energy Economics; and advocacy organizations and trade groups including the American Council for an Energy-Efficient Economy, the American Wind Energy Association, Chesapeake Climate Action Network, Hoosier Environmental Council, and the Solar Energy Industries Association (EPA 2018).

Methodology

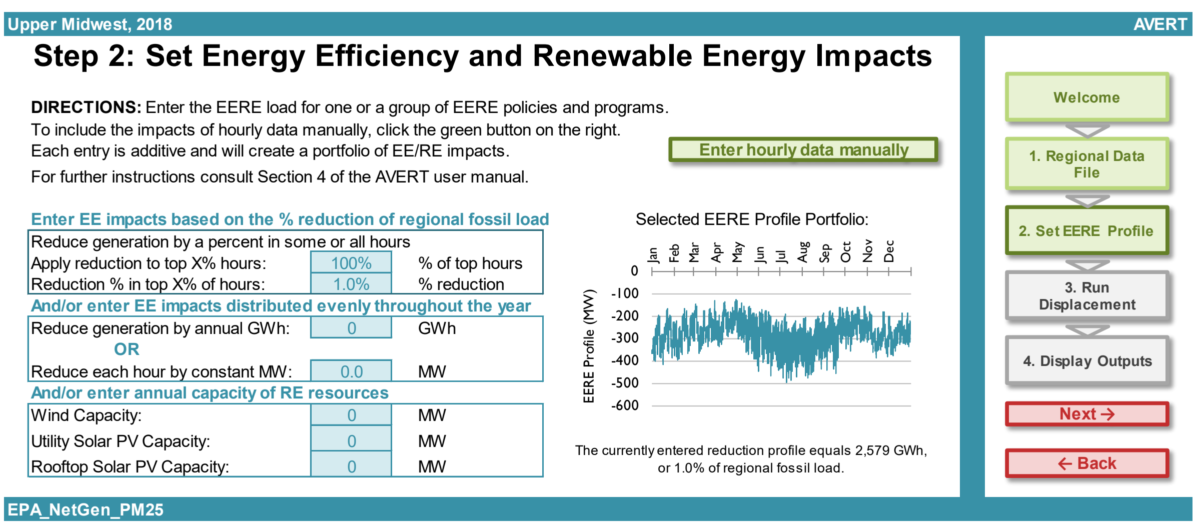
The first page in the AVERT model allows one to fill out the file information and model run (edition) information.



Step 1. Select a region and download the regional data file from the Environmental Protection Agency’s website.

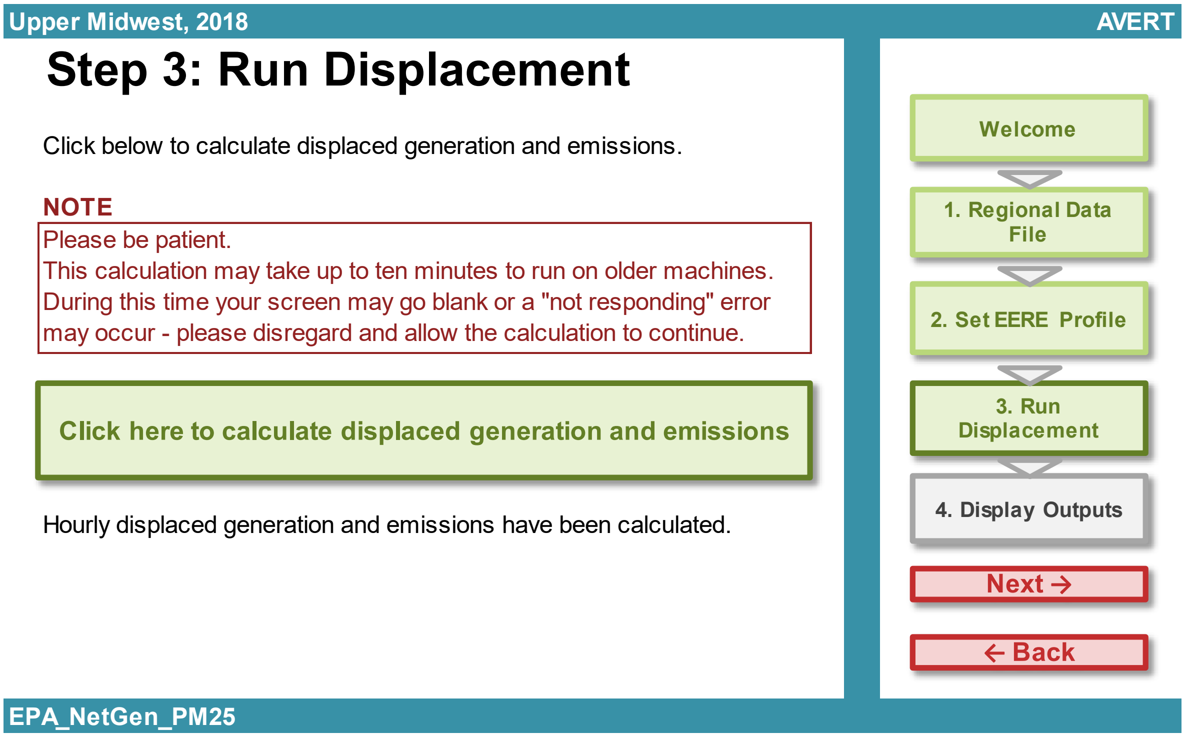


Step 2. Select from a number of clean energy resources including energy efficiency, wind, and solar. Several options are available for the load profiles of energy efficiency, which can also be customized by manually entering in the hourly data.



*In the analysis described in this report we modified line losses to 0 percent in tab "CalculateEERE."

Step 3. The model estimates the resources that would be displaced based on a statistical calculation. After the model run is complete, a wide range of outputs are available for the user to explore.



Output: Annual regional displacements of emissions. Blue text indicates UCS calculations that are not produced by AVERT automatically. This is one of many outputs provided by the Excel-based version of the model.

Upper Midwest, 2018 AVERT

Output: Annual Regional Displacements

Click here to return to Step 4: Display Outputs

	Original	Post-EERE	Impacts
Generation (MWh)	257,380,900	254,811,060	-2,569,840
Total Emissions from Fossil Generation Fleet			
SO_2 (lbs)	613,697,850	609,145,220	-4,552,620
NO_x (lbs)	371,056,430	367,890,630	-3,165,800
CO_2 (tons)	268,859,750	266,561,460	-2,298,300
$PM_{2.5}$ (lbs)	27,499,620	27,280,540	-219,070
Fossil Generation Fleet Emission Rates			EE Avoided Emissions Rate
SO_2 (lbs/MWh)	2.384	2.391	1.772
NO_x (lbs/MWh)	1.442	1.444	1.232
CO_2 (tons/MWh)	1.045	1.046	0.894
$PM_{2.5}$ (lbs/MWh)	0.107	0.107	0.085

Negative numbers indicate displaced generation and emissions.

All results are rounded to the nearest ten. A dash ("—") indicates a result greater than zero, but lower than the level of reportable significance.

AVERT also produces a summary table of annual data for every fossil unit in the region selected by the user. This is the page that we used to map unit generation and emissions data to fuel costs and variable operations and management costs from S&P Global Market Intelligence.

Upper Midwest, 2018

Summary table of annual data, detailed unit data

Click here to return to Step 4: Display Outputs

ORSPL (Plant ID	Unit ID	Unit Name	Primary Fuel	State	County	Latitude	Longitud	Peak Gross Generation, Post-EERE (MW)	Annual Gross Generation, Post-EERE (MWh)	Capacity Factor (Calculated, Post-EERE) (%)	Annual Displaced Generation (MWh
1915	1	Allen S King 1	Coal	MN	Washington	45.03	-92.78	499	2,697,213	62%	-24,931
55867	BLR-1	Benson Power Biomass Plant BLR-1	Coal	MN	Swift	45.30	-95.56	44	173,292	45%	554
1893	1	Boswell Energy Center 1	Coal	MN	Itasca	47.26	-93.65	59	438,749	85%	-2,288
1893	2	Boswell Energy Center 2	Coal	MN	Itasca	47.26	-93.65	55	401,679	83%	-2,283
1893	3	Boswell Energy Center 3	Coal	MN	Itasca	47.26	-93.65	350	2,273,221	74%	-13,292
1893	4	Boswell Energy Center 4	Coal	MN	Itasca	47.26	-93.65	561	4,089,621	83%	-22,725
1943	2	Hoot Lake 2	Coal	MN	Otter Tail	46.29	-96.04	47	215,080	52%	-3,128
1943	3	Hoot Lake 3	Coal	MN	Otter Tail	46.29	-96.04	67	297,248	51%	-5,372
10849	PB1	Northshore Mining Silver Bay Power PB1	Coal	MN	Lake	47.29	-91.26	35	250,479	83%	1,056
10849	PB2	Northshore Mining Silver Bay Power PB2	Coal	MN	Lake	47.29	-91.26	41	127,849	36%	-1,624
6090	1	Sherburne County 1	Coal	MN	Sherburne	45.38	-93.90	592	2,805,884	54%	-45,180
6090	2	Sherburne County 2	Coal	MN	Sherburne	45.38	-93.90	665	4,313,585	74%	-33,392
6090	3	Sherburne County 3	Coal	MN	Sherburne	45.38	-93.90	839	5,042,381	69%	-48,166
1904	5	Black Dog 5	Gas	MN	Dakota	44.81	-93.25	264	773,073	34%	-21,377
1904	6	Black Dog 6	Gas	MN	Dakota	44.81	-93.25	208	169,048	9%	-11,749
8027	7	Blue Lake Generating Plant 7	Gas	MN	Scott	44.79	-93.43	129	45,362	4%	-3,993
8027	8	Blue Lake Generating Plant 8	Gas	MN	Scott	44.79	-93.43	138	63,057	5%	-3,945
2038	2	Cambridge Station 2	Gas	MN	Isanti	45.60	-93.21	110	57,795	6%	-4,277
56241	CT-01	Cannon Falls Energy Center CT-01	Gas	MN	Goodhue	44.54	-92.91	120	58,652	6%	-4,404
56241	CT-02	Cannon Falls Energy Center CT-02	Gas	MN	Goodhue	44.54	-92.91	119	51,362	5%	-4,154
6058	CT2	Cascade Creek CT2	Gas	MN	Olmsted	44.03	-92.49	22	13,778	7%	-928
6058	CT3	Cascade Creek CT3	Gas	MN	Olmsted	44.03	-92.49	22	14,198	8%	-924
55010	1	Cottage Grove Cogeneration 01	Gas	MN	Washington	44.80	-92.91	252	242,745	11%	-13,201
2039	ERPS11	Elk River ERPS11	Gas	MN	Sherburne	45.30	-93.55	108	36,412	4%	-3,534
56164	EU006	Faribault Energy Park EU006	Gas	MN	Rice	44.34	-93.29	252	645,877	29%	-26,577
1912	7	High Bridge 7	Gas	MN	Ramsey	44.93	-93.11	266	1,230,280	53%	-24,810

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ENDNOTES

1. Minnesota Public Utilities Commission's January 3, 2018, Order in Docket No. E-999/CI-14-643.
2. Xcel Energy presented the natural gas price forecast in Docket No. E-002/PA-18-702. The selection of these values in this study does not indicate an endorsement by UCS as these values being the appropriate values to use; rather, they were selected to make our analysis as comparable as possible to the utility's assumptions.
3. Because this study is not a full cost-benefit analysis and is intended only to provide guidance on how to improve one of the calculations used as an input for that type of analysis, it focuses on only a subset of the benefits that efficiency can provide (avoided energy and avoided emissions). Energy efficiency programs, of course, help utilities avoid more than just energy and emissions costs. Efficiency programs help utilities avoid the need to procure capacity, build transmission lines, or incur various other costs. All other benefits of energy efficiency must be included when conducting a cost-benefit screening to determine the levels of energy efficiency that are cost effective. Those screening tests should also include appropriate costs, which this study also does not attempt to monetize.
4. This analysis leveraged data and data aggregation services provided by S&P Global Market Intelligence; however, all the data inputs can be calculated using publicly available data sources.
5. Including, but not limited to, avoided capacity and transmission and distribution costs, wholesale price suppression effects, avoided costs of complying with the renewable portfolio standard, reduced risk, and other benefits. See Table 3 in Malone, Woolf, and Goldberg 2018.
6. In 1983, the first Conservation Improvement Program legislation was passed, requiring utilities with annual revenues of more than $50 million to operate an energy conservation program. In 1989, that requirement was expanded to all investor-owned utilities. See CEE, Optimal Energy, and Seventh Wave (2018).
7. Minn. Stat. § 216B.2401.
8. Minn. Stat. § 216B.241.
9. 1993 Minn. Laws, ch. 356, § 3 (codified at Minn. Stat. § 216B.2422, subd. 3).
10. January 3, 2018, Order in Docket No. E-999/CI-14-643, Page 6.
11. Minn. Stat. § 216H.02, subd. 1.
12. January 3, 2018, Order in Docket No. E-999/CI-14-643, Page 9.
13. January 3, 2018, Order in Docket No. E-999/CI-14-643, Page 6.
14. January 3, 2018, Order in Docket No. E-999/CI-14-643, Page 57.
15. January 3, 2018, Order in Docket No. E-999/CI-14-643, Page 58.
16. See Minnesota Department of Commerce Decision, In the Matter of Gas Utility BENCOST Inputs, Docket No. G999/CIP 18-782 (May 20, 2019).
17. The Minnesota Department of Commerce issued a decision on May 20, 2019, in Docket No. G999/CIP-18-782 in the Matter of 2020–2022 Gas Utility BENCOST Inputs.
18. Approved: UPPCO (Michigan Public Service Commission, Case No. U-18094), Entergy (Louisiana Public Service Commission, Docket No. U-32148), Entergy (Mississippi Public Service Commission, Docket No. 2016-UN-32). Proposed: Xcel Energy (Colorado Public Utilities Commission, Proceeding No. 17A-0462EG). This list is not comprehensive.
19. At the time of this writing, the Minnesota PUC has an investigatory docket open on self-committing (Docket No. 19-704). Xcel Energy also received approval from the Minnesota PUC on May 21, 2020, on the company's petition to operate the Allen S. King Generating Station and Unit 2 of the Sherburne County Generating Station on a seasonal basis (Docket No. 19-809).
20. Or amounts of other resource if the avoided cost is being calculated for rooftop solar or the Public

Utilities Regulatory Policies Act.

21. Daniel, J. August 21, 2019, testimony on DTE Electric Company's Integrated Resource Plan (IRP) presented to the Michigan Public Service Commission (Case No. U-20471).
22. Authors' calculation of data retrieved from Table 6.5 of Energy Information Administration Electric Power Monthly Data for January 2020 (release date: March 24, 2020), https://www.eia.gov/electricity/monthly.
23. Including fuel and variable operations and maintenance data. This analysis does use data procured through a subscription to S&P Global Market Intelligence; however, all those data could be supplied by alternative suppliers or obtained from publicly available data sources.
24. The Allen S. King and Sherburne County (Sherco) plants are owned by Xcel Energy, Hoot Lake by Otter Tail, and Clay Boswell by Allete, Inc. doing business as Minnesota Power (in 2019, two units at the Boswell plant retired). Minnesota also imports coal-generated electricity from North Dakota via a high-voltage direct current transmission line, but for purposes of this analytical option we examined only coal plants located in Minnesota.
25. Nameplate capacity is the maximum rated output, typically expressed in MW, of a power plant unit under specific conditions selected by the manufacturer.
26. Economic minimum (also known as "min cap" or "p-min") is the minimum level at which a power plant can be operated under non-emergency conditions. For fossil steam plants, this might be assumed to be 50 percent of nameplate capacity but can vary greatly, with most (although not all) coal-fired plants having a p-min/min-cap of 40 to 60 percent of nameplate.
27. AVERT is available in both an Excel-based and a web-based version. This analysis relied on the Excel-based version which allows users access to more back-end data.
28. We calculate line losses exogenously because it is unknown whether Xcel Energy or other utilities include line losses in their avoided energy values or include them as a separate line item benefit; additionally, it is not known what line loss values utilities use. Calculating line losses exogenously allows for reporting with and without line losses, making for an easier comparison of this analysis to other sources.
29. Displaced generation that could not be matched was backed out of the calculation during the normalization step.
30. Xcel Energy's gas price forecast was provided in nominal dollars and is developed by a third party (Ventura) without an explicitly assumed inflation rate. To convert Xcel Energy's nominal values into constant dollars, this analysis used a 2 percent annual inflation rate, based on guidance received from representatives of Xcel Energy. Our use of Xcel Energy's forecast is solely to maintain consistency and should not be misconstrued as a position affirming the reasonableness of those gas prices.
31. Our use of these externality cost values and CO2 compliance costs is solely to maintain consistency and should not be misconstrued as a position affirming the reasonableness of those values and cost figures.
32. The Minnesota Department of Commerce issued a decision on May 20, 2019, in Docket No. G999/CIP-18-782 in the Matter of 2020–2022 Gas Utility BENCOST Inputs. The value in the order was calculated to be $25.76 in US$(2015). All values in this report have been converted to US$(2018) unless otherwise noted.
33. See Xcel Energy, Attachment F (Figure 1) of Petition for Approval of the Acquisition of the Mankato Energy Center (MEC), Docket No. IP6949, E002/PA-18-702.
34. The Minnesota Department of Commerce issued a decision on May 20, 2019, in Docket No. G999/CIP-18-782 in the Matter of 2020–2022 Gas Utility BENCOST Inputs. The values in the order were calculated in US$(2015); all values in this report have been converted to US$(2018) unless otherwise noted.
35. It is also possible that gas plants would need to be retrofitted with carbon capture and storage technology in a fully decarbonized electricity sector; retrofits in carbon capture and storage are expected to increase the heat rate of gas plants. See, for example, EIA (2020a).
36. The societal discount rate was calculated using the Department of the Treasury's 20-year constant maturity (CMT) rate, which averaged 3.02 percent from January 2 to December 31, 2018. The

Minnesota Department of Commerce concluded that "[t]he Treasury's 20-year Daily CMT Rate captures the market's expectations regarding inflation, along with a small risk factor." In the Matter of Greater Minnesota Gas, Inc.'s 2017-2019 Natural Gas Conservation Improvement Program Plan, Docket No. G022/CIP-16-118 (Nov. 3, 2016). However, our analysis excludes all inflation, so using an inflated discount rate would not make sense. The 7 percent WACC value was derived by the Minnesota Department of Commerce based on an average of utility WACCs.

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