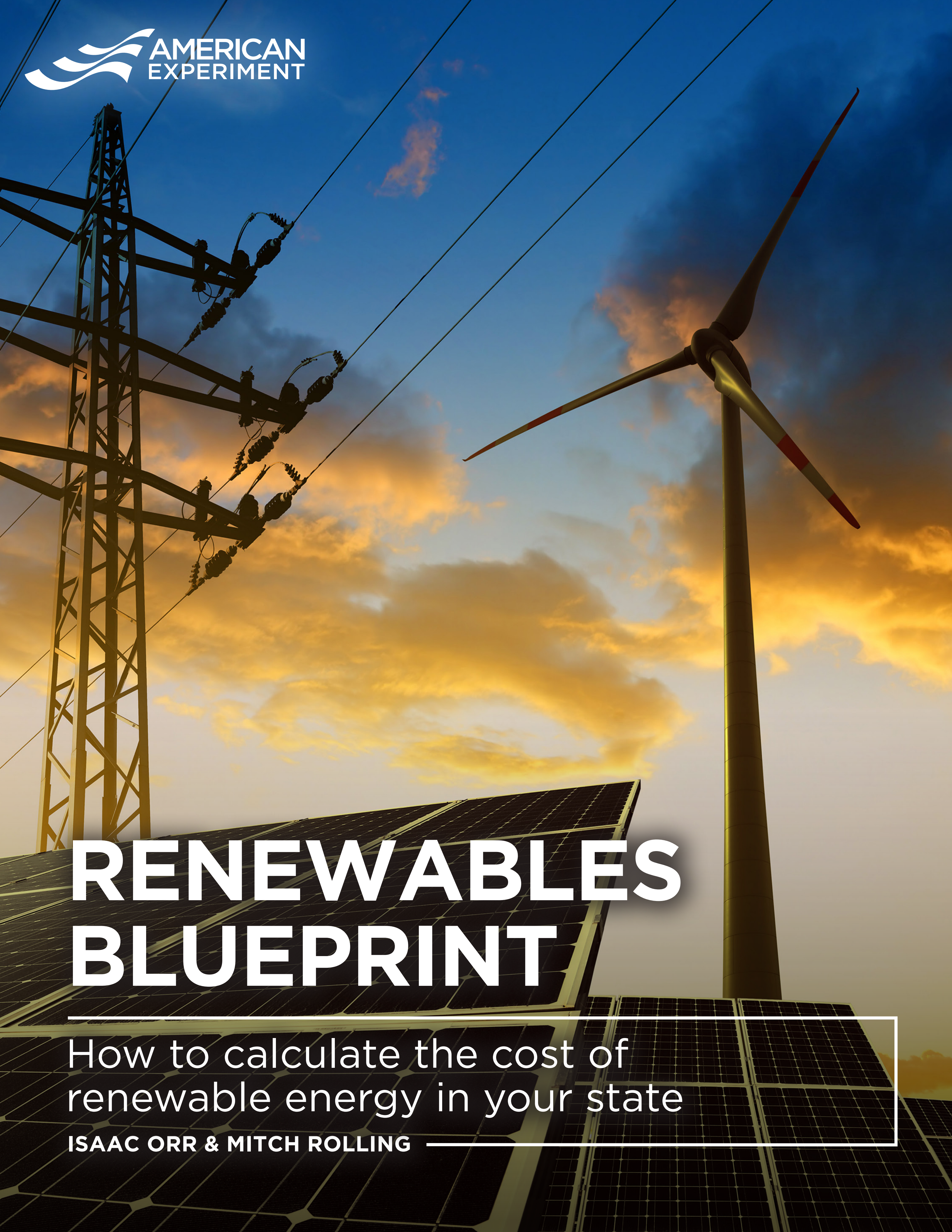

AMERICAN EXPERIMENT

RENEWABLES BLUEPRINT

How to calculate the cost of renewable energy in your state

ISAAC ORR & MITCH ROLLING

Isaac Orr is a policy fellow at Center of the American Experiment, where he writes about energy and environmental issues.

Isaac has written extensively on hydraulic fracturing, frac sand mining and electricity policy, among other energy and environmental issues. His writings have appeared in *The Wall Street Journal*, *USA Today*, the *New York Post*, *The Hill*, *Orange County Register*, *The Washington Times*, and many other publications.

Mitch Rolling is a policy analyst at Center of the American Experiment, assisting policy fellows on projects ranging from energy issues to education. He graduated from the University of Minnesota with degrees in history and Jewish studies, gaining nationwide coverage for his reporting on college campus issues.

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8421 Wayzata Boulevard ★ Suite 110 ★ Golden Valley, MN 55426

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Renewables Blueprint

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Introduction

As the Green New Deal and ever-increasing mandates for wind and solar in California, Colorado, Minnesota, New Mexico, New York, Washington and other states propose to completely transform the American electricity sector, and thus the entire American economy, it has never been more important to have accurate and transparent information regarding the cost of renewable energy.

Government-approved monopoly utilities are also increasingly seeking to retire reliable, affordable sources of electricity like coal and nuclear plants in favor of building wind, solar and natural gas, at a huge expense to American families and businesses.

Government-approved monopoly utilities are seeking to retire reliable, affordable sources of electricity like coal and nuclear plants in favor of building wind, solar, and natural gas, at a huge expense to American families and businesses.

Unfortunately, most literature examining the cost of renewable energy is at best incomplete, and at worst intentionally misleading. This report will teach readers about the basic factors that influence the cost of electricity, and then serve as a step-by-step blueprint for calculating the cost of different energy sources in their own states. It also allows readers to evaluate the cost impacts of resource plans proposed by monopoly utilities on different rate classes, such as residential, commercial and industrial customers.

This blueprint leans heavily on Center of the American Experiment's 2019 report, "Doubling Down on Failure: How a 50 Percent by 2030 Renewable Energy Standard Would Cost Minnesota $80.2 Billion."[1] We encourage you to read our report to get a feel for how your study may read, and even to copy/paste sections of Doubling Down while changing portions of it when necessary to make them applicable to your state.

We compare the cost of renewable energy with three other potential energy scenarios: a Short-Term Nuclear, Long-Term Nuclear and an Affordable Clean Energy (ACE) scenario, which is the Trump Administration's replacement for the Clean Power Plan. We encourage you to use the spreadsheets we have provided not only to calculate the cost of renewable energy in your state, but to offer better alternatives in the form of nuclear power and continued use of coal-fired power plants.

Part 1 of this blueprint is energy policy theory, which acts as an "Energy 101" course explaining much of the theory behind the cost of generating electricity. It identifies the basic tools used by various organizations throughout the country to estimate the cost of electricity.

This section begins with the terms used in the industry and provides an explanation of the very basic concepts of electricity — the units that are used to measure electricity — and discusses how electricity must be generated at the exact moment it is consumed.

After the basics are covered, the guide discusses the concepts you'll need to know to calculate the true cost of renewable energy in your state. These concepts include: Levelized Cost of Energy (LCOE) estimates, capacity factors, useful lifespans of power plants, why some LCOE estimates are different than others (namely Lazard and the U.S. Energy Information Administration), overbuilding, idle capacity, and how the fixed costs for power plants influence electricity prices.

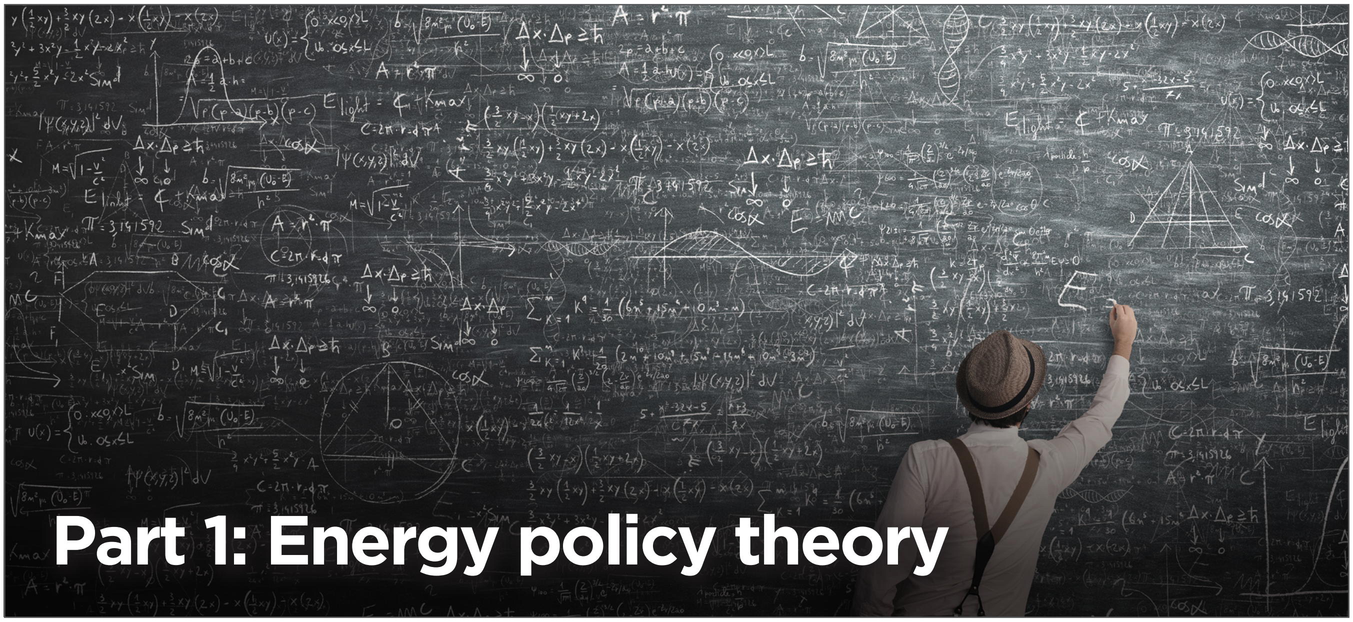
The blueprint also discusses how factors such as overbuilding, transmission expenses, property taxes, depreciation and utility profits significantly increase the cost of incorporating renewable energy sources to the grid, even though these additional expenses are seldom discussed by renewable energy advocates.

Part 2, Calculating Generation Costs, explains how to use the Microsoft Excel spreadsheets that accompany this report. The spreadsheets are optimized to reduce the amount of work you will have to do on the number-crunching side.

Part 3, Key Takeaways From the Report, discusses some of the more essential topics to take from the report. Mainly, it discusses why renewable energy mandates are so costly, such as the need to overbuild the grid, the existence of large amounts of idle capacity, and why fuel savings do not provide enough cost savings to offset the expenses resulting from renewable energy mandates.

Part 4, Humanizing the Rising Cost of Electricty, gives examples of how you can humanize the rising cost of electricity in your state. Cost estimates are best able to influence public policy if they are presented in a way that reflects the human cost of higher energy prices. This section gives suggested talking points and borrows heavily from Section II in American Experiment's "Doubling Down on Failure: How a 50 Percent by 2030 Renewable Energy Standard Would Cost Minnesota $80.2 Billion."

Limitations: Like all models, ours has limitations. According to the regional grid operator in the Midwest, the Midcontinent Independent Systems Operator (MISO), it becomes exponentially more difficult to incorporate wind and solar after a 30 percent market penetration.[2] As a result, we caution readers against using our renewable model to calculate the cost of renewable energy beyond a 50 percent wind and solar energy mandate in their state. ■



Part 1: Energy policy theory

A. Terminology to Know Before Reading

To understand the content of this report, it is extremely helpful to understand the basic terminology and ideas that are used within it. This section details some of the most frequently used terms and ideas that are important to understand for proper use of the models. It is designed to be a dictionary of sorts for you to reference while putting the models to use for your own state or region.

This section can probably feel a little intimidating for people who are new to the energy space, so you may want to take a moment to look over the contents now, and then come back to this section when you are reading the rest of the report so you can get a feel for how these terms are used in context.

i. **Power vs Energy:** These are terms that are often interchanged but represent two different things. Power is the rate at which "work" can be produced per unit of time, and energy is the total quantity of work over the course of any given time period. In our case, "work" is the electricity produced by electrical generating power plants. The power rating of a generator facility is represented by its capacity (see capacity), and energy is represented by the total generation it produces (see generation).

ii. **Capacity:** Capacity represents the maximum power output of an electric generating facility. As the Department of Energy explains, "Capacity is the amount of electricity a generator can produce when it's running full blast."[3] It is commonly referred to as "nameplate capacity" and is typically expressed in units of power such as megawatts (MW) for large plants or kilowatts (KW) for smaller plants. The capacity of a power plant represents the maximum rate at which it can produce energy over one hour. For example, a 100 MW capacity power plant can potentially produce 100 megawatt-hours (MWh) (see generation) in one hour if it were running at full capacity. In 24 hours, this same plant can potentially produce 2,400 MWh. To find the potential generation from any particular power plant over the course of any timeframe, simply multiply the capacity of the plant by the number of hours in the timeframe (i.e., 8,760 for one year).

Potential Generation = Capacity x Hours

iii. **Generation:** The total electricity output from a power facility over a given timeframe, typically expressed in units of energy such as megawatt-hours (MWh) or kilowatt-hours (KWh).

iv. **Capacity Factor:** This metric is a proxy for how often a power plant runs at full efficiency. It is expressed as a percentage measuring how much of the maximum capacity of a generator facility was used to generate electricity throughout a given timeframe. For example, if a 100 MW power plant produced 50 MWh of electricity over one hour, the capacity factor would be 50 percent. To find the capacity factor, simply divide the total electricity generation it produced over a given timeframe by the potential generation it could have produced — based on the nameplate capacity of the facility — over the same timeframe.

Capacity Factor = Total Generation / Potential Generation

v. **Capacity Value:** The amount of reliable capacity expressed in percentages that each grid operator and/or utility assigns to an energy source and/or power facility. This term can be expressed with many other terms — such as accredited capacity, effective load carrying capability (ELCC), net dependable capacity, etc. For example, the grid operator for Minnesota, the Midcontinent Independent System Operator (MISO), accredits a 16.6 percent capacity value (which they label as the ELCC) to wind farms.[4] This means that out of 100 MW of wind capacity on the grid, MISO counts 16.6 MW as reliable for planning purposes.

vi. **Dispatchable Power:** Power sources that can adjust their electricity output based on demand. Energy sources such as coal, natural gas, nuclear, biomass and other fuel-based power sources are considered dispatchable power because the amount of power that these facilities generate can be turned up or down so the supply of electricity matches demand.

vii. **Non-Dispatchable Power:** Power sources that are "intermittent" and generate electricity based on the weather or natural resources and cannot produce more or less electricity based on demand. Energy sources such as wind, solar and some hydro-electric are considered non-dispatchable.

viii. **Baseload Power:** Power sources that are traditionally relied upon to produce large amounts of electricity to support the "base" of electricity demand, while other energy sources "ramp up or down," increase or decrease, to match electricity demand (electricity demand is often referred to as the "load," hence "baseload"). Baseload Power sources typically include coal, nuclear and natural gas combined cycle facilities.

ix. **Intermittent Power:** Power sources that cannot be relied upon to produce large amounts of electricity consistently to support the bulk of demand due to relying on the weather to produce electricity, unlike fuel-based energy sources. Intermittent Power sources include wind and solar facilities.

x. **Ramping:** When power facilities must produce more or less electricity (i.e., it ramps up or down) to match load or to make room for other energy sources. Ramping adds extra maintenance costs to power facilities due to increased wear and tear — imagine what happens to a car engine when you repeatedly accelerate and stop, as opposed to driving continually at a certain speed. Traditionally, ramping facilities were natural gas combustion turbine (CT) and combined cycle (CC) facilities, which are more equipped for ramping purposes. However, in the era of renewable energy, many coal facilities are being forced to become ramping sources, as well as nuclear plants, both of which they are not designed to do, and ramping adds tremendous cost to their upkeep.

xi. **Renewable Power:** Energy sources that rely on "renewable" sources of power such as the wind, sun, water or reusable fuel.

xii. **Carbon-Free Power:** Power sources that do not emit CO^2 when producing electricity. Energy sources such as wind, solar, nuclear, hydro, biomass and others are considered carbon-free sources.

xiii. **Idle Capacity:** Capacity that is connected to the grid and maintained at the expense of ratepayers but isn't being used to generate electricity. Increasing renewable energy on an electrical grid inherently increases the amount of idle capacity on the grid. If renewable sources are generating electricity, fuel-based sources sit idle. If the wind isn't blowing and sun isn't shining, renewable sources sit idle.

xiv. **Common Energy Sources:**

a. **Coal** — coal-fired power plants; baseload power; dispatchable power; fuel-based power.

b. **Natural Gas Combined Cycle (CC)** — baseload power; dispatchable power; fuel-based power.

c. **Natural Gas Combustion Turbine (CT)** — baseload power; dispatchable power; fuel-based power; commonly referred to as "peaker" plants due to them often being used to ramp up and down to match electricity demand.

d. **Nuclear** — baseload power; dispatchable power; fuel-based power; carbon-free power.

e. **Hydro** — can be baseload or intermittent power; renewable power and carbon-free power.

f. **Wind** — intermittent power, non-dispatchable power; renewable power and carbon-free power.

g. **Utility Solar** — solar owned and operated by utility companies; intermittent power; non-dispatchable power; renewable power.

h. **Community Solar** — solar owned and operated by community or single-operators who are paid by utility companies for the energy produced and sent into the market; intermittent power; non-dispatchable power; renewable and carbon-free power.

i. **Biomass** — baseload power; dispatchable power; fuel-based power; renewable and carbon-free power.

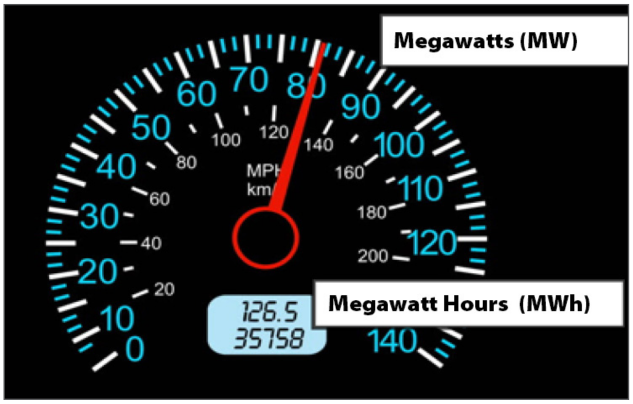
B. What's a Kilowatt and Kilowatt Hour, or Megawatt and Megawatt Hour?

Many people, energy professionals included, don't fully understand the difference between a kilowatt (KW) and kilowatt-hour (KWh) and megawatt (MW) and megawatt-hour (MWh). Understanding these basic concepts is critical if you want to be able to calculate the cost of renewable energy in your state.

The difference between a watt and a watt-hour is the difference between power and energy.

A kilowatt (KW) and megawatt (MW) are units of electric power that represent the rate at which a power plant can generate electricity. For example, KW and MW are units used to represent the capacity of power facilities, which are expressed in the amount of potential power each power plant has over a one-hour time period.

A kilowatt-hour (KWh) and megawatt-hour (MWh), on the other hand, are volumetric mea-



MEGAWATT RATINGS INDICATE HOW MUCH ELECTRICITY A POWER PLANT CAN GENERATE WHEN OPERATING AT FULL CAPACITY. MEGAWATT HOURS ARE A VOLUMETRIC MEASUREMENT OF HOW MANY MEGAWATTS HAVE BEEN GENERATED FOR A ONE-HOUR TIME PERIOD.

surements, like a gallon of gasoline or a barrel of oil, which measure the total electric output of a power plant over a given timeframe. For example, a 100 MW (capacity) power plant can produce 100 MWh in one hour if it produced its maximum potential.

In this way, a KW or MW is like the speedometer on a car, which tells you the speed — or the rate per hour of which car is moving — at any given moment, and a KWh or MWh is like the odometer, which is a measurement of the distance driven, or in this case, the number of megawatts that have been generated over the course of a 60-minute interval.[5]

Megawatt ratings indicate how much electricity a power plant can generate when operating at full capacity, megawatt hours are a volumetric measurement of how many megawatts have been generated for a one-hour time period.

The electricity you use in your home is measured in KWh, whereas power plants measure their output in MWh. There are 1,000 KWh in one MWh. This means if you used 748 KWh of electricity a given month, your electricity consumption would be 0.748 MWh of electricity.

1 MW= 1,000 KW
1 KW = 0.001 MW
1 MWh =1,000 KWh
1 KWh = .001 KWh

C. Electricity Cannot Be Stored. It Must Be Used the Second it is Generated.

Perhaps the biggest roadblock to educating people about how wind and solar increase electricity costs is the general public's lack of understanding about electricity, more generally.

Many people, probably most, do not know that electricity cannot easily be stored; it must be consumed at the second it is generated. Think of what happens to a lamp when you unplug it from the wall; the light instantly goes out. This loss of electricity demand by unplugging the outlet is matched instantaneously by the electrical grid, which forces a power facility to lower electricity production.

Unfortunately, many people think of the grid as a device that stores electricity for later use, like a giant bathtub that fills with power that can be accessed when needed at a later time. This misconception leads people to believe that wind and solar can increase the availability of electricity on the grid and improve reliability.

The reality is much more complicated than that. The supply and demand for electricity must be perfectly matched at all times, down to the second. If there is too little power on the grid, blackouts ensue. If there is too much, the transmission systems overload and the grid can be damaged.[6]

Wind and solar are known as "non-dispatchable" energy sources, meaning that they can only generate power when the wind is blowing or the sun is shining. This means their energy output cannot be turned up or down, or "ramped" up or down, to make sure that electricity supply matches demand.

As such, the grid must rely on "dispatchable" energy sources, like natural gas, coal and nuclear, that are able to ramp up and down production to meet electricity demand. During very sunny or windy periods, coal and natural gas plants must reduce their electricity output to keep the grid balanced. When it is not windy or sunny, the grid relies upon natural gas and coal plants to increase their electricity production to make sure the lights stay on.

The intermittent, weather-dependent nature of wind and solar production, along with the difficulties of predicting the amount of power they will generate on a minute-to-minute basis, make the electricity balancing act more difficult to navigate, as well as more costly.

Many renewable energy advocates call for large-scale deployment of battery storage technology to store the energy generated by wind and solar facilities for later use. However, research from the Massachusetts Institute of Technology (MIT) shows that battery storage is far too expensive to play a major role in providing around-the-clock energy for the grid, even after assuming large declines in the cost of battery storage technologies.[7]

Xcel Energy, one of the largest utility companies in the country, also notes that "current battery storage systems are limited (typically to 4-hour discharge periods) with significant time needed to recharge. Unless overbuilt many times over, these resources would not be able to provide energy for the full duration of [events where wind and solar are unavailable for extended periods of time]; they also may not be able to recharge fast enough to be a viable resource during the consecutive periods of low renewable output."[8]

For these reasons, our models do not take battery storage costs into account.

However, in Sheet xbatterystoragecalculator, we give you the ability to estimate the cost of one day's worth of battery storage in your state based on recent cost estimates for battery storage technology.[9] This calculates the amount of battery storage needed to provide 24 hours of electricity in the event that no wind or solar installations were able to produce electricity.

In Minnesota, we found just 24 hours of battery storage would cost nearly $50 billion, which would alone increase the cost of electricity for each Minnesota household by $310 per year, for 20 years![10]

However, 24 hours will not be nearly enough storage for a 100 percent renewable grid. Experts believe weeks, or even months, of battery storage would be needed to reach 100 percent renewable or carbon-free goals. At this point, the cost of batteries would dwarf the cost of the entire energy system.

D. What Affects the Cost of Electricity?

Total electricity costs are affected by four main components: generation, transmission, taxes and utility profits. Each is described in this section. Renewable energy sources have a unique component of load balancing costs that we will also discuss in detail. Readers will likely be most familiar with the cost of generation — or LCOE values — but transmission expenses, property taxes and utility profits constitute a significant portion of the total cost of the electricity system.

Generation costs:

Generation costs represent the cost of building, operating, and maintaining a power facility over the course of its useful life. These expenses are calculated using a measurement known as the Levelized Cost of Energy (LCOE). We will explain LCOE values in greater detail in Section 2 and teach you how to tailor the results of your study to reflect the specific conditions in your state.

Generation costs in the renewable model also account for the need of "backup generation" from coal and natural gas power plants through higher LCOE values. Because wind and solar energy sources may be producing zero electricity, there must be enough backup energy facilities on the grid to produce electricity in the case that there is no renewable generation. This ensures that the system remains balanced and electricity service is not interrupted due to a lack of wind and solar generation.

However, these backup facilities must ramp down production, on average, to make room for higher penetrations of renewable energy. As a result, these facilities have higher LCOE values due to their "fixed costs" — or expenses that are the same no matter how much electricity is produced — being spread over fewer MWh of generation.

Load balancing costs (Renewable Only):

Load balancing costs for renewable energy sources arise from the need to build additional dispatchable power sources like natural gas when retiring coal, nuclear, or hydro plants to satisfy renewable energy mandates.

Due to wind and solar energy sources not being able to meet electricity demand on their own, reliable energy sources are needed when renewables aren't producing any electricity. The models in this report assume that natural gas will be used as this energy source. The extra costs associated with building backup energy sources — consisting of the generation, property tax, and utility profit expenses of these plants — are referred to as the cost of "load balancing" for renewable energy sources.

Total electricity costs are affected by four main components: generation, transmission, taxes and utility profits.

Within the renewable model, load balancing costs are accounted for by the building of natural gas power plants necessary to maintain reliability when replacing coal, nuclear or hydro energy sources with that of wind and solar. While the costs associated with new natural gas facilities are not the only costs associated with load balancing — which includes the cost of ramping, among others — these are the largest expenses and the most easily quantifiable.

We assume natural gas plants will be used for load balancing because they are the most capable of ramping up and down to meet demand, and they have historically been built by utility companies that shut down coal facilities and nuclear plants in the name of satisfying renewable mandates. This is why Xcel Energy, which is one of the most aggressive utilities seeking to build wind and solar, plans to build so many new natural gas plants along with wind and solar facilities in Minnesota.

For example, in Xcel Energy's latest integrated resource plan (IRP), it shows that the company plans to build 3,500 MW of new wind, over 4,600 MW of new solar, and over 3,450 MW of new natural gas energy sources to compensate for the closure of 4,342 MW of coal and natural gas capacity. This totals more than 11,500 MW of wind, solar, and natural gas to replace 4,300 MW of retiring coal and natural gas; a 2.65:1 replacement.[11]

Most importantly, Xcel's IRP and those of many other utility companies reflect the same trend: The retiring of coal-fired power plants is met not only with new wind and solar facilities, but natural gas facilities as well.

Because new natural gas facilities are built solely to accommodate new renewable energy sources in the absence of coal facilities, the costs associated with these facilities are attributed to the levelized cost of wind and solar energy as the "Levelized Load Balancing" factor.

The renewable model does this because it is designed to convey, better than any other model, the true "all-in" cost of satisfying renewable energy mandates. The all-in cost of renewable energy mandates must account for the need for backup energy when used to compare the cost of replacing coal-fired, nuclear, or hydro power plants. In other words, if backup energy is needed to replace coal, nuclear, or hydro energy sources with renewables, then the cost of the backup energy must be considered — not just the cost of the renewables.

Our model allocates this additional cost to wind and solar generators in the "Results" tab.

Xcel Energy described the necessity for load balancing in its IRP by stressing the need for dispatchable energy sources like natural gas no matter how much renewable capacity is online at the time.

On Feb. 5, 2019, Xcel notes that "between 7:00

TABLE 1

Hourly Wind and Solar Capacity Factors

Feb. 5, 2019

Hour Ending	Wind Capacity Factor	Solar Capacity Factor
1	9%	0%
2	9%	0%
3	6%	0%
4	5%	0%
5	7%	0%
6	6%	0%
7	7%	0%
8	4%	0%
9	3%	0%
10	3%	3%
11	2%	6%
12	3%	6%
13	3%	5%
14	7%	5%
15	12%	4%
16	13%	2%
17	11%	1%
18	11%	0%
19	9%	0%
20	6%	0%
21	5%	0%
22	4%	0%
23	3%	0%
24	4%	0%

SOURCE: SEE ENDNOTE 8

a.m. and 11:00 p.m., there were 16 consecutive hours where…all wind and solar resources on the system combined to have an average hourly capacity factor of six percent, and there were particular hours when neither wind nor solar resources had a capacity factor greater than three percent.

We provide the hourly capacity factors for wind and solar resources [to the right]. **Because we currently have access to sufficient baseload and firm dispatchable resources on our system [i.e., coal, natural gas, nuclear and hydro], we were able to serve customers reliably and affordably throughout the duration of this period."**

Notice how Xcel explains that because it had enough fuel-based "dispatchable" resources, the system was able to maintain reliability. Without reliable energy sources on the grid to support, or backup, renewable energy, Xcel's customers would have lost power.

Xcel went on to say, "Simply increasing the amount of solar and wind generation on the Company's system is an unrealistic approach to addressing capacity shortfalls. In order to have sufficient capacity to meet the customer demand discussed in the scenarios above, the Company would need in excess of 180,000 MW of nameplate capacity wind and solar generation. And, even this amount of renewable generation may be insufficient given the declining capacity value of renewable generation… and the probability there will be times with extremely low levels of wind and sunlight."

Within the model, load balancing capacity can be divided between natural gas combined cycle (CC) and combustion turbine (CT) capacity. We have set percentages at 30/70 in favor of CT to start. However, each individual operator will have the option to decide this for themselves by changing these percentages in favor of one energy source or the other.

Transmission costs:

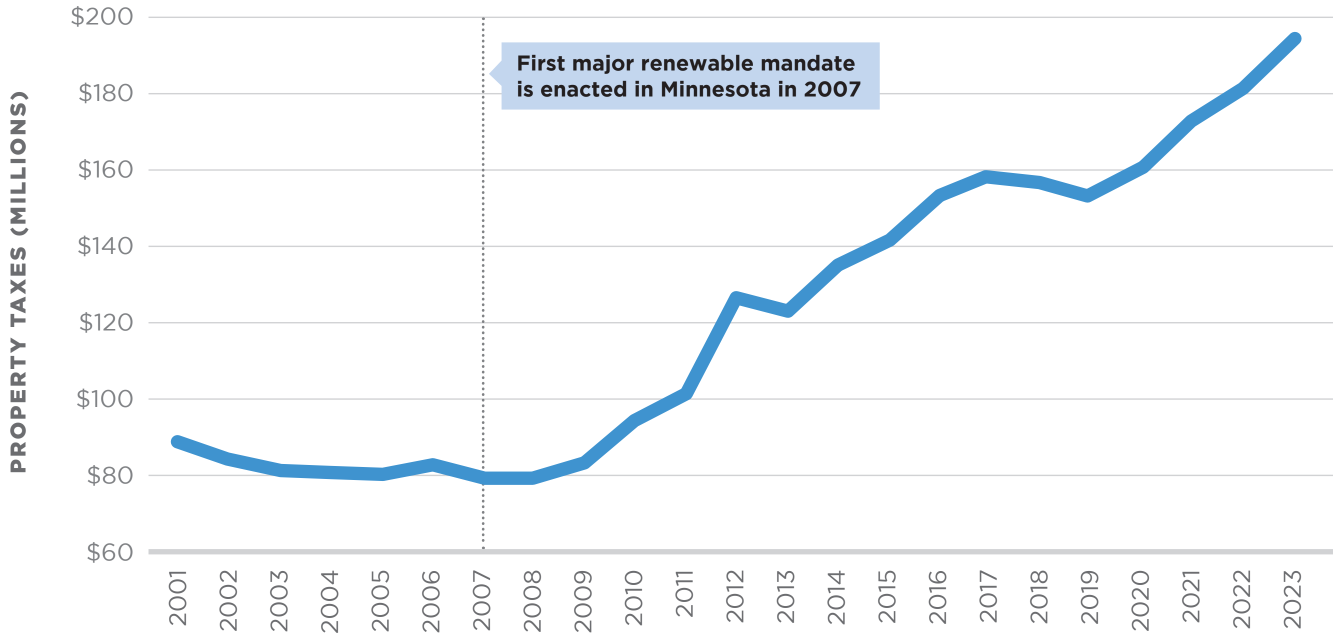
Transmission costs are important. It does no good to generate electricity if there are not enough poles and wires to transport it to the families and businesses who need it.

Transmission costs are seldom talked about, but that doesn't negate the fact that renewables require more transmission lines than traditional energy sources. Wind turbines, and to a lesser extent solar installations, are frequently built far away from the areas where the electricity will be

FIGURE 1

Xcel Energy Annual Property Tax Expense

Property taxes for Xcel Energy skyrocketed in Minnesota in the years following the passage of the state's 25 percent renewable energy mandate as additional wind turbines, solar panels, and transmission lines were built.



SOURCE: SEE ENDNOTE 12

used by customers. Additionally, current transmission systems, like the one in Minnesota, are built around large, dispatchable energy sources like coal and nuclear facilities and are designed to take-in large amounts of electricity at these points and distribute them to other areas.

Because of this, renewable energy "transitions" require a complete transformation of the transmission grid to accommodate electricity intake and distribution from a large number of distant renewable energy facilities. High-voltage transmission lines routinely cost $1 million per mile, and large transformations of the transmission grid often cost tens of billions of dollars — which will increase the cost of electricity for families and businesses.

In contrast, coal, nuclear and natural gas have lower transmission costs because they can be located closer to major population centers, and the current state of the transmission grid is typically designed to incorporate these sources more easily.

Because transmission costs are site-specific, you will need to decide how to best account for these costs. We offer two suggestions:

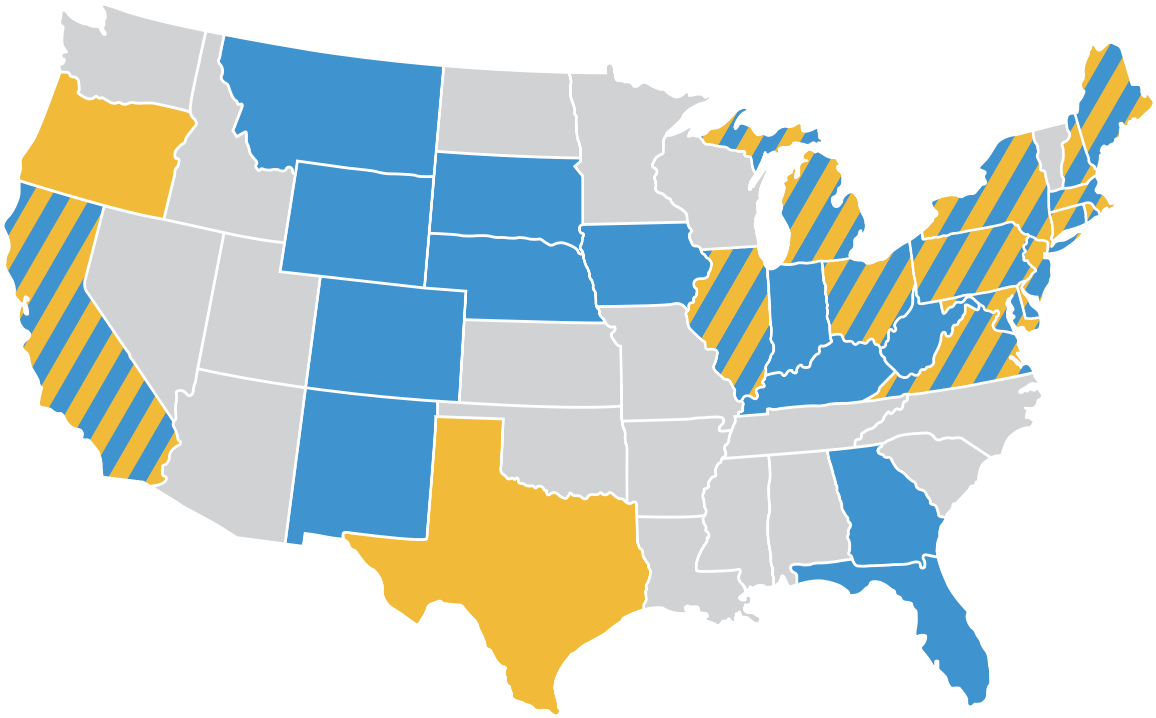
1. Look for recent cost estimates filed by utilities at your state utility regulatory agency. This will be more work but will yield the best result because the estimates are taken directly from the utilities currently operating in your state.
2. Use our numbers from Minnesota. This method can help give you a rough rule of thumb. In Minnesota, it cost $4 billion to meet our 25 percent renewable energy mandate, so we estimated it would cost a total of $8 billion to reach a 50 percent renewable energy mandate.

Property taxes:

FIGURE 2

Regulation of Markets for Electricity Generators

The figure shows regulated and deregulated markets for electricity generators as of 2018. Some states, like Michigan, are a mix of regulated and deregulated markets, so you will want to double check the status of utility regulation in your state.



Regulated Gas and Electricity Markets **Deregulated Gas Market** **Deregulated Electricty Market**
Deregulated Gas and Electricity Markets

SOURCE: SEE ENDNOTE 14

Property taxes are a cost of doing business for every type of power plant. However, due to significant overbuilding and the need for more transmission lines, transitioning to renewable energy uniquely increases property tax costs for utility companies — and thus ratepayers — because there is more property to tax.

For example, the largest electric utility in Minnesota, Xcel Energy, saw its property taxes increase exponentially as it built wind, solar and transmission facilities in the state to satisfy renewable energy mandates. From a low in 2007 of $79 million, property tax expenses are now up by more than 143 percent to $192 million projected in the year 2023.[12]

While property taxes assessed on power plants can help raise revenue for the communities where power plants are located, they effectively increase the cost of producing and providing electricity. These additional costs are paid by all electricity consumers in the form of higher electricity prices.

Our models allow you to calculate the additional costs imposed by increasing property taxes in your state. However, due to the state-specific nature of property taxes, you will need to find the property tax rate as a percentage of the rate base of the utility or state in question by looking at utility planning documents, and insert the property tax rate into the models.

Utility profits:

Many states have investor-owned utilities (IOUs), which are not private businesses but rather monopolies sanctioned by state governments. Many states prohibit the sale of electricity to the public by any business other than a utility, explicitly preventing competition and free markets.[13]

The map to the left shows "deregulated" states, which allow for competition in electricity generation.[14] If you live in a state that has deregulated electricity markets, utility profits will not play into your cost analysis. If you live in a regulated market, incorporating the cost of utility profits will help give a more holistic view of the true cost of renewable energy in your state because these profits are determined by the "rate of return" decided by your state utility commissions.

In regulated markets, monopoly utility companies are not allowed to make a profit based on how much electricity they sell. Instead, they operate under a "cost of service" business model in which the companies are guaranteed to make enough money to cover their operating expenses, plus a profit margin that is approved and guaranteed by government regulators, no matter how much electricity is sold to end consumers.

In this system, utility companies earn a guaranteed profit when they spend money on capital assets such as power plants, transmission lines, and even new corporate offices. The investments from these capital assets are added to the utility's "rate base," minus the accumulated depreciation of those assets, and the rate of return is then multiplied by this rate base every year to establish the profit the utility will make. This system often encourages utility companies to make unnecessary investments and spend as much as possible in order to increase their corporate profits — also known as the Averch-Johnson effect.

Due to significant overbuilding and the need for more transmission lines, transitioning to renewable energy uniquely increases property tax costs for utility companies — and thus ratepayers — because there is more property to tax.

These profits generally range from 6 to 12 percent on new capital expenditures. You will have to look through utility filings to your utility regulator, typically a Public Utilities Commission or a Public Service Commission, to see what the allowed profit, or rate of return, is in your state.

We encourage you to stop here and read the article titled "There is No Free Market for Electricity, Can There Ever Be?" by Travis Kavulla in the journal *American Affairs* for deeper insight on this topic.[15] You will want to understand the utility Revenue Requirement formula and how the Rate of Return is applied in it to better understand how our final utility profits are calculated.

A simplified version of the Revenue Requirement for utility companies is as follows:

Revenue Requirement = (Rate Base x Rate of Return) + Operating Expenses + Depreciation + Taxes

The (Rate Base x Rate of Return) is what determines the utility profits, and all other expenses are simply passed through directly to ratepayers. ■

Part 2: Calculating generation costs

While we encourage you to calculate generation costs using state-specific data for the models, you can also use our presets and automatic functions already pre-filled.

Note: If you are attempting to use the model to determine the cost of a renewable energy mandate, then we suggest you use the numbers that are automatically generated by the model. If you are using the model to calculate the cost of a specific resource plan proposed by a utility, we suggest you use the manual option. No matter which one you decide, however, there will be required inputs that need to be inserted in order for the model to function properly.

Almost all studies that examine the cost of renewable energy use a methodology called the Levelized Cost of Energy, or LCOE, to assess the cost of different energy technologies.

To get started calculating generation costs in the model, on the setup page of each model you will need to fill in the existing capacity and capacity factors for each energy source on the system you are studying, whether you are modeling your state or a particular utility company. If a state, you will find information on capacity and capacity factors on the EIA electricity profile on your state. (Within the link, click on your state and download the "Full Tables 1–16." Then, go to tab "4. Capacity" to find the capacity in your state and tab "15. Capacity Factors Annual" for capacity factors. For Natural Gas CT, include any natural gas energy source that is not combined cycle). If a utility, you can find this information in FERC Form 1 filings or utility submissions to your state's public utility commission (PUC) or public service commission (PSC). FERC Form 1 filings will be discussed in section B below.

Regardless of whether you are choosing to do manual inputs or relying on the model's automatic settings, you will need to insert the following on the setup page:

1. EVERY MODEL – What year you're beginning the model, which will act as the base year for calculating additional costs. The model will automatically calculate costs for 31 years after this year.
2. RENEWABLE MODEL – The capacity factor of new wind and solar energy sources. For example, in Minnesota, we would put 50 percent for wind and 17.7 percent for solar based on assumptions from utility companies in the state.

If you are relying on the automatic settings, you will also need to insert inputs for the following steps:

1. RENEWABLE AND NUCLEAR MODEL – The renewable energy target or the carbon-free target and by what year it needs to be achieved. The renewable energy target will likely be guided by proposed or enacted energy mandates in your state. For the nuclear model, try to insert the same carbon-free goals of renewable energy mandate (if they exist).
2. RENEWABLE MODEL – The percentage of wind vs. solar of the renewable energy target. This will largely depend on where your state is located, and which energy source is better for your region. If the percentages are left blank, it will default to 50-50.
3. RENEWABLE MODEL – If you are retiring coal, nuclear and/or hydro resources. You will have the option to retire as much of these resources as you like and determine by which year the amount of capacity you're retiring will be completed. If you choose to retire these resources, simply type either coal, nuclear or hydro in the spaces provided.
4. NUCLEAR AND ACE MODEL – If you are retiring existing wind and/or solar energy sources. Similar to the renewable model, you will be able to choose what percent of these sources you retire, as well as by what year.
5. NUCLEAR MODEL – If you are retiring coal, natural gas (CC), and/or natural gas (CT). While you have the option to retire all three energy sources, the model will limit how much natural gas capacity you can retire based on how much baseload and dispatchable capacity you have on the system. There is no limit to the amount of coal capacity you can retire.
6. RENEWABLE AND NUCLEAR – The amount of backup natural gas capacity that will come from combined cycle (CC) or combustion turbine (CT). These percentages are defaulted to 30-70 in favor of CT.

Note: Higher amounts coal, nuclear and hydro capacity retired in the renewable model will result in more backup natural gas being added to the system. This will inherently increase the costs of the model.

Next, capacity additions for all models can either be set automatically by the model itself based on the information you enter on the "Setup" tab, or you can insert additions manually by inserting "manual" in the space provided in the "Capacity" tab. If you wish to use the models' automatic setting, simply leave the space to write "manual" blank on the tab and proceed with the model.

In the "Expenses" tab, for every model and regardless of whether you're inserting manually or using the automatic settings, you will need to fill out capital cost assumptions for each new energy source provided at the top. These energy sources will differ based on which model you are using. We have prefilled these with generic cost assumptions, but you can find state and region-specific capital cost assumptions in the EIA Annual Energy Outlook (AEO). Look for your region on the map provided on page 1 and look for region-specific capital cost assumptions in Table 4 on page 7. For "wind repowering" capital costs, use the same capital cost as wind. Additionally, on the "Expenses" tab, look for the rate of return percent that your utility companies use to determine their profits, as well as the property tax rate as a percentage of the rate base. This will be a historical percentage that will be found in utility rate case filings. We have prefilled this at 2 percent.

Then, in the "Emissions" tab, for every model you will need to insert the CO^2 emissions per MWh for coal, natural gas CC and natural gas CT. You can find these values through your state's EIA electricity profile, found here. (Within the link, click your state and download the "Full Tables 1–16.") Divide total CO^2 emissions found on tab "7. Emissions" by the total generation on tab "5. Generation" for each source and insert this value in the area provided on the "Emissions" tab of the model. While this is not a cost, this step is essential in order to calculate the cost per metric ton of CO^2 reduced in the "Results" tab.

Lastly, the "LCOE" tab — which stands for the Levelized Cost of Energy generation — will allow you to either fill out LCOE values manually, or use the presets already given. If you want to do them manually with state-specific generation costs, type "manual" in the area provided and follow the instructions below. If you want to use the presets, simply leave the area for typing "manual" blank, proceed with the model, and use the below guidelines as a reference for understanding LCOE values for new and existing resources.

Below we will discuss how to manually insert LCOE values for your state, as it will be the most time-consuming aspect of the model.

A. Levelized Cost of Energy (LCOE) for New Generation Assets

Almost all studies that examine the cost of renewable energy use a methodology called the Levelized Cost of Energy, or LCOE, to assess the cost of different technologies.

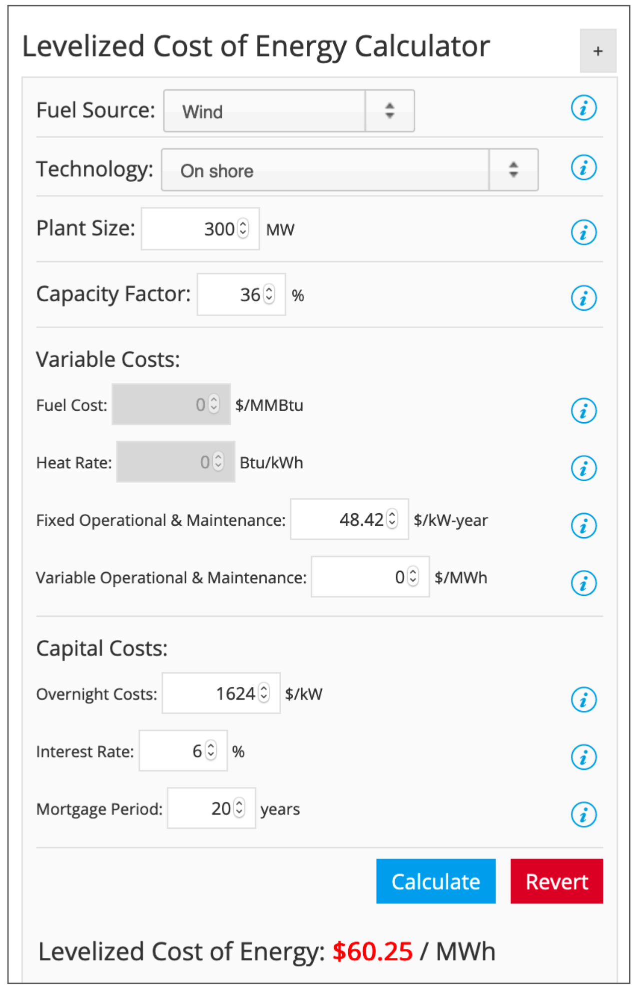
LCOE estimates reflect the cost of generating electricity from different types of power plants, on a per-unit of electricity basis (generally megawatt hours), over an assumed lifetime and quantity of electricity generated by the plant (see Table 3). In other words, LCOE estimates are essentially like calculating the cost of your car on a per-mile basis after accounting for expenses like initial capital investment, fuel costs and maintenance.

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

FIGURE 3

Levelized Cost of Energy Calculator

You will use this Levelized Cost of Energy (LCOE) calculator to determine the per megawatt-hour cost of energy in your state.



Use an LCOE calculator

For this paper, you will use an LCOE calculator, such as this one, with region-based cost estimates used as inputs to calculate the LCOE values in your state. We will explain how to find each of the inputs you need for the calculator below.

There are a number of benefits to calculating your own LCOE values, rather than relying on generalized LCOE values from EIA or Lazard.

First, most energy sources have different economic and useful lifespans, yet LCOE values are oftentimes calculated using 30 years for every energy source. Calculating your own LCOE values allows you to differentiate the mortgage period for each source of energy as they would in real life.

Second, LCOE values from Lazard and EIA are not specific to your region. For example, onshore wind capital costs, according to the EIA's Assumptions to the Annual Energy Outlook for 2020 (AEO), can range from as low as $1,231 per KW to as high as $2,782 per KW depending on which region your state is in. Conducting your own LCOE calculations allows you to utilize region-based cost estimates specific to your state.

Cost assumptions from the U.S. Energy Information Administration (EIA) AEO will be used for capital costs, heat rates, variable O&M, and fixed O&M costs.[16] Fuel costs for coal and natural gas, and capacity factors for wind and solar power plants, will be taken from EIA State Electricity profile tables and used to tailor your findings to your specific state. (Within the link, click on your state and download the "Full Tables 1-16.") Useful generating lives will be described below in the section titled "Useful Operating Lifetimes," and put into the calculator in the field titled "Mortgage Period."

The LCOE values found at the bottom of the calculator will then be inserted into the model to calculate the cost of different generation technologies. We recommend finding LCOE values for each new energy source based on all the capacity factors that each energy source may hit, and including them into the "New LCOE Reference Chart" on the "LCOE" tab.

Overnight costs:

Overnight costs are the capital costs of building a power plant as if no interest were incurred during its construction. This distinction isn't important for our purposes, so just take the number in this column and put it in the "Overnight Cost" field in the LCOE calculator.[17] To get the capital costs for your desired technology, you will use Table 4 found on page 7, labeled "Total overnight capital costs of new electricity generating technologies by region."

EIA breaks down capital costs by "Electricity Market Module regions." Regions are shown on a map on page 1, and capital costs are listed by region on page 7. In order to utilize these region-based capital costs, you will need to know which region your state lies in, or if there are multiple major regions as in the case of California, Mississippi and others.

Note: Pay close attention to EIA's estimated capital costs. Many pro-renewable studies take liberties with their future wind and solar cost assumptions to artificially reduce the capital costs of these technologies, to reduce their LCOE estimates.

Capacity factor:

This is the percentage of electricity produced by a power plant, compared to its theoretical maximum output. If a power plant produces half of its potential output (in MWh), then its capacity factor would be 50 percent.

Capacity factors for new energy sources in the model will range annually, depending on the inputs of the model. Because of this, it is important to calculate LCOE values using different capacity factors (1 percent to 100 percent, ideally) and insert these into the "New LCOE Reference Chart" for each energy source before running the model so that it can calculate costs automatically and appropriately.

Fuel cost:

Coal, natural gas and nuclear power all use fuel to generate electricity, and are typically expressed in per million British thermal units (MMBtu).[18] You will find the fuel costs of coal and natural gas in your state on Sheet 6 "Fuel" of your state's EIA electricity profile.

For nuclear fuel, click here and find EIA's estimate of the cost of delivery for your state.[19] If your state does not have a nuclear plant, use the values for the closest state with a nuclear power plant to approximate uranium costs.

TABLE 2

Heat Rate Comparison

Heat rates describe how much fuel must be burned to generate one MWh of electricity. The higher the heat rate, the more fuel it takes to generate one MWh of electricity.

Technology	Heat Rate (Btu/kWh)	Heat Rate (MMBtu/MWh)
Coal-fired steam turbine	10,000-12,000	10-12
Gas-fired steam turbine	10,000-13,000	10-13
Combined-cycle gas turbine	6,000-9,000	6-9
Single-cycle gas turbine	10,000-12,000	10-12

SOURCE: SEE ENDNOTE 20

Heat rate:

Heat rates measure the amount of fuel needed to generate one megawatt hour (MWh) of electricity. These are expressed in million Btus (MMBtu) per MWh. The heat rate is similar to a gas mileage rating, but in this case a lower heat rate is better, as it means the power plant is more efficient at producing electricity using fuel (See Table 2).[20]

You can also calculate the cost of fuel per MWh of electricity produced using the heat rate and fuel cost per MMBtu. Sheet 6 "Fuel Costs" in your EIA State Energy Profile will provide coal and natural gas prices in dollars per MMBtu delivered to power plants in your state. For example, in 2016, the delivered cost of coal to Minnesota power plants was $2.06 per MMBtu, and natural gas cost $3.10 per MMBtu.

This information gives us an easy way to calculate the cost of fuel per megawatt hour (MWh).

For Coal: $2.06 (cost per MMBtu) x heat rate of 10 = $20.60 per MWh

For CC Gas: $3.10 (cost per MMBtu) x heat rate of 6 = $18.60 per MWh

For CT Gas: $3.10 (cost per MMBtu) x heat rate of 10 =$31.00 per MWh

It is important to remember that combined-cycle natural gas plants are much more efficient than coal-fired power plants, but single-cycle gas turbines (another name for CT combustion turbines) are not. This has important implications for cost and emissions.

Variable operational & maintenance:

Variable O&M costs can include fuel costs, but also maintenance costs for running a power plant if these costs are dependent upon how frequently a plant is run. These are provided in EIA's Annual Energy Outlook Electricity Market Module.

Fixed operational & maintenance:

Fixed O&M costs include the cost of financing, operators, maintenance materials and maintenance staff. These costs are called fixed costs because they do not change based on how often a plant is utilized. These are provided in EIA's Annual Energy Outlook Electricity Market Module.

Useful operating lifetime, or mortgage period:

Different types of power plants have different useful lifetimes and mortgage periods, and these variations have important implications for calculating the cost of electricity from different energy sources. For your study, you will use mortgage periods that reflect the actual useful lifetimes of the power plants.

The National Renewable Energy Laboratory (NREL) states wind turbines have a useful lifetime of only 20 years.[21] Wind facilities must be rebuilt, or "repowered" after 20 years, due to limitations that prevent them from operating economically past this time.

Repowering wind facilities adds to the overall cost of wind power overtime. For example, in order to keep existing wind facilities operational after their 20-year expiration date, our models automatically repower these wind farms (unless you choose to retire them in the nuclear and ACE models), which requires additional capital costs and adds more expenses to ratepayers in the form of utility profits, property taxes and depreciation expenses.

Unlike wind and solar energy sources, traditional power facilities such as natural gas, coal and nuclear can operate years after their mortgage periods are over, meaning they provide inexpensive electricity to ratepayers as a result with zero capital payments — only fixed and variable O&M costs.

Solar panels last 25 years, while natural gas facilities are initially expected to run for 30 years. Nuclear power plants are given an initial license of 40 years, with the ability to extend their licenses in 20-year increments up to 80 years.[22]

Therefore, we recommend you use a 20-year mortgage period for wind, 25 years for solar, 30 years for natural gas CC and CT, and a 40-year mortgage period for nuclear.

As mentioned above, the useful lifetimes used in this report differ from the LCOE estimates conducted by EIA. EIA uses a 30-year cost recovery period for all generation technologies, even though wind facilities need repowering after 20 years — the cost of which is similar to the cost of building a brand new wind farm. Additionally, coal and natural gas plants can easily run for 60 years with upgrades, and nuclear plants can be updated and retrofitted to run for 60 to 80 years.

Calculating the repayment period over 30 years for all technologies does two things: It artificially reduces the cost of wind power by spreading its costs over 30 years, when 20 would be more appropriate, and it artificially inflates the cost of traditional sources like nuclear and coal by not calculating their costs over the entirety of their useful lifetimes.

We corrected for these useful lifetimes to present the most realistic costs that would be borne by Minnesota families and businesses. Even then, making these corrections still underrepresents the cost benefits of traditional sources like coal, natural gas and nuclear, which are all able to operate well past their standard useful lifespans. After this time, these facilities will provide cost savings to ratepayers who no longer have to pay off the capital investments, or "mortgage," of these plants.

B. Levelized Cost of Energy (LCOE) for Existing Generation Assets

LCOE estimates for new generators are helpful for understating the cost of new power plants coming online, but to truly understand the price of renewable energy, it is crucial to compare the cost of new wind, solar and natural gas to existing coal, natural gas and nuclear plants. To do this, you will need to calculate the levelized cost of electricity from existing power plants.

Levelized generation costs for existing energy sources can be calculated based on data from the Federal Energy Regulatory Commission (FERC) Form 1 filings submitted by electric utilities across the country. This will give you information on utility power facilities that you need to calculate LCOE values for existing sources statewide. Because information is rarely available on non-utility electricity providers, the LCOE values you obtain from FERC filings will be used to estimate costs for electricity providers state-wide.

To view FERC Form 1 filings, you will need to have software that can read the files. You can follow the instructions on the FERC website, but we recommend using DBF Manager, which is the software we use successfully to view filings.

Due to the sheer volume of data contained in FERC Form 1 filings, they are divided into many separate folders. In addition, data are shown based on reference numbers for each utility company. For example, Minnesota Xcel Energy is reference number 120. You will need to find these reference numbers in the first file — F1_1 — and search for the utility companies in your state. The most notable files that will guide your cost estimates are the following:

- F1_1 – reference numbers for utility companies
- F1_31 – fuel expense data
- F1_33 – small and renewable generator data
  - » Use the column labeled "COST_PLANT" to estimate capital payments.
  - » Use the columns labeled "OPERATION," "EXPNS_FUEL" (fuel expenses), and "EXPNS_MAIN" (maintenance expenses) for total production costs.
- F1_39 – monthly sales and peak load demand data
- F1_86 – hydro-electric facility data
  - » Use the column labeled "COST_PLANT" to estimate capital costs. Most hydro facilities are operating past their initial capital payments.
  - » Use the column labeled "EXPNS_TOT" (total expenses) for total production costs.
- F1_89 – large generator data
  - » Use the column labeled "COST_OF_PL" (cost of plant) to estimate capital payments.
  - » Use the column labeled "TOT_PRDCTN" for total production expenses. While fuel costs are listed separately, "TOT_PRDCTN" includes fuel costs.

Note: In order to estimate capital payments accurately, you may be required to download several years' worth of data from FERC Form 1 filings to see if there have been any recent upgrades to facilities. In the case of Minnesota, for example, several coal facilities underwent conversions to natural gas facilities, while others had significant upgrades. In addition, Minnesota's two nuclear facilities have also had significant upgrades to their facilities. These costs must be factored into LCOE estimates and will only be noticeable when looking at several years of data.

Other important categories to get are the capacity ratings of the facilities and the net generation of the facility (which are normally listed in KWh with some exceptions).

Using the costs and plant data listed in the filings, you will need to find the following inputs:

1. Levelized capital costs — i.e., capital costs per MWh of generation.
2. Levelized production costs — i.e., capital costs per MWh of generation.
3. Capacity factors — net generation divided by (capacity multiplied by 8,760) multiplied by 100.

To find the capacity factor for a specific power plant, take the MWh produced by the plant and divide by the MW of capacity (listed in the FERC forms) multiplied by 8,760, the number of hours in a year. Then multiply the number by 100 to get the percentage.

Capacity Factor = [MWh produced / (MW of capacity x 8,760] * 100

A capacity factor simply lets us know what percentage of generation a power plant produced compared to its theoretical maximum. The graph below shows capacity factors for nuclear, hydroelectric, coal, wind, natural gas combined cycle, solar, and combustion turbine natural gas in Minnesota for the year 2019.

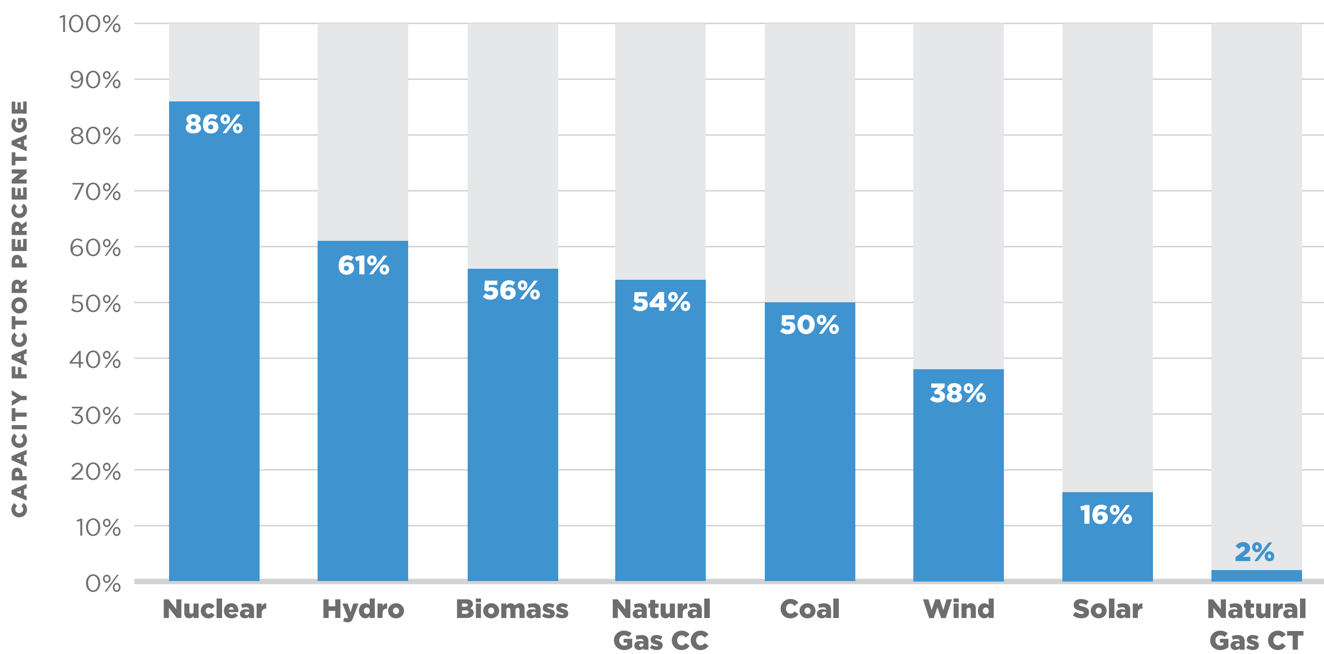
As you can see, the capacity factors for wind and solar were lower than nuclear, hydroelectric, biomass, natural gas CC and coal. Wind and solar only operated at a higher capacity factor than natural gas CT.

However, there are problems with a direct comparison of capacity factors because humans control the output for coal, natural gas and nuclear power by deciding when and how much electricity they generate. In contrast, the capacity factors for wind and solar are a function of fluctuating weather conditions. Coal, nuclear and natural gas facilities, including CT, could run at 85 percent capacity factors, or higher, if they were sufficiently supplied with fuel to do so. Wind and solar are maxed out at the capacity factors you see here based on the weather conditions in that year.

FIGURE 4

Capacity Factor of Minnesota Power Plants

In Minnesota, the capacity factor for nuclear power plants was 86 percent, hydroelectric was 61 percent, coal was 50 percent, natural gas CC was 54 percent, wind was 38 percent, and solar was 16 percent.



SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION STATE ENERGY PROFILE, MINNESOTA

Since utility companies may not be the only providers of electricity in your state, for the model you will need to use state-specific capacity factors that can be found in Sheet 15 "Capacity Factors Annual" of your EIA state electricity profile.

The LCOE values for existing utility power plants, taken from FERC Form 1 filings, will be used to guide your cost estimates statewide by adjusting to match the capacity factor using the capacity factor and fixed costs per MWh from utility facilities. For example, in Minnesota, utility companies run coal plants at a 49.85 percent capacity factor with capital costs (which are fixed costs) of $3.55 per MWh and an overall LCOE of $34.33 per MWh. However, state-wide capacity factors for coal facilities are 48.8 percent. In order to use the utility data to estimate statewide LCOE values for existing sources, we need to adjust the LCOE for the statewide capacity factor. In order to do this, we need to take the utility capital cost per MWh ($3.55) multiplied by the utility capacity factor (0.4985) and divide this total by the statewide capacity factor (0.488). Then, we need to add this to the utility LCOE value minus the utility fixed costs. The formula is the following:

State LCOE = [(utility capital cost * utility capacity factor) / state capacity factor] + [utility LCOE – utility capital cost]

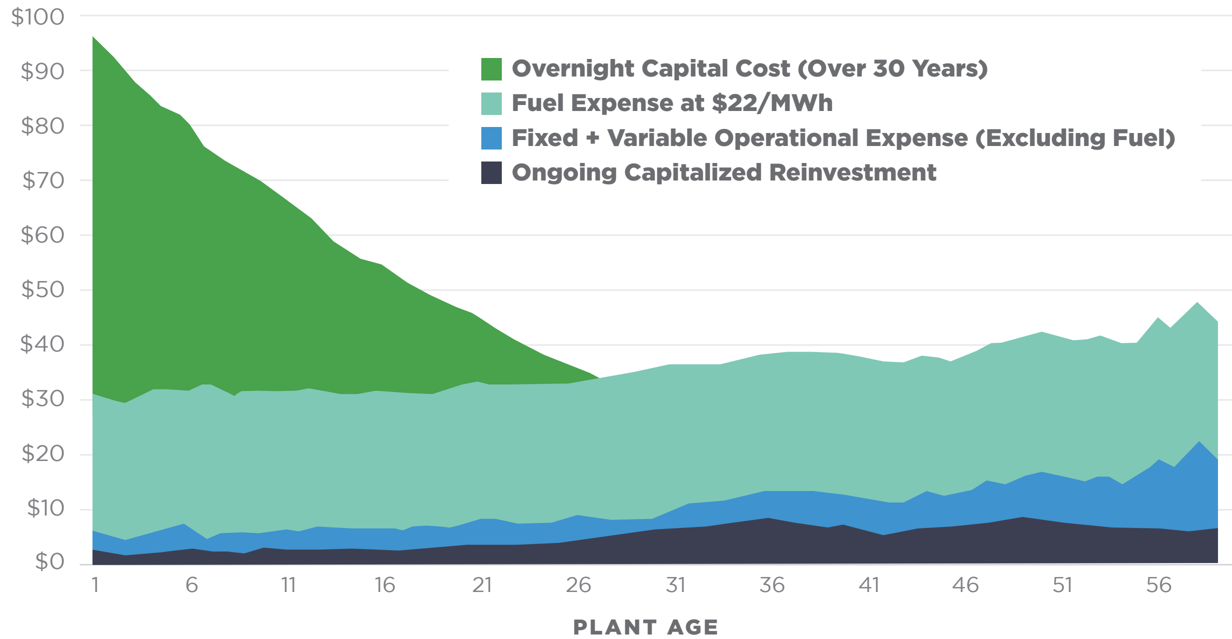
All you need to do is figure out the inputs based on utility FERC form data. Then, in the model, simply add the inputs — the capacity factor, LCOE, and capital cost per MWh — in the area provided on the "LCOE" tab and the model will do the rest for you.

It is important to understand that existing coal, nuclear, hydro and natural gas plants are likely to be more affordable than new power plants because

FIGURE 5

LCOE from Coal in 2013 $/MWh by Plant Age

As power plants pay off their up-front capital costs, or their "mortgages," the cost of producing electricity from them falls. When the power plants are completely paid off, they produce electricity for the lowest cost, just as it is least expensive to live in your house after you've paid off your mortgage or to own your car after you've paid it off.



SOURCE: INSTITUTE FOR ENERGY RESEARCH

they have paid off much of their upfront capital costs, or the "mortgage" on the plant. As EIA noted in 2017, the average age of natural gas facilities in the U.S. is 22 years, while coal is 39 years, nuclear is 36 years, and hydro is 64 years.[23] This suggests that most of the existing coal, nuclear, hydro and natural gas power facilities in use today are operating past the payback period for their initial capital costs and are thus operating at a discount for ratepayers compared to new power facilities that would have capital costs yet to pay off.

Figure 5 shows the cost of producing electricity falling as capital costs are paid down. After power plants pay off their initial costs, they produce the lowest-cost electricity.[24]

This is why closing down existing coal plants almost always leads to higher electricity prices.

Using FERC data, you can determine the cost of producing electricity from coal, nuclear, natural gas and hydroelectric power plants that are owned by investor-owned utilities in your state. Wind and solar costs are more difficult to obtain from FERC data because wind and solar generators do not appear to be required to file the same paperwork as conventional generators.

It is important to have the cost of existing generators to contrast with the LCOE values of new renewable energy sources that would be replacing these existing generation resources.

Tables 3 and 4 show the unsubsidized LCOE of new and existing power plants at Minnesota-specific capacity factors and fuel prices, using realistic useful lifetimes and region-specific cost estimates for new LCOE values, and FERC Form 1 data for existing LCOE values. Table 3 also includes levelized transmission costs, levelized property tax costs,

TABLE 3

Capacity Factors and LCOE Values for Existing Minnesota-Specific Power Plants

Energy Source	Existing Cap Factor	Existing LCOE
Coal	29.33%	$36.81
Natural Gas (CC)	41.19%	$28.11
Natural Gas (CT)	3.98%	$83.90
Hydro	58.50%	$14.78
Nuclear	97.20%	$36.70
Wind	32.60%	$39.09
Utility Solar	17.30%	$54.83
Community Solar	16.96%	$150.11
Biomass	59.80%	$88.88

SOURCE: FEDERAL ENERGY REGULATORY COMMISSION AND ENERGY INFORMATION ADMINISTRATION

levelized costs for utility profits, and total LCOEs.

Notice that before additional costs are added to LCOE values, wind energy appears to be the least expensive source available. However, after including additional costs uncovered by our model, wind energy is more than double the cost of new natural gas facilities. Furthermore, it becomes even more expensive than nuclear power.

The cost of solar is also underrepresented by the normal LCOE value and increases by more than $210 per MWh when all additional costs are attributed. Higher capacity factors result in lower LCOE values because the cost of generating electricity is spread over more units of electricity. Existing power plants produce electricity at lower costs because they have already paid down a portion of their "mortgages," which reduces the capital cost, and these plants are partially depreciated, reducing property taxes and utility profits (See Figure 5 on page 22).

C. Why Are These LCOEs Different than EIA and Lazard?

Wind and solar advocates cite LCOE estimates from EIA and Lazard's Levelized Cost of Energy Analysis to suggest that wind and solar are now more affordable than conventional sources of generation, such as coal, natural gas and nuclear power. The differences between the LCOE estimates calculated here and those of Lazard and EIA will largely be the product of assessing the mortgages over more appropriate timeframes and using state-specific capacity factors and fuel costs.

The Lazard study uses assumed capacity factors for wind ranging from 38 percent to 55 percent, and solar capacity factors are assumed to range from 21 percent to 32 percent. However, Lawrence Berkeley Labs data show there is not a single wind facility in the United States with a capacity factor over 52.5 percent, and no U.S. state had annualized solar capacity factors of 32 percent in 2017. Arizona and California had the highest solar capacity factors at 28.9 percent and 28.5 percent, respectively.[25]

Lastly, Lazard and EIA do not incorporate the additional costs that our model quantifies, such as expenses for generating backup electricity when the wind is not blowing or the sun is not shining, transmission costs, property taxes, or utility profits. Therefore, cost estimates from Lazard and EIA are not an estimate of the total cost of electricity that will be paid by consumers, but rather a small piece of a much larger puzzle.

D. If the LCOE of Wind Is Less than or Equal to Nuclear, How Can A Nuclear Future Be Less Expensive?

Looking at Table 4, it is fair to wonder how transitioning to wind and solar can cost more than transitioning to nuclear power. After all, the LCOE of nuclear is only slightly less expensive than the LCOE of wind, but in Doubling Down we found that a 50 percent renewable energy mandate under the

TABLE 4

Capacity Factors, LCOE Values, and Levelized Additional Costs for New Minnesota-Specific Power Plants

You will be able to generate "all-in" cost calculations for each energy resource by using the model.

		Normal LCOE	LCOE Including Additional Costs				
Energy Source	**New-Capacity Factor**	**New LCOE**	**Levelized Property Taxes**	**Levelized Transmission**	**Levelized Utility Profits**	**Levelized Load Balancing**	**Adjusted LCOE**
Natural Gas (CC)	63%	$40.69	$1.85	$1.52	$7.09	NA	$49.63
Natural Gas (CT)	4%	$269.75	$29.70	$24.10	$112.80	NA	$460.57
Nuclear	97.2%	$64.63	$8.51	$0.92	$32.59	NA	$106.63
Wind	45%	$33.87	$3.72	$29.51	$14.24	$65.79	$147.12
Utility Solar	17.7%	$53.67	$8.26	$25.72	$31.66	$133.81	$253.12

Renewable scenario would cost nearly 40 percent more than the Short-Term Nuclear scenario, and more than 4.25 times more than the Long-Term Nuclear scenario.

There are two main reasons why the Renewable scenario is so much more expensive.

One, wind and solar are weather-dependent resources, and as such these energy sources require backup power generators when the wind isn't blowing or the sun isn't shining. This is called overbuilding the grid to ensure the reliability of the energy system. It is necessary to overbuild the grid to meet state-mandated renewable energy targets without creating an electrical grid more prone to blackouts.

Because of the need for overbuilding, there are more expenses for property taxes, utility profits and transmission upgrades for the utility — and thus, ratepayers. As mentioned earlier, utility companies earn a profit based on the assets they build. If utilities are allowed by the PUC or PSC of their state to build more capacity — which transitioning to renewable energy requires — then utility companies will make more profit. Nuclear scenarios require far less overbuilding than renewable scenarios, and as such it saves ratepayers money compared to grids that rely heavily on wind, solar and natural gas.

We will discuss overbuilding more in the section below.

Two, wind generators only last 20 years at the most. This means that utility companies must repower them more often than other energy facilities that last 30 to 40 years or longer, resulting in a new round of utility profits that ratepayers have to pay for. In this way, facilities that last longer than 20 years — such as coal, natural gas and nuclear power plants — offer savings to ratepayers by being more reliable for a longer period of time.

In fact, traditional energy sources like coal, natural gas and nuclear often operate longer than their initial capital payment time period, and therefore provide electricity at a discount compared to new facilities with capital payments still to pay off. This kind of savings is not possible with renewable energy facilities like wind and solar. ■

Part 3: Key takeaways from the report

A. The Need for Overbuilding to Ensure Reliability

Contrary to popular belief, building wind and solar power plants does not replace coal-fired power plants by themselves. Typically, if coal power is being retired, there is a near equivalent amount of natural gas capacity being added to replace on top of the wind and solar being added to satisfy renewable energy mandates.

For example, enacting a 50 percent renewable energy mandate in Minnesota would replace coal-fired power plants with wind, solar and natural gas — enough natural gas capacity to generate up to 100 percent of electricity needs when wind and solar are generating zero electricity.

This is why in Doubling Down we found that for every 1 MW of coal-fired power being retired by Minnesota utilities, they plan to build 1.6 MW of wind, 0.62 MW of solar, and 1.1 MW of natural gas — for a total of 3.32 MW added for every 1 MW of coal-fired capacity retired.

Overbuilding the grid with new wind and solar installations, along with adequate natural gas backup capacity, is incredibly expensive.

The amount of wind and solar needed to reach 50 percent renewable will depend on capacity factors in your state, but one thing will remain constant: You will need enough natural gas capacity to ensure the lights stay on if wind and solar are producing zero power. In this way, you essentially have two grids operating at the same time. One when renewable energy sources are producing electricity, and another for when they aren't.

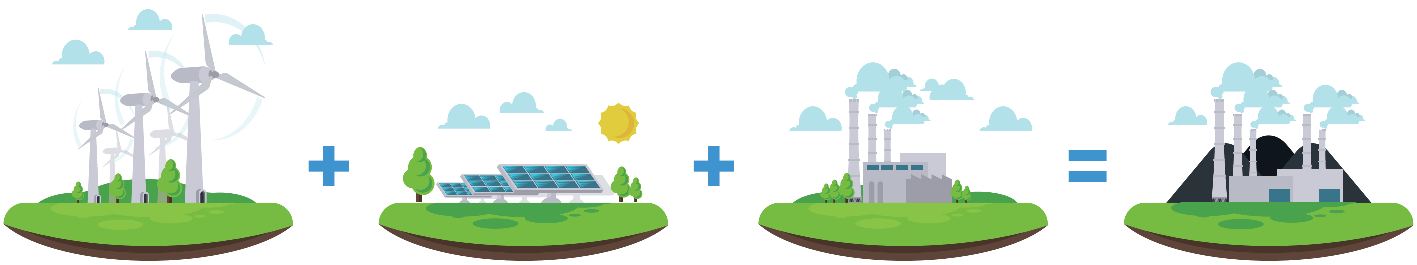
Overbuilding the grid with new wind and solar installations, along with adequate natural gas backup capacity, is incredibly expensive. Figure 7 shows the amount of installed capacity in Minnesota would grow 24.2 percent from 18,396 MW in 2018, to more than 22,846 in 2030 and beyond to meet renewable energy targets and ensure reliable electricity when renewables are not generating power.

Based on its electricity consumption, Minnesota only needs an annual average of 6,706 MW of capacity, assuming a 100 percent capacity factor for the entire system. This means there would be enough generation capacity on Minnesota's grid

FIGURE 6

The True Cost of Retiring a Coal Plant

For every MW of coal that is retired, Minnesota utilities plan to build 3.32MW of electricity generation — at a combined cost of nearly $4.8 million per MW of coal replaced — simply to replace electricity generation capacity that they already have. These expenditures are the reason electricity prices in Minnesota continue to climb.



WIND	+	SOLAR	+	NATURAL GAS	=	COAL
1.6 MW $1.26 Million/MW		**0.62 MW** $1.31 Million/MW		**1 MW** $1.12 Million/MW		**1 MW** Already Paid For
$2.86 million TOTAL COST		**$812,200** TOTAL COST		**$1.12 million** TOTAL COST		

SOURCE: U.S. ENERGY INFORMATION ADMINISTRATION ASSUMPTIONS TO THE ANNUAL ENERGY OUTLOOK

to power 3.4 Minnesota's using wind, solar and natural gas, assuming electricity demand remains constant (22,846 MW/6,706MW= 3.4).

The growth in generation capacity would occur despite the closure of 4,465.7 MW of coal and 2,100 MW of wind that would need to be repowered before 2030. With repowered wind included, the total new capacity built between 2019 and 2030 is 11,015.6 MW. This means 48 percent of the power plants on the grid would have been built in this 11-year timeframe.

Similar capacity builds will likely be necessary in your state in order to satisfy renewable energy mandates.

B. Overbuilding to Meet Renewable Mandates

A major driving factor as to why the grid must be overbuilt under renewable scenarios is the need to meet renewable energy mandates in the face of low capacity factors and capacity values.

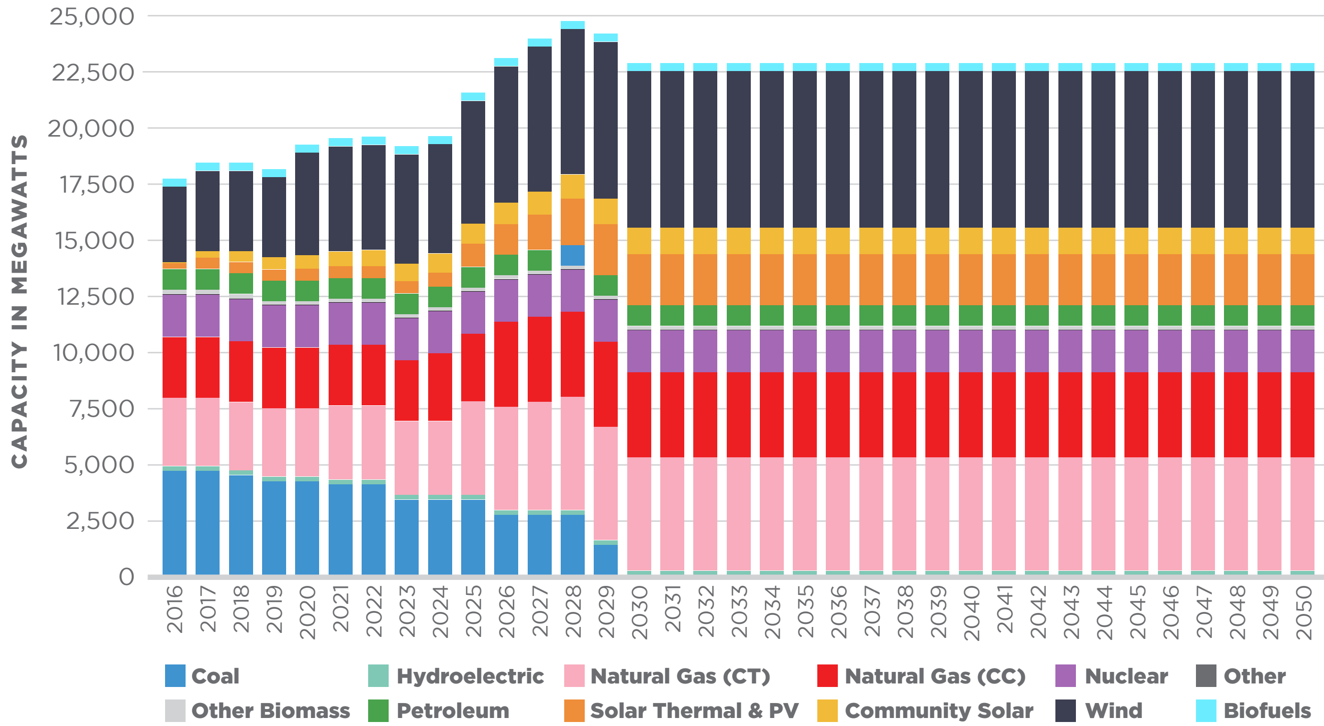
Capacity factors represent the percentage of power produced compared to the maximum power it could have produced, and capacity values represent the amount of capacity that can be relied upon for meeting demand as determined by grid operators.

For an example of both, take wind energy. Wind

FIGURE 7

Renewable Scenario Installed Capacity by Source

In 2030, wind comprises 6,972 MW of installed capacity, utility solar accounts for 2,268.6 MW, and community solar comprises 1,200 MW. Together, wind and solar account for 10,440 MW of capacity, whereas nuclear comprises 1,871 MW, CC gas 3,799.6 MW, and CT gas 5,044.8 MW.



SOURCE: MODEL CALCULATIONS TO MEET ELECTRICITY DEMAND AND MAINTAIN RELIABILITY

farms in Minnesota in 2017 had an average capacity factor of 35.9 percent, and their capacity values are closer to 15.7 percent. Capacity values for wind are lower than their capacity factors because wind farms sometimes generate less than 10 percent of their potential output — and these times of low production are sporadic and ever-changing based on wind cycles.

It's even possible for wind turbines to be using more power than they produce. As noted by Xcel during one July day in 2018, "the entire MISO wind portfolio (over 17,000 MW at that time) had a combined output of minus 11 MW — meaning the wind turbines that were online were taking more power than they were producing."[26]

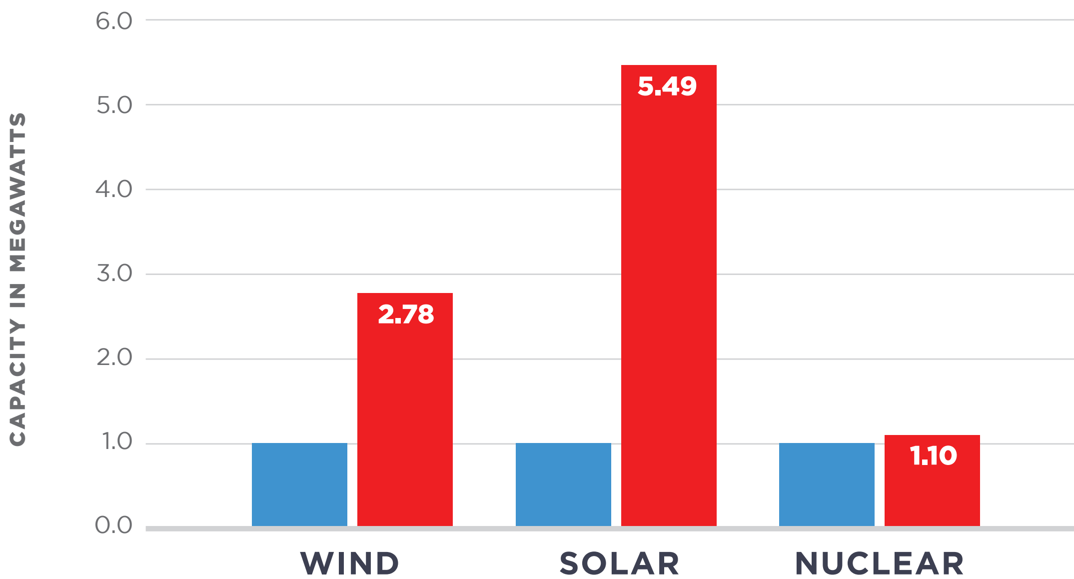
So, while the capacity value of wind is rated at 15.7 percent — the percentage that grid operators determine to be reliable at all time — and the annual capacity factor is 35.9 percent, electricity generation from wind farms can at times be zero, or less. Furthermore, capacity factors for wind and solar energy sources can only be so high because the wind isn't always blowing, and the sun isn't always shining. These factors play an important role as to why overbuilding the grid must happen in order to satisfy renewable energy mandates.

To illustrate this point, imagine we wanted to generate 1 MW of power from wind on an annual basis. Because the capacity factor of wind in Minnesota was 35.9 percent in 2017, building

FIGURE 8

Required Capacity for 1 MW of Power

Using 2017 capacity factors for wind and solar, 2.78 MW of wind would need to be installed, and 5.49 MW of solar would need to be installed to generate 1 MW of electricity.



SOURCE: CALCULATION BASED ON U.S. EIA CAPACITY FACTOR DATA

only 1 MW of wind capacity would result in 0.359 megawatts of electrical output. In order to generate 1 MW of power with a 35.9 percent capacity factor, we would need to build 2.78 MW of wind capacity, as shown by Figure 8. Solar energy with an annual capacity of 18.2 percent in 2017 would require even more — 5.49 MW — to produce 1 MW of power over the course of one year.

If we imagine doing the same with an energy source like nuclear, on the other hand, it will require far less capacity because nuclear has historically high capacity factors from 85 to 100 percent. In Minnesota, based on 2017 capacity factors of 91 percent, nuclear capacity would only need 1.1 MW to produce 1 MW of power annually.

The cost for this overbuilding will manifest itself in your renewable energy study by requiring more capital costs to satisfy electricity demand.

It is important to note that our study likely underestimated the amount of overbuilding that would need to occur for wind capacity. This is due to the fact that we assumed all newly built wind turbines would operate at a 44 percent capacity factor, therefore requiring "only" 2.27 MW of wind to be built to achieve 1 MW of output, as opposed to 2.78 MW.

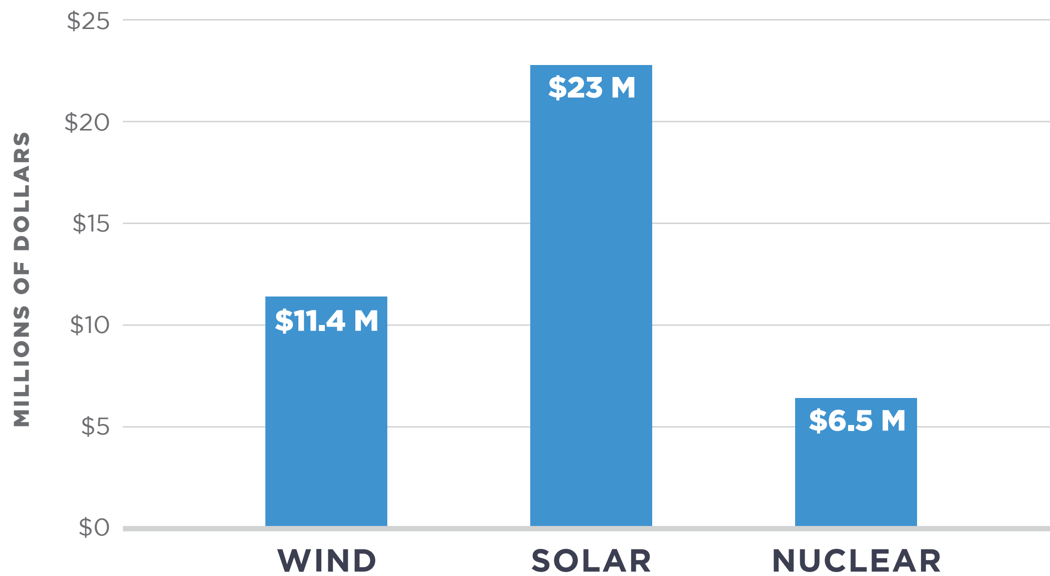
Nonetheless, the need to overbuild in this way increases costs dramatically. For example, EIA's assumptions for its Annual Energy Outlook estimated the cost of wind to be $1.26 million per MW of installed capacity. However, this must be multiplied by 2.27 to get the actual amount that would need to be spent to generate 1 MW, resulting in a cost of $3.63 million per MW of power.

Likewise, the capital cost of solar ($1.31 million per MW) would need to be multiplied by 5.49, resulting in a cost of $7.2 million to generate 1 MW of electricity. The capital cost of nuclear ($5.95 million per MW) would need to be multiplied by 1.1, resulting in a cost of $6.57 million to generate 1 MW of electricity.

FIGURE 9

Cost to Generate 1 MWh of Power for 80 Years

Nuclear power has the lowest capital costs over an 80-year timeline because nuclear plants last longer than solar panels and wind turbines, which would need to be rebuilt to maintain energy output over this timeframe. Nuclear plants will need upgrades and maintenance, however, which can be very expensive. These expenses are not reflected in the graph.



SOURCES: U.S. ANNUAL ENERGY OUTLOOK; EIA CAPACITY FACTOR DATA

At first blush, these numbers would likely lead you to believe that nuclear power is the most expensive option for generating electricity. However, it is important to remember that nuclear plants last for 80 years, whereas wind turbines last for 20 years, and solar panels last for 25. After accounting for the need to "rebuild" wind and solar facilities over the course of 80 years, nuclear has the lowest capital costs of these three technologies (See Figure 9).

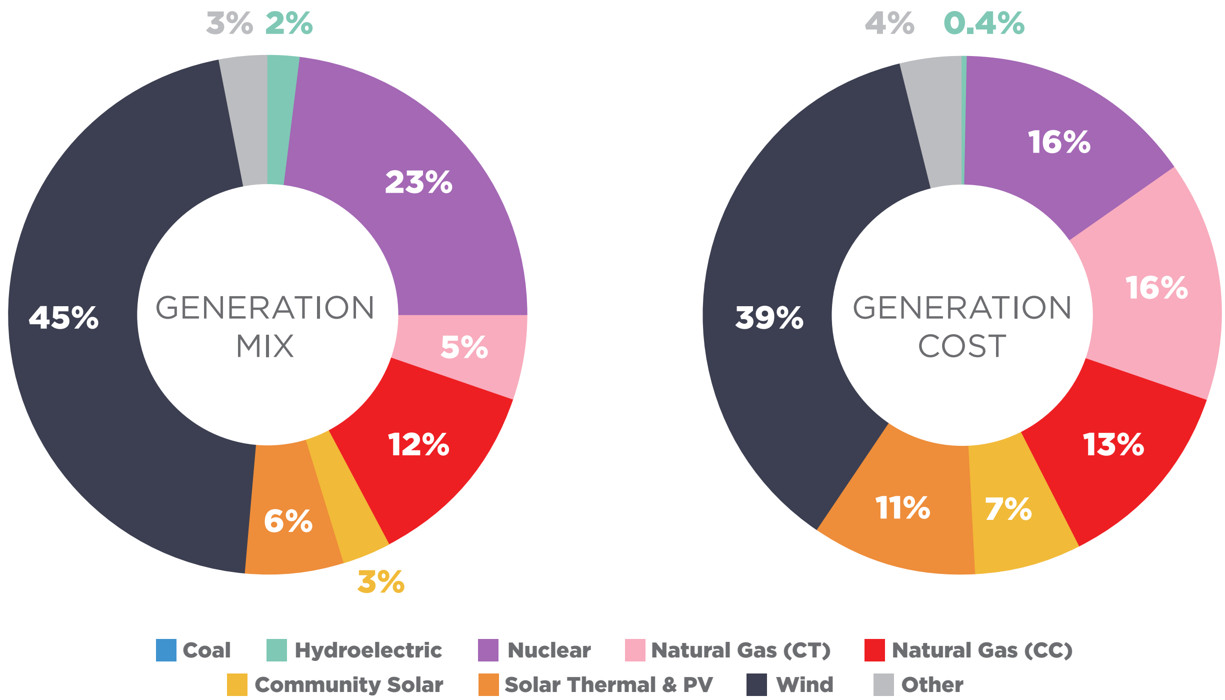
While these numbers do not influence the LCOE of specific generation sources, because the capital costs and capacity factors of wind, solar and nuclear are already taken into account, the need to overbuild and rebuild adds considerable costs for generation, transmission and utility profits. These hidden costs are not encapsulated by simple LCOE estimates, yet they are crucially important for giving the public a more complete understanding of the high cost of intermittent renewable energy sources. Note: Since originally publishing Doubling Down, Xcel has substantially expanded the amount of renewable and natural gas capacity it plans to build in Minnesota — which only increases the numbers you see above. For example, based on its latest IRP, Xcel alone plans to build more than 11,500 MW of new capacity — more than all three utilities we studied combined in our report for Doubling Down.

It is crucially important for readers to understand that electricity customers do not pay for either renewables or natural gas, depending on which of these options is more affordable or more available at the time. They pay for both, at significant cost, even though many of these power plants will be not be used much of the time. This is known as "idle capacity."

FIGURE 10

2030 Renewable Generation Mix vs Generation Cost

Low capacity factors result in large amounts of idle capacity on the grid. For example, Community Solar accounts for just 3 percent of generation (left pie), but 7 percent of generation costs (right pie). Likewise, Utility Scale Solar makes up 6 percent of generation but 11 percent of generation costs, and CT Gas accounts for just 5 percent of generation but 16 percent of generation costs.



SOURCE: MODEL RESULT "GRAPHS" TAB

C. Idle Capacity

As we stated before, many people think the grid is a giant battery that stores electricity for later use. It is not. The amount of electricity generated by power plants must carefully match the demand for electricity at all times. Balancing the supply and demand is like a teeter-totter that must always remain in equilibrium.

If the wind is not blowing, natural gas plants must ramp up their production to meet demand, and if wind power is generating substantial quantities of energy, gas must dial back its production so as not to overload the grid.

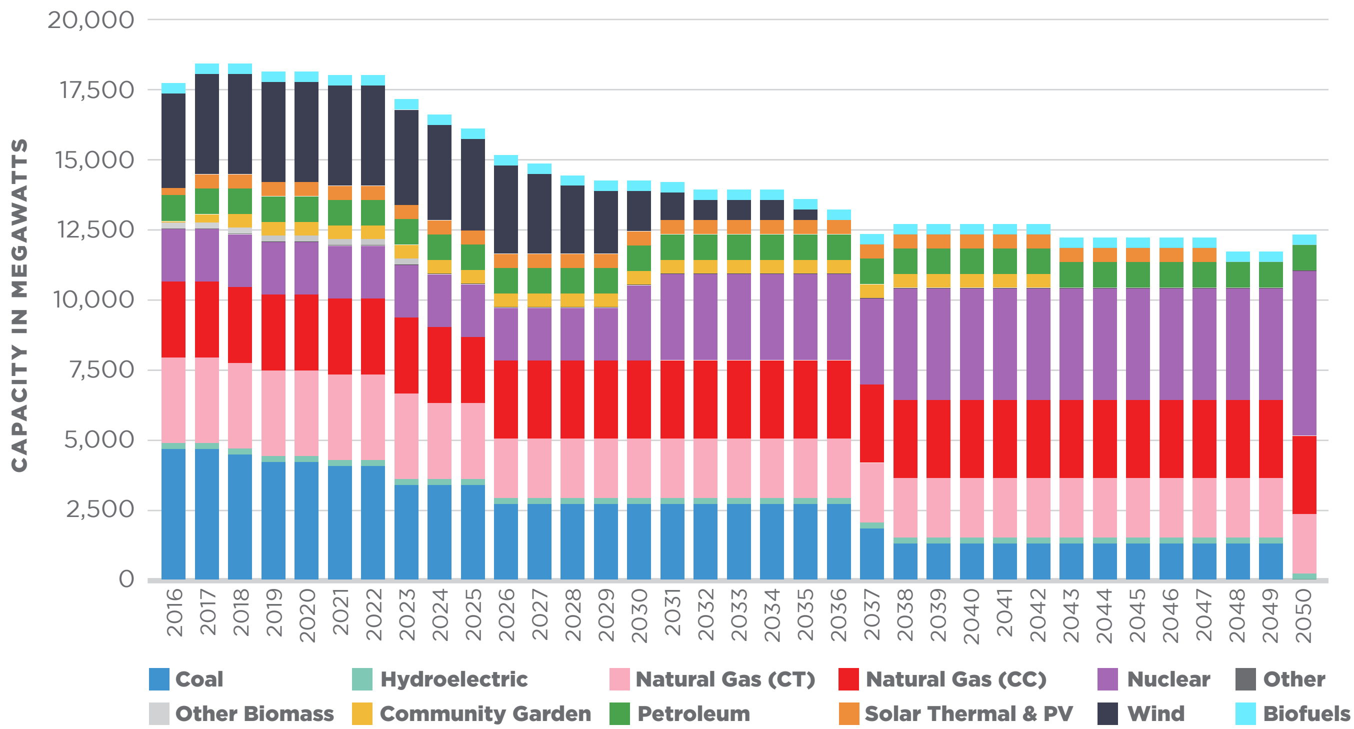
As we discussed earlier, wind and solar cannot be turned on and off to match demand. In industry lingo, this means they are non-dispatchable resources. Adding non-dispatchable sources of power like wind and solar necessarily results in a situation where a large portion of power plant capacity is sitting idle at any given time. This is demonstrated by the fact that the grid-wide capacity factor for the Renewable scenario in Doubling Down on Failure is only 30 percent in 2050, compared to 56 percent in both nuclear scenarios and 55 percent in the Affordable Clean Energy scenario.

Even though 70 percent of the power plant generation capacity in the Renewable scenario would be idle at any given time, Minnesota families and businesses would still have to pay the costs asso-

FIGURE 11

Long-Term Nuclear Annual Capacity MW

Electricity generating capacity falls from more than 18,000 MW of installed capacity in 2018 to 11,154.4 MW of installed capacity in 2050 as wind turbines gradually reach the end of their 20-year lifetimes and nuclear plants replace coal-fired power plants as they reach the end of their useful lifetimes.



SOURCE: MODEL RESULT "GRAPHS" TAB

ciated with maintaining these power plants. That is why little-used plants make up a disproportionately large share of the cost of operating the grid (see Figure 10).

We recommend showing generation mix vs generation cost pie charts to demonstrate the relative value of each source of electricity. Notice how, in Figure 10, combustion turbine (CT) natural gas (in gray) represents only 5 percent of generation yet accounts for 16 percent of generation costs. This is because as the main ramping source for non-dispatchable renewable sources, natural gas CT power plants sit idle much of the time. These plants still have costs associated with them, however, and ratepayers are forced to pay for the maintenance of them on top of newly built wind and solar.

D. Touting "Fuel Cost Savings" Ignores Higher Fixed Costs for Power Plants and Consumers

Utility companies and renewable energy lobbyists often talk about how much money consumers will save on fuel costs by building more wind turbines and solar panels, but this is a bait-and-switch tactic that never looks at the higher fixed costs passed along to consumers as more wind and solar are added to the grid.[27]

Every power plant has costs that are fixed, meaning they do not fluctuate based on how frequently the plant is used. Fixed costs include repaying capital costs (the "mortgage" on the plant), interest, insurance, salaries and wages, maintenance, and property taxes. Utility companies in Minnesota also make a guaranteed 10 percent profit on every single dollar they spend building new power plants, which is why they try to justify building as many as possible.

The only costs that need not be paid when facilities are idle are the cost of fuel and operation and maintenance costs resulting from running them more often, but the savings from burning less fuel are often overstated.

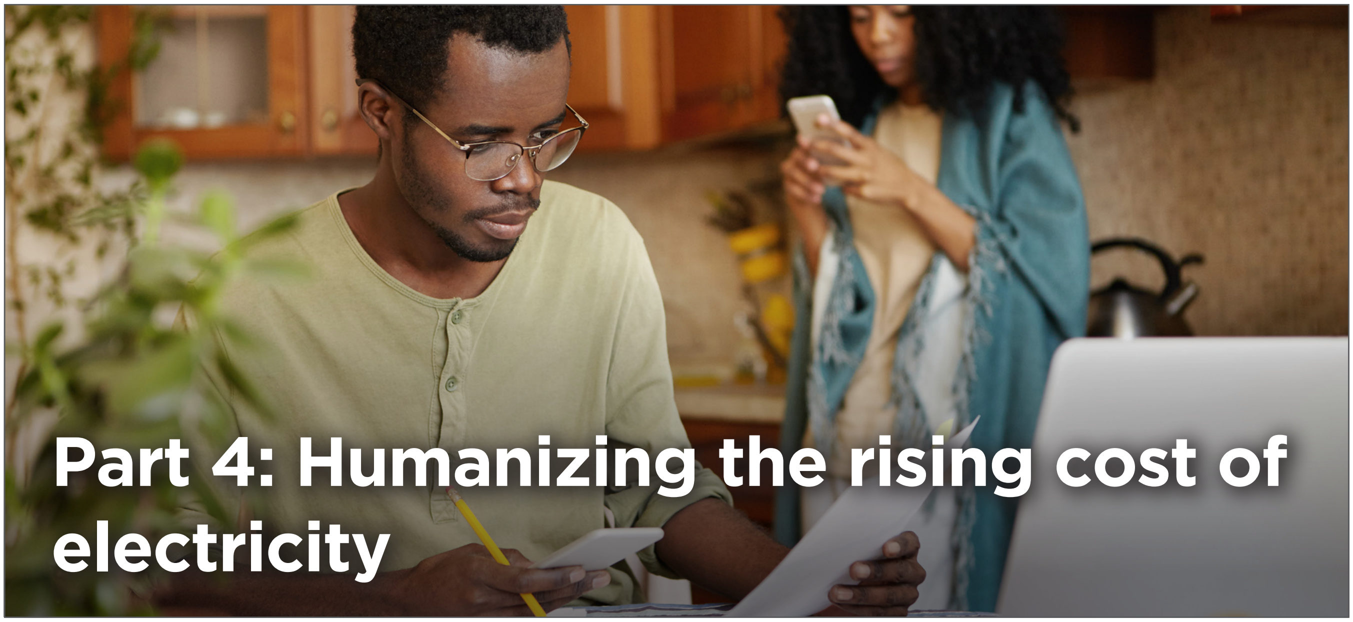
Claims that building renewables will make your state less vulnerable to spikes in the price of fossil fuels fail to consider that natural gas will still be burned when the wind is not blowing or the sun is not shining. Because the capacity factors of wind and solar are generally below 35 and 25 percent, respectively, this means your state will still burn large quantities of natural gas.

Furthermore, the delivered cost of natural gas in your state may be more expensive than burning coal, even after taking into consideration the fact that combined-cycle natural gas plants are more efficient than coal-fired power plants.

This is why claims that utilities are swapping fuel costs for capital costs — Xcel Energy in Minnesota claims it is "swapping steel for fuel" — are incorrect. In many cases, utilities are simply swapping steel and more-expensive fuel for fuel, which is why the Renewable Scenario is so much more expensive than either nuclear scenario or the Affordable Clean Energy scenario.

In Doubling Down, we showed that each Nuclear scenario would save Minnesota at least $22.3 billion compared to the Renewable Scenario, in part because the grid would not need to be overbuilt because nuclear power plants can produce a steady, constant and predictable flow of electricity, and do not require backup power sources. Therefore, using nuclear power would decrease the amount of installed capacity on the grid (see Figure 11).

Reducing the amount of capacity on the grid has the advantage of eliminating the fixed costs that are duplicated by systems that rely heavily upon renewable energy sources. Residents in your state will not be forced to pay twice for electricity they use once by relying on an energy source that can meet electricity demand on its own. Reducing the amount of capacity on the grid also has the added bonus of reducing transmission costs, property taxes and utility profits. ■



Part 4: Humanizing the rising cost of electricity

The first question most people ask when presented with new information is, "How does this affect me?" While this may seem cynical, marketing research suggests it is true.

This is why it is so important to humanize the cost of renewable energy mandates in a way that makes intuitive sense for the target audience. Because most people feel their eyes glazing over when they hear terms like kilowatt hour and megawatt hour, it is imperative that you translate the cost increases you find in your study to concepts people can readily identify with.

It helps to discuss the impacts in terms of how it will increase electric bills for consumers, schools, businesses and hospitals. Because we use electricity in virtually every aspect of our lives, rising electricity prices, especially when driven by government mandates, are a tax on our quality of life.

It helps to discuss the impacts in terms of how it will increase electric bills for consumers, schools, businesses and hospitals.

Increasing electricity prices are regressive because they disproportionately harm low-income households. This is because low-income families spend a higher percentage of their income on energy costs than wealthier households. For all the talk about "environmental justice" and "climate justice," the policies advocated by proponents of the Green New Deal will further contribute to the inequalities they claim to care about.

Rising electricity costs are especially harmful to energy-intensive industries like manufacturing, farming and mining, because they consume massive quantities of electricity. You can humanize these costs by talking about lost jobs.

Start by going to the "Results" tab in the model to find the additional cost per kilowatt hour of electricity. This tab will also allow you to plug in the number of customers in your region and it will calculate the average annual cost increase per customer.

In addition, the "Results" tab allows you to calculate the cost attributed to each rate class simply by plugging in information found within your state's EIA electricity profile on tab "8. Retail Sales." Insert (or copy and values paste) the retail sales, revenue, customers and price for each of the three rate classes listed: residential, commercial and industrial. Then, this feature will calculate how much the average residential, commercial and industrial customer bill will increase per month and year. This feature assumes that historical rate factors — or the percentage difference of rates between each rate class — remains constant.

The Big Picture: Because nearly every good or service requires electricity, increasing the cost of electricity will raise the price of virtually everything. This is why we suggest your topline number be in terms of additional costs per household.

To do this, divide the additional cost of renewable energy in your state by the number of households. This will give you the total per-household cost of the renewable program. To get the annual cost, divide this by the number of years you use in your analysis.

Remember, this number will include the higher electric bills paid by families, higher prices paid at the grocery store (and everywhere else), and higher taxes as governments raise tax rates to offset their own increasing electricity costs.

Households: To find the increase in monthly electric bills, click here to find the average KWh consumption in your state.[28] Multiply the increase in electricity costs by the KWh use.

Taxes: Government buildings are large consumers of electricity, and rising costs mean state and local governments will increase taxes to pay for these costs. Depending on your state law, you may be able to file a public records request for certain government buildings and obtain their KWh use. Then multiply the additional cost to quantify lost revenue for government agencies. The government will need to cut services, which may also be a good talking point, or raise taxes.

Because nearly every good or service requires electricity, increasing the cost of electricity will raise the cost of virtually everything.

Schools: After staffing, energy costs constitute the largest expense for school districts.[29] As a result, rising electricity prices represent a very real opportunity cost for students because every extra dollar spent on energy is one less dollar that could have been spent enhancing their education.

One effective way to frame this argument is to talk about how many teachers would need to be laid off to pay for rising electricity costs. This is a fairly simple thing to figure out.

Some schools post their electricity use online, but if the school you wish to use as an example does not post this information, a freedom of information request can get you the numbers you need. You'll want to ask for the total KWh usage for the school district, as this will give you a comprehensive view of the cost to the district.

Simply take the KWh usage and multiply it by the cost increase calculated in XSHEET to get the total additional cost. Then, divide that number by the average salary of teachers in your area and you'll know how that particular school district would be impacted by higher electricity prices.

If the school district does not raise taxes, this is the number of teachers who would be laid off to make payroll.

Commercial and industrial use: Businesses are large consumers of electricity. To calculate the increasing costs to businesses, you can go to Tab 8 "Retail Sales" in your EIA state profile and take the number of MWh in the "commercial," and "industrial" categories. Multiply this number by 1,000 to change MWh to KWh. Then, multiply this by the additional cost per KWh.

Lastly, take the number of commercial and industrial customers — this is found in Tab 3 "Retailers" in your EIA state dataset — and you will have the average cost per commercial and industrial user.

Obviously, this is a rough metric because some industries are much more energy-intensive than others, but it is a useful tool.

A. Jobs

One of the main talking points for renewable energy advocates is job creation. One thing to keep in mind for these jobs numbers is that they are almost always artificially inflated.

Artificially inflated "clean jobs" numbers: Most claims about "clean energy jobs" come from one report, the "Energy Employment Report By State."[30] In that report, the largest segment of "clean jobs" in each state is in energy efficiency, which counts jobs in HVAC (heating, ventilation, and air conditioning) and window installation. These jobs would exist without renewable energy on the grid at all, and most jobs in the wind and solar industry are temporary construction jobs.[31] You can also reference the section "Renewable Energy Jobs are Temporary Construction Jobs," in Doubling Down on Failure, for more ideas.

Job losses from high electricity prices: High electricity prices reduce the ability of companies to hire and retain employees. High electricity prices also make it difficult for companies to increase compensation for their current employees. Using the economic modeling software IMPLAN, you can estimate the number of jobs lost due to higher electricity prices.

IMPLAN software licensing is state-specific, so you will need to purchase the license for your state, which usually costs $6,000. If you decide this is worth the investment, American Experiment will work with you to help calculate job losses.

If you do not have the desire or resources to purchase an IMPLAN license, here are a few suggestions:

Manufacturing jobs: Manufacturers are often classified as industrial users, so if you take the extra cost incurred by industrial electricity consumers divided by the average manufacturing wage in your state (your local manufacturers association should have this information) you can approximate the number of manufacturing jobs lost due to higher costs.

Commercial jobs: Commercial job losses can be calculated using the same methodology for industrial consumers of electricity.

B. No Environmental Benefits: Calculating Temperature Changes as a Result of Renewables

As strange as it may seem to hear, switching to renewable energy will have no measurable impact on global temperatures or traditional air pollutants like nitrous oxide, sulfur dioxide, lead, ozone, or particulate matter.

Impact on future global temperatures: To calculate the impact these policies would have in your state, you will look at the purported impact of the Obama administration's Clean Power Plan, widely considered to be his signature climate change initiative.

The Clean Power Plan would have averted 730 million metric tons of carbon dioxide per year when fully implemented.[32] According to the Obama administration's climate models, this regulation would have averted 0.019 degrees C by 2100, an amount too small to be measured.[33]

To determine the impact of these policies on global temperatures, go to the "Emissions" tab in our model and see the amount of global warming that would be averted by 2100 if carbon dioxide emissions were reduced by a given amount (in tons). This number will be automatically calculated for you.

Fails a cost-benefit analysis

In the "Results" tab you will see the cost of reducing each ton of carbon dioxide from the atmosphere. This is important, because both the Trump administration and the Obama administration have attempted to quantify the economic damages, in dollars, incurred by releasing one ton of carbon

TABLE 5

Obama: Social Cost of CO_2 (in 2007$ per Metric Ton)

The Obama Administration attempted to quantify the economic damages of each ton of carbon dioxide in the atmosphere. However, these models were vulnerable to user manipulation.

Year	5% Average	3% Average	2.5% Average	High Impact (3% 95th percentile)
2015	$11	$36	$56	$105
2020	$12	$42	$62	$123
2025	$14	$46	$68	$138
2030	$16	$50	$73	$152
2035	$18	$55	$78	$168
2040	$21	$60	$84	$183
2045	$23	$64	$89	$197
2050	$26	$69	$95	$212

SOURCE: TECHNICAL SUPPORT DOCUMENT: TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866 (MAY 2013, REVISED AUGUST 2016)

dioxide into the atmosphere. This metric is called the Social Cost of Carbon (SCC).

While the Obama administration was aggressive in using this metric, research from The Heritage Foundation shows the statistical models on which the Obama administration relied to estimate the SCC are highly prone to user manipulation and thus not credible tools for policymaking.[34]

Some states, like Colorado and Minnesota, have adopted their own SCC estimates, but in all likelihood your state has not, so you will use those established by the Obama administration and the Trump Administration to demonstrate that the costs of these policies outweigh the benefits.

You probably won't be surprised to learn that the Trump administration and the Obama administration have come to very different answers on what the social cost of carbon should be. Table 5 is from the U.S. Environmental Protection Agency and shows the Obama administration's SCC values.[35]

Table 6 shows the SCC produced by the Trump administration, which is much lower than the values presented by the Obama administration.

Why the Trump administration numbers are more credible

Unlike the Trump administration, the Obama Administration calculated the global "benefits" of reducing each ton of carbon dioxide, rather than using an SCC value that reflected only the costs and benefits to the United States. This method inappropriately forced Americans to pay a disproportionately high cost for benefits that would be globally disbursed, putting American industry and workers at a disadvantage relative to their global peers.

The Trump administration's SCC value reflects only the costs and benefits of reducing carbon dioxide (CO^2) to the United States, and it also uses more realistic financial assumptions that were recommended by the federal Office of Management and Budget.[36]

For your purposes, the Trump administration's values will more closely reflect the SCC for your state. However, in all likelihood, the cost of reducing each ton of CO^2 using wind and solar in your state will exceed even the Obama administration's SCC values.

TABLE 6

Trump: Social Cost of CO_2 (in 2016$ per Metric Ton)

The Trump Administration determined the social cost of carbon was much lower than the Obama administration.

Year	3% Average	7% Average
2015	$6	$1
2020	$7	$1
2025	$7	$1
2030	$8	$1
2035	$9	$2
2040	$9	$2
2045	$10	$2
2050	$11	$2

NOTE: THESE SC-CO^2 VALUES ARE STATED IN $/METRIC TON CO^2 AND ROUNDED THE NEAREST DOLLAR. THESE VALUES MAY BE CONVERTED TO $/SHORT TON USING THE CONVERSION FACTOR 0.90718474 METRIC TONS IN A SHORT TON FOR APPLICATION TO THE SHORT TON CO2 EMISSION IMPACTS PROVIDED IN THIS RULEMAKING. SUCH A CONVERSION DOES NOT CHANGE THE UNDERLYING METHODOLOGY NOR DOES IT CHANGE THE MEANING OF THE SC-CO^2 ESTIMATES. FOR BOTH METRIC AND SHORT TONS DENOMINATED SC-CO^2 ESTIMATES, THE ESTIMATES VARY DEPENDING ON THE YEAR OF CO^2 EMISSIONS AND ARE DEFINED IN REAL TERMS, I.E., ADJUSTED FOR INFLATION USING THE GDP IMPLICIT PRICE DEFLATOR.

Traditional pollutants

Not only will renewable energy have no perceptible impact on future global temperatures, it will have minimal impact on traditional pollutants like nitrous oxide, sulfur dioxide, lead, ozone or particulate matter.

The environmental agency in your state will likely have data showing air pollution trends over time. These data are collected at EPA sampling sites. If your state does not have these data readily available, you can go to the Environmental Protection Agency's website Our Nation's Air, which shows that the United States has made dramatic improvements in air quality since 1990.[37]

You can also graph pollution reductions at individual power plants in your state using the EIA Electricity Data Browser.[38] You can click on your state to get a more granular look at the energy production and emissions of each individual plant, comparing MWh generation with sulfur dioxide and nitrous dioxide emissions. This aspect of the data browser is currently in the beta phase and may have complications from time to time. It's a government website, after all.

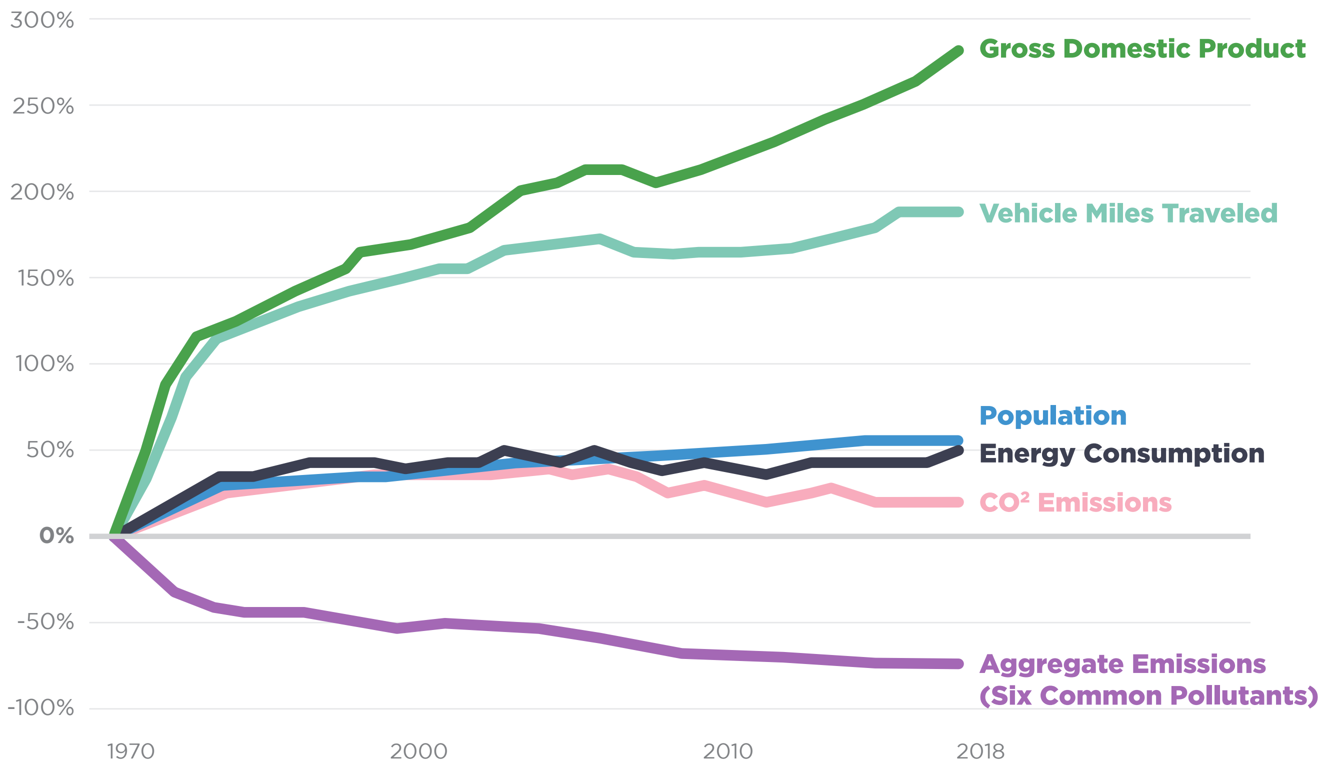
It is important to talk about these traditional pollutants as well. Environmental groups often like to talk about increasing incidences of asthma and respiratory diseases as a reason to close down coal-fired power plants, but virtually every location in the country meets the air quality standards established by EPA to protect human health.

In fact, many places have such good air quality that the economy-wide shutdowns that were implemented to slow the spread of coronavirus had no measurable impact on air quality despite a 40 percent reduction in traffic. This occurred in Minnesota (as you can see in Figure 13) and several other areas of the country.[39,40]

If shutting down much of the economy to

FIGURE 12

Comparison of Growth Areas and Declining Emissions



SOURCE: U.S. ENVIRONMENTAL PROTECTION AGENCY

slow the spread of COVID-19 does not produce measurable improvement in air quality, then it is unlikely that closing down existing coal or natural gas plants will make any meaningful impact on air quality in your region of the country.

Indoor air quality is worse than outdoor air quality

Outdoor air quality in the United States is already very good. In the last several years, a growing body of scientific evidence has indicated that the air within homes and other buildings can be more seriously polluted than the outdoor air in even the largest and most industrialized cities.[41] Other research indicates that people spend approximately 90 percent of their time indoors. Thus, for many people, the risks to health may be greater due to exposure to air pollution indoors than outdoors.

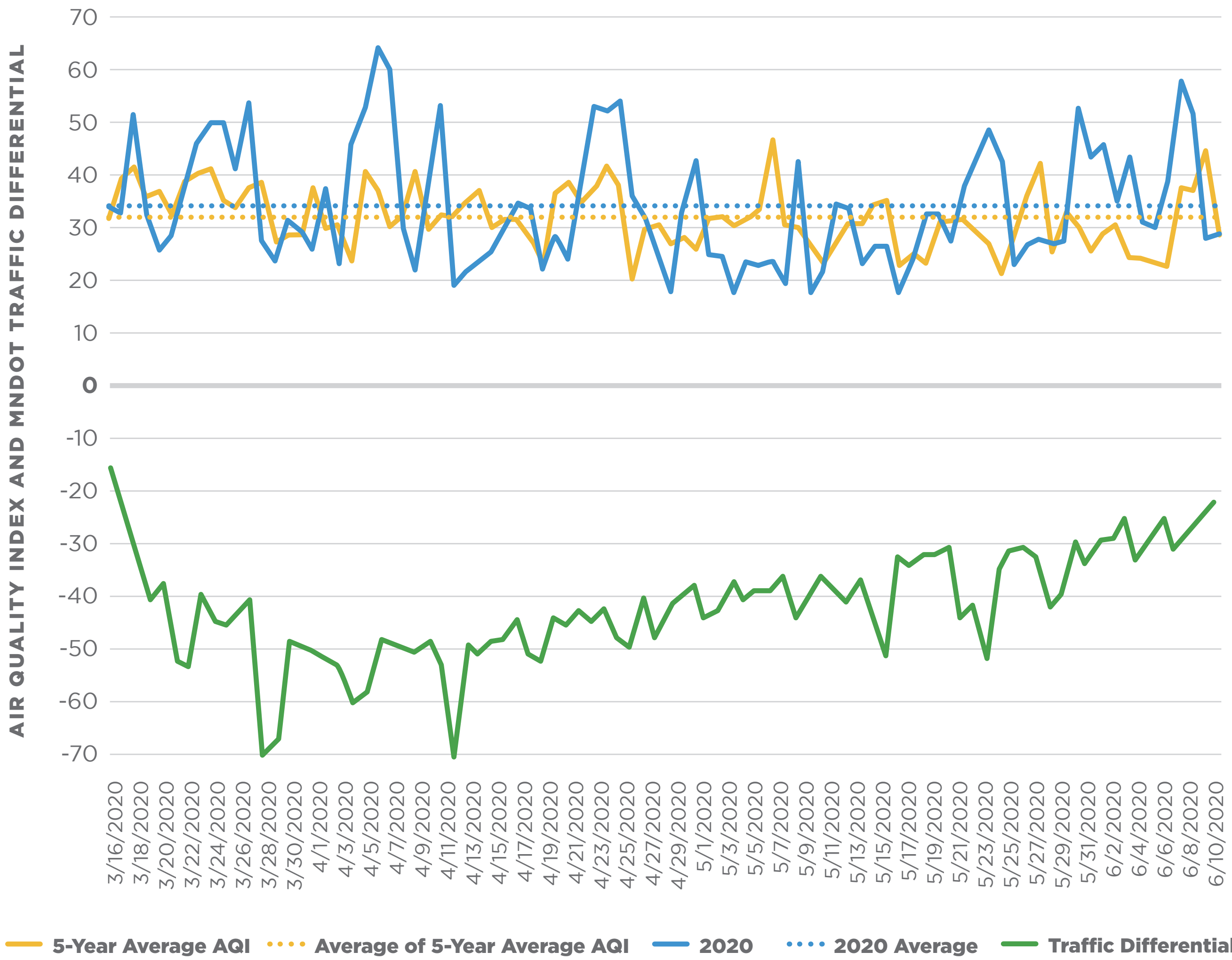
In addition, people who may be exposed to indoor air pollutants for the longest periods of time are often those most susceptible to the effects of indoor air pollution. Such groups include the young, the elderly, and the chronically ill, especially those suffering from respiratory or cardiovascular disease.

It can therefore be credibly argued that poor ventilation and indoor air quality likely play a larger role in certain illnesses than outdoor air quality. ■

FIGURE 13

Air Quality in Hennepin County 2020 vs 5-Year Average with Traffic Differential

EPA air monitoring data show air quality in Minnesota was actually slightly worse during the COVID-19 shutdowns than the previous five-year averages.



SOURCE: U.S. ENVIRONMENTAL PROTECTION AGENCY DATA AND MINNESOTA DEPARTMENT OF TRANSPORTATION TRAFFIC DATA

Conclusion

Increasing electricity prices are ultimately a regressive increase in the cost of electricity on families and businesses in your state. Seniors and low-income households are hardest hit because the cost of energy makes up a relatively larger percentage of their income than other groups.

Using our models, you will be able to demonstrate that renewable energy mandates increase the cost of electricity without adding any measurable benefit to the environment. The economic harm imposed by renewable energy mandates and the resulting higher electricity prices is vast, and the environmental benefits are scientifically undetectable.

This guide will be a helpful tool for calculating the cost of electricity in your state, and conveying the negative impact higher prices will have to the general public. ■

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