Radical Reorganization of Colorado's Electric Grid: The Cost of Keeping the Lights On

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Executive Summary

Climate change is "an existential threat to our security, our health, our economy, our public lands and ecosystems, and our very way of life," said Colorado Governor Jared Polis to the House Select Committee on Climate Crisis at an August 2019 meeting in Boulder.[1]

It didn't take long for the Governor and his fellow Democrats to act on what they perceive as an "existential threat." But their actions will come at a very high price for every Colorado family and have virtually no impact on the global issue of climate change.

Since Colorado Democrats took control of both the executive and legislative branches following the 2018 elections, Polis, his administration, and Democrat state lawmakers have passed several energy bills and initiatives, and in May, the Governor released his roadmap with the stated goal to quickly reorganize how Colorado generates electricity – namely, to generate all of the state's electricity with renewable energy sources (i.e., wind, solar, and batteries) by 2040 in order to lower Colorado's carbon emissions.

Missing from it is the cost that will be passed on to generations of Colorado ratepayers.

This is not the first time Governor Polis has failed to provide a price for his grandiose ideas. As a candidate for Governor in 2017, he ran on the goal of transitioning Colorado to 100 percent renewables by 2040, promising savings through lower energy bills but also failing to calculate the real costs with such a transition. Prior to the 2018 gubernatorial election, the Independence Institute commissioned an Energy Ventures Analysis study titled, *The Cost and Impact of a 100 Percent Renewable Energy Portfolio Standard* to quantify Governor Polis' renewable energy campaign promise. The study priced it at nearly $45 billion.[2]

This paper builds on that EVA study and presents a more detailed and extensive analysis on Governor Polis' goal of 100 percent renewables by 2040. It quantifies what Governor Polis did not calculate in his roadmap: the cost that Coloradans will have to pay for this massive reorganization of how our state powers our homes and businesses for generations to come.

The costs are significant, while the benefits are negligible:

- Build out of wind and solar – $33.5 billion
- Premature retirement of baseload hydrocarbon power plants – $7.6 billion
- Transmission lines – unknown but likely hundreds of billions of dollars
- Battery storage – $900 billion to $4 trillion
- Total – $941 billion +
- Significant job loss
- Virtually no global environmental benefit

The Colorado Demography Office predicts our state's population will be eight million by 2040.[3] So do the math. Even with this significant increase in population, the cost of reorganizing the way Colorado is powered could be nearly $120,000 for every man, woman, and child or close to a half million dollars – $480,000 – for a family of four.

Electricity is a necessity in today's high-tech society; it intimately touches all of us. Therefore, the cost of this new system should require disclosure, or better yet, allow Coloradans to vote directly on whether or not they want to invest their hard-earned dollars in renewable energy and utility-scale storage.

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Because of the immense price of transitioning to renewable energy in both dollars and jobs, Colorado should consider other alternatives to reducing energy related carbon emissions. We propose two.

First, Colorado should entertain adding nuclear power to its generating portfolio. Upfront costs for nuclear are high and the regulatory framework is stringent, but its high efficiency and reliability, low operating and maintenance costs, reduced land needs and zero carbon emissions makes nuclear an economically attractive alternative to industrial wind, solar and battery storage.

The second option, and the more free market option, is to consider incentivizing microgrids. Microgrids put individuals or small self-selecting groups in charge of their own investments and generation, which would create wealth for individuals versus the enrichment of Colorado's investor-owned utilities. Currently, adopting microgrids would be expensive, but they come with avoided costs and are an investment in individuals – an unquantifiable but noteworthy consideration.

Admittedly, this study is imperfect. Likely we've left out important costs and cost savings. But that's the point. There are expenses associated with this transition that we don't and really can't know. Our goal is simply to highlight some of them and encourage others to ask important questions *before* elected officials commit Colorado ratepayers to pay for it.

What Polis and his supporters are suggesting is an extreme transformation with an associated extreme net price and little climate change benefit. If elected officials are going to reorganize so radically how Colorado powers its economy and homes in the 21st century, then those same officials have a responsibility to share with Coloradans how much it will cost and consider more cost-effective alternatives that achieve the same goal of lowering carbon emissions.

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Introduction

The Centennial state is well known for its vast coal reserves and its status as a leader in natural gas production.[4] Despite the favorable economics underpinning these resources, many lawmakers and some of the public have been pushing them aside for intermittent energy sources, which for the most part have been industrial wind and solar power generation.[5] In 2004, Colorado was the first state in the nation to pass a constitutional amendment for a Renewable Portfolio Standard (RPS), mandating Investor Owned Utilities (IOU's) generate a minimum of 10 percent of their electricity from renewable sources (Amendment 37).[6] Since then, the mandate has increased from 10 to 20 to 30 percent. First under Governor Bill Ritter's New Energy Economy, the standard went from 10 to 30 percent, and more recently, Governor Polis has embraced the aggressive goal of 100 percent by 2040.[7]

Table 1: Projected Energy Portfolio Under Governor Polis' Plan (2040)

Capacity Type	Current Capacity	Capacity Under 100% Renewables by 2040
Electricity Generation Capacity		
Solar	418 MW	16,858 MW
Wind	3023 MW	12,110 MW
Coal	5129 MW	N/A
Natural Gas	6064 MW	N/A
Oil	168 MW	N/A
Hydro	687 MW	687 MW
Nuclear	N/A	N/A
Back-Up Capacity		
Storage	N/A	10,000 MW

Source: Energy Ventures Analysis, ***Cost and Impact of a 100 Percent Renewable Energy Portfolio Standard for the State of Colorado***, Independence Institute IP-6-2017, December 2017.

According to Colorado statute, renewable energy sources include small hydroelectric (10 MW or less), geothermal, anaerobic digestion, coal mine methane, landfill gas, recycled energy, woody biomass, and pyrolysis power generation.[8] However, this report assumes Governor Polis intends for a build out of industrial wind, utility-scale and distributed solar, and in-front-of-the-meter, utility-scale storage facilities.

The reason for the massive fuel switching is that the Democrat majority in the General Assembly and Governor Polis want Colorado to reduce its carbon footprint.

The recently signed House Bill 1261 establishes the goal of reducing economy-wide carbon emissions 90 percent from 2005 levels by 2040. This will be an immense lift, as Colorado's 2005 carbon footprint measured at 96.8 million metric tons with a population of 4.656 million people, roughly 20.4 metric tons per capita.[9] To achieve the Democrats' 90 percent reduction goal means that Colorado will have to cut 87.12 million metric tons of CO_2. With a projected population of 8 million people in 2040, it translates into about 1.21 metric tons per capita – a drastic change compared to 2005's 20.4 metric tons per person.

To put 1.21 metric tons per capita into context, that would put Colorado in the same emissions range with Tonga but behind Moldova. According the World Bank, Colorado also would be behind economically challenged countries like Syria and Cuba at 1.6 and 3.1 metric tons respectfully.[10]

New studies also reveal the substantial cost of drastically reducing CO_2 emissions. Despite this, Democrats and Governor Polis have plowed ahead and passed a raft of green bills (See Appendix One) in order to further their climate change agenda.[11]

The focus of this study, however, is electricity generation and the cost of achieving the 100 percent renewable energy goal set by Governor Polis. Interestingly, elected officials (including the Governor), and Xcel Energy, Colorado's largest IOU serving over 1.4 million ratepayers, seem to be at odds over a grid powered only by renewable sources and industrial storage facilities. Xcel is not convinced that Polis' radical plan is possible, although the utility does say it can

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reduce carbon emissions through natural gas and potentially nuclear.

> *"There is a difference," Fowke (Xcel CEO) said. "I like to listen to science, and scientists today will tell you that on a big grid, not an individual community or home or business, 65, 70 percent renewables is probably the most we can do."*[12]

Nevertheless, Governor Polis insists on 100 percent renewables, stating in the press release about his roadmap to 100 percent renewable energy:

> *"This [his roadmap to 100 percent renewable energy] is our plan for creating a pathway to 100 percent renewable energy in our state, creating good green jobs that can never be outsourced, and saving people money on electricity."*[13]

...even a country such as Iceland, which generates 99 percent of its electricity from lower-cost renewable sources like hydroelectricity, still relies on fossil fuel generation despite their best attempts and stated goals.

Nowhere in the world has such a policy been attempted successfully in such a short time frame. For example, even a country such as Iceland, which generates 99 percent of its electricity from lower-cost renewable sources like hydroelectricity, still relies on fossil fuel generation despite their best attempts and stated goals.[14] Remember, Colorado does not include large scale hydropower as a renewable resource.

As Governor Polis has laid out, his roadmap for a radical reorganization of the grid to 100 percent renewables by 2040 provides no figures and no support for his cost-savings claims.[15] In fact, all evidence points to the contrary. This very costly policy is untested at best and fiscally devastating at worst. It has the potential to bankrupt the state and send residents fleeing to other states as economic refugees.

This report is focused on the two things the Polis plan leaves out – the cost of an electric grid powered predominately by wind, solar, and storage facilities and the resultant financial impact on Colorado residents. Aside from that, it also includes recent legislation passed by the Democrat majority in the state legislature as well as examines two alternative routes the Governor and lawmakers should consider. One would be better for the economy and both would accomplish the same goal – reducing the electric grid's carbon footprint.

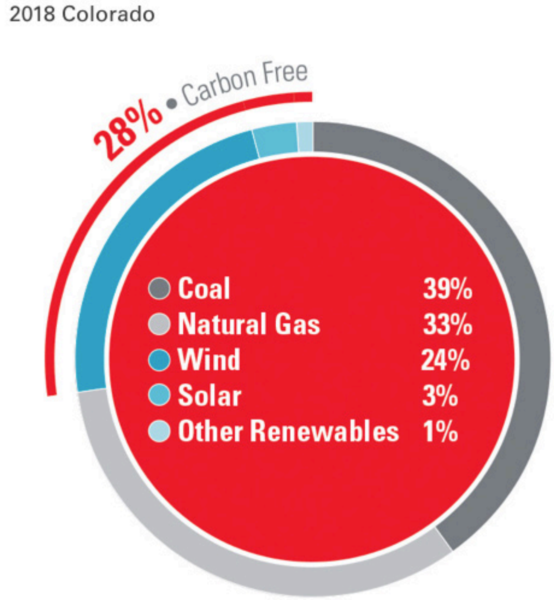
Colorado Energy Portfoliio

Since 2004, first voters and then Colorado elected officials have pushed the state toward a grid with more and more intermittent sources. None, however, has gone as far as the current Polis administration. The overly ambitious nature of his goal becomes evident upon analyzing Xcel Energy's current power generation breakdown:

- Coal – 39 percent
- Natural gas – 33 percent
- Wind – 24 percent
- Solar – 3 percent
- "Other Renewables" – 1 percent[16]

Seventy-two percent of the utility's generated electricity comes from fossil fuels, with renewables (predominantly industrial wind) making up the remaining 28 percent.

Figure 1: Xcel Energy: Colorado Portfolio (2018)



Xcel Energy's Colorado power generation portfolio. **Source:** Xcel Energy Inc., "Power Generation: We produce the power that keeps your lights on."

The breakdown of Colorado's installed, nameplate electricity can be seen in Table 2.

Table 2: Colorado Energy Profile: Nameplate Capacity By Source

Capacity Type	Current Capacity
Solar	418 MW
Wind	3023 MW
Coal	5129 MW
Natural Gas	6064 MW
Oil	168 MW
Hydro	687 MW
Nuclear	N/A

Table 2 Data is from Energy Venture Analysis. **Source:** Energy Ventures Analysis, ***Cost and Impact of a 100 Percent Renewable Energy Portfolio Standard for the State of Colorado***, Independence Institute IP-6-2017, December 2017.

Fossil fuels account for most of Colorado's electricity, with approximately 11,361 MW, wind follows with 3,023 MW and the remaining capacity is made up of hydro and solar.

It is important to understand that nameplate capacity is the "maximum rated output of a generator…or other electric production equipment under specific conditions…"[17] For intermittent sources like wind and solar that must rely on weather conditions, the "nameplate capacity" is the generating capacity under prime weather conditions. Since perfect weather conditions aren't always available, wind and solar are considered to have a low capacity factor unlike fossil fuels which have a high capacity factor. Meaning wind and solar cannot be expected to sustain power generation close to their nameplate capacity over a period of time.

These numbers demonstrate Colorado's dependency on fossil fuels, which according to former Democrat Governor John Hickenlooper, generate clean electricity and provide good paying jobs.[18]

Colorado is blessed with an abundance of natural resources such as coal, natural gas, and oil among others.[19] Specifically, it has approximately 129 billion tons of potentially mineable coal reserves, placing it 4th in the entire country.[20] In terms of natural gas, it has the 6th largest reserves

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in the country and is among the top five natural gas producing states.[21] Estimates are that in 2015, the natural gas industry alone contributed $31 billion to the state.[22]

Despite this, Governor Polis and Democrat lawmakers also passed bill SB19-181, which could reduce new drilling and oil and natural gas production across the state, killing tens of thousands of jobs and losing billions in tax revenues.[23]
While this paper doesn't focus on energy development, the passage of SB19-181 does show how Colorado Democrats are more concerned with CO_2 emissions than economics. It also provides a glimpse into why maybe the Polis administration has not provided any costs.

The Costs of a Renewable Grid

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So far, no industrialized country powers its grid with 100 percent renewables. Advocates are banking on technological advances to get Colorado there. Regardless, the path will impact Coloradans' pocketbooks for generations to come.[24]

A study by the Energy Policy Institute at the University of Chicago (EPIC) found that:

> *"…electricity prices increase substantially after RPS adoption. The study found that RPS mandates cause electricity rates to rise by 11 percent within seven years and by 17 percent within 12 years.*
>
> ***The largest burden of RPS laws falls not on businesses, the study found, but on residential ratepayers.*** *The cumulative effect seven years after the passage of the legislation initiating an RPS, consumers in the 29 states studied had paid $125.2 billion more for electricity than they would have in the absence of the policy."*[25]

The $125.2 billion figure the EPI study cites pales in comparison to the amount that Coloradans might be forced to pay. Governor Polis says his plan promises to deliver savings, but experts say this could be based on analysis that omitted key factors such as stranded costs, interconnection costs, and operations as well as maintenance among others.[26]

Further, Colorado's electric rates are on the rise and the initially agreed upon bid prices for Xcel Energy's *Colorado Energy Plan* have been found to be too low.[27] What appeared to be unrealistic was in fact, unrealistic.

Although not a single accurate figure exists regarding the total cost of a carbon free grid powered by renewables, we can assess the various elements involved in attempting to build such an electric grid and try to price out each one individually to find a total cost. To reach 100 percent renewables by 2040 would require the addition of approximately 27,427 MW of wind, utility solar, distributed generation, and battery capacity at a $941 billion plus cost to Coloradans.

Achieving what Governor Polis most likely considers to be a renewables only electric grid, powered predominantly by industrial wind, solar, and batteries, is a mammoth task that has yet to be achieved in any U.S. state or country in the world. In other words, Colorado ratepayers will be test subjects.

This section of the report is focused on the cost implications, direct and indirect, of powering the state's electric grid with renewable energy generation plus storage. Below is a non-exhaustive list of the various 'cost' factors that need to be considered when trying to accomplish Polis' objective. Each will be discussed in more detail below.

- Addition of wind, solar/distributed generation capacity
- Battery storage capacity
- Curtailment and cycling
- Job losses from shutting down coal/oil and gas plants, impact on taxes for state, lost revenue for state from oil and gas royalties
- Cost of new transmission lines/interconnection issues/eminent domain
- Premature retirement of fossil fuel stations/stranded costs

Additional wind capacity

As of December 2016, Colorado had 3,023 MW of wind capacity. EVA's projections show that Colorado would require at least 9,087 MW of additional wind capacity to meet the "100 by 40" target. This figure considers the capacity already under development as well as other proposed projects that account for roughly 800 MW of capacity. Colorado would need to effectively triple its wind capacity in 20 years' time, and this accelerated timeline means that dozens of current and new projects would have to be completed in a relatively short time span.

Most importantly for Colorado residents, the cost of adding this additional wind capacity (only until 2040) is estimated to be roughly $9.7 billion. For perspective, Colorado's Department of Education spent just over $7 billion on all school districts in 2018 and the entire budget for the state of Colorado for the 2018-19 financial year is $30.63 billion.[28] Adding new wind capacity of only 9,087 MW to the grid would cost just over 1/3 or approximately 32 percent of the state's annual budget.

Another major cost to adding wind capacity is the associated transmission lines. A study by the Edison Electric Institute (EEI) found that:

> *"65% of a representative sample of all planned transmission investments in the U.S. over a ten-year period, totaling almost $40 billion for 11,400 miles of new transmission lines, were primarily directed toward integrating renewable generation."*[29]

A separate study across the U.S. on the cost of adding wind capacity to the grid found a wide range of figures.[30] They ranged from $0 (projects close to existing transmission) to $2,000/kW with a median cost of approximately $300/kW. Thus, building transmission lines to the additional 9 GW of wind capacity in Colorado could potentially cost billions of dollars.

For comparison, Xcel's 600 MW Rush Creek Wind Farm required an 83-mile, 345 kilovolt (kV) transmission line (with two substations) at a cost of $120 million.[31]

There are too many variables to generalize the final cost of transmission lines for new renewable energy capacity in Colorado. These variables include the nameplate capacity of the project; voltage of the line; substations' distance to load centers (i.e. where is the project site relative to the end users); and the terrain on which transmission lines are built.[32] But the cost is likely to be very high.

Research from the *Wall Street Journal* (WSJ) shows that integrating wind onto the grid is challenging for several other reasons, also with cost implications, including:[33]

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- **Eminent domain:** Wind farms tend to be built a long distance from their end users meaning high voltage and long-distance transmission lines are often required. They typically need to cross numerous properties once built and this poses legal challenges for the utilities and land/property owners.
- **Generation Curtailment:** Wind resources can also peak when electricity demand is lowest. This leads to the necessary curtailment of a wind farm's generation output. For example, its output must be suppressed because at points during the day or in the middle of the night, there is little to no demand for electricity. In extreme cases, the wind farm is required to completely stop providing electricity. This will be discussed fully in a separate section below.
- **Low capacity factor:** A powerplant's capacity factor is the ratio between what it is capable of generating versus its actual generation output over a period of time.[34] Wind energy is a variable resource and typically operates at a capacity factor of 30 percent.[35] Said a different way, a windfarm such as Xcel's Rush Creek will not always produce electricity at its full nameplate capacity of 600 MW.
- **Decommissioning/recycling:** Decommissioning is the process of returning a site to its preconstruction state and removing the power station equipment. The cost of decommissioning wind farms is typically part of the overall cost of the project thus states/local governments generally do not have to pay for this. The author of a Texas Law Review article analyzed different reports to arrive at a per turbine cost. He found that it can be as high $55,308 per turbine and reported that the average net decommissioning cost is around $25,500 per turbine. This figure considers the resale/scrap value of turbines.[36] For perspective, Xcel's Rush Creek wind farm has 300 turbines with a decommissioning cost of $7.6 million.[37]

Another issue which affects the cost of wind farms (and renewables in general) is land, whether it is purchased outright or leased from landowners. The Union of Concerned Scientists list land/siting as one of the major barriers to renewables: "Siting is the need to locate things like wind turbines and solar farms on pieces of land. Doing so requires negotiations, contracts, permits, and community relations, all of which can increase costs and delay or kill projects."[38]

The EVA study assessed land use requirements. Using 49 acres/MW as a baseline, a total of 776,842 acres of land in Colorado will be required by 2040 to build 16.4 GW of renewable capacity.[39] For comparison, Xcel's Rush Creek wind farm used 95,000 acres of land for 600 MW which works out to 158 acres/MW.[40] This does not include the land needed for burial once the turbines' blades are decommissioned.

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Additional utility solar and distributed capacity

The EVA study predicts that Colorado will need approximately 9,457 MW of utility solar.[41] There is no singular definition for utility solar but generally: "A utility-scale solar facility is one which generates solar power and feeds it into the grid, supplying a utility with energy."[42] Similarly, there is no fixed size for what constitutes utility solar with ranges from over 1 MW all the way up to 50 MW.

Table 3: The breakdown of land use required for renewable energy generation in Colorado.

LAND USE REQUIREMENTS FOR RENEWABLE ENERGY DEVELOPMENT (ACRES)					
Policy	2020	2025	2030	2035	2040
Existing RPS	210,096	240,319	252,649	265,614	279,247
Scenario 2 100 percent RPS	216,777	317,947	431,357	587,635	776,842
Incremental Acreage Requirements for Scenario 2 RPS	6,681	77,629	178,078	322,021	497,596

Source: Energy Ventures Analysis, ***Cost and Impact of a 100 Percent Renewable Energy Portfolio Standard for the State of Colorado***, Independence Institute IP-6-2017, December 2017.

According to EVA, Colorado will also need roughly 6,983 MW of distributed generation or rooftop PV. Distributed generation is defined as "Electricity produced at or near the point where it is used. Distributed solar energy can be located on rooftops or ground-mounted and is typically connected to the local utility distribution grid."[43]

Figure 2 shows a projection on how Colorado might ramp up electricity production from utility solar and rooftop PV between now and 2040. If 16.4 GW of new solar capacity is added onto the grid between now and 2040, solar would account for 54 percent of Colorado's electricity generation. This is a major leap from the current position where solar is used to generate a minimal one percent of Colorado's electricity at 418 MW. Colorado would have to go from 418 MW to 16,400 MW in effectively 20 years to hit the 2040 target as currently set. The EVA study suggests that the baseline cost is $12.4 billion for 9,457 MW of utility solar and $10.4 billion for 6,983 MW of rooftop PV for a combined cost of almost $23 billion.

Integrating such a large amount of solar on the grid comes with several other challenges, as summarized by Table 4. Many of them stem from the intermittency of solar energy.[44]

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In simple terms, the sun does not always shine and when it does, it is during the day. It is therefore not always easy to predict how much output any given solar power plant (or rooftop PV) will produce in relation to its nameplate capacity.

Figure 2: Solar Generation of 100% RPS Compliance

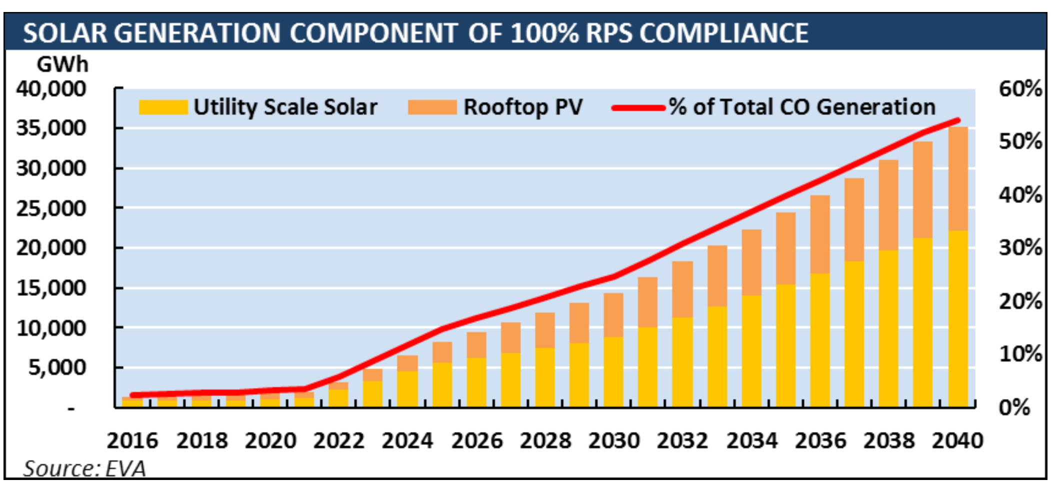

Figure 2 Graph displaying required solar generation capacity to achieve Colorado's 100 percent RPS. **Source:** Energy Ventures Analysis, ***Cost and Impact of a 100 Percent Renewable Energy Portfolio Standard for the State of Colorado,*** Independence Institute IP-6-2017, December 2017.

Table 4: Characteristics of PV Electricity Generation and Associated Integration Challenges

Solar Characteristic		Potential Economic Challenge to Integration: Energy Value & Curtailment	Potential Economic Challenge to Integration: Capacity Value
Variability	PV output can vary as underlying resource fluctuates.	Supply/demand mismatch coupled with generator inflexibility leads to curtailment.	PV may not be able to replace conventional capacity during periods of peak demand.
Uncertainty	PV output cannot be predicted with perfect accuracy.	Part-load operation of thermal plants for operating reserves leads to curtailment.	Capacity needed for provision of operating reserves.
Non-synchronous generation	PV does not currently help maintain system frequency.	Part-load operation of thermal plants for provision of frequency response leads to curtailment.	Capacity needed for provision of frequency response.

Table 4 Paull Denholm, Kara Clark, and Matt O'Connell, ***Emerging Issues and Challenges in Integrating High Levels of Solar into the Electrical Generation and Transmission System,*** National Renewable Energy Laboratory, May 2016.

plant (or rooftop PV) will produce in relation to its nameplate capacity.[45]

This is one of the major challenges and costs associated with solar (and renewables in general), that they require backup generation when the sun doesn't shine and when the wind doesn't blow. Typically, the backup generation is in the form of natural gas power plants.[46] However, in Colorado's case, fossil fuels are not an option because of the complete movement away from hydrocarbon powered electricity. Thus, battery storage will be required to ensure that the grid stays perfectly balanced.[47] Storage at both the residential and industrial level will be discussed in more detail later in the report.

As it stands, adding solar and wind capacity would cost Colorado a minimum of $33.5 billion until 2040 (excluding other additional costs described through-out this report). This amount eclipses the entire state's budget by roughly $2 billion dollars. Without full disclosure from the Polis administration on how these costs would be accounted for, Colorado ratepayers are in for a shock as some of the true costs emerge.

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Battery storage and back-up generation

Unlike other commodities, the amount of consumer electricity demand must always match the amount of electricity supplied. Lack of balance leads to brownouts or potentially blackouts.

A brownout is an intentional or unintentional drop in the voltage surging through an electric grid that usually occurs when demand is too high or during severe weather.[48]

Blackouts on the other hand are large- and small-scale electrical service breaks, known commonly as power outages. They can result from equipment failures or not having enough supply to meet energy demand, and they are sometimes purposely induced by electric utilities in order to reduce the strain on an overly taxed grid.

If intermittent renewables are not coupled with the appropriate battery storage or back-up generation, the risk of brownouts or blackouts will increase. Research shows that blackouts across the United states cost businesses and the economy approximately $164 billion annually. This doesn't include a social cost of not having power, including the inability to keep lifesaving

medical equipment running. Battery storage is therefore required to store the power generated through renewables, so theoretically power is available when needed.

Utility scale battery storage is in its infancy technologically, but we assume it will advance in the future and therefore commissioned a study by Dr. David Wojick to attach a cost to the battery storage capacity Colorado will need to meet Polis' 2040 target. Wojick's study was done in the absence of costs from the Polis administration for utility-scale battery storage. The study modeled two theoretical scenarios, one with 100 percent wind power and another with 50 percent wind power and 50 percent solar power. For the purposes of this report, we will consider the 50/50 scenario.[49]

Using 2018 Energy Information Administration (EIA) data, the cost of battery storage capacity was $1500 per kWh or $1.5 million per MWh. To calculate the total amount of capacity Colorado requires, the study assumed peak storage for wind power would be 24 hours per day, for seven days. In other words, the worst-case scenario where the wind does not blow for seven days. Peak storage for solar power is roughly half – three full days. To get to these figures, the study used data analyzing when and how much the wind blows as well as when the sun shines. The study also assessed all of Colorado's 140+ distribution utilities to find the state's peak demand – which is 10,000 MW – and used that figure for the calculations in Appendix Two.

Admittedly, the study is an extremely simplified version of the dozens of variables involved in calculating accurate figures around battery storage capacity costs. But the numbers begin to paint a picture of how exorbitant it will be to get the necessary battery storage capacity for Colorado. In total, it would cost Colorado at least $900 billion for roughly 1.2 million MWh of battery storage capacity (See Appendix Two).

For comparison, in 2015 Colorado consumed 77 billion kWh's of electricity in total or 77 million MWh's.[50] Multiplying 77 million MWh's by the battery storage cost of $1.5 million/MWh gives a number that looks like this on a calculator: **1.155e+14**, that means after 1.155 there are 14 zeros. In other words, $115,500,000,000,000.00 or $116 trillion (rounded up). If we generously assume that battery costs will decline by 50 percent over the next 10 years, the number becomes 5.775e+13 or $57,750,000,000,000.00 or $58 trillion (rounded up). **These may sound like science fiction type figures, but the Polis administration has refused to put pencil to paper and share with Coloradans what the costs are and how they are figured. Maybe we know why.**

Colorado will not have to store every MWh it uses in a given year, but the figures in the preceding paragraph at least help to rationalize the scale of Governor Polis' goal. The power sector is known for big numbers and expensive equipment, and battery storage technology possibly exemplifies these two characteristics the best.

If Colorado were to choose renewables without battery storage then elected officials and Colorado residents must be willing to accept the risk of blackouts, the resulting economic shutdown and loss of lifesaving power that will accompany them. Otherwise, Coloradans must be prepared to pay what could be trillions of dollars for a state transformation away from hydrocarbons in favor of industrial wind and utility-scale/distributed solar and battery backup.

These may sound like science fiction type figures, but the Polis administration has refused to put pencil to paper and share with Coloradans what the costs are and how they are figured. Maybe we know why.

Other battery costs that Wojick's study does not consider are line items like battery operation/maintenance, permitting fees, interconnection fees, etc. However, a National Renewable Energy Laboratory (NREL) study shows that these costs are also significant. For a model 60 MW lithium-ion battery storage system with a duration of between 0.5-4 hours, they can add up to $11,648,623.[51]

Clearly the Polis administration plans on Colorado being a trail blazer with this mandated movement to intermittent resources. The scale of storage systems required to meet Colorado's ambitious goals goes beyond the scale of anything in the United States or globally. As shown in Figure 3, large scale battery storage is still in its infancy. By 2040, the end date of Governor Polis' plan, the U.S. Energy Information Administration projects that there will be less than 40 gigawatts of storage system power capacity in the United States. If Colorado is to have at least 10,000 MW of storage power capacity, that means the state will have contained in its borders over 25 percent of the what's projected to be the storage power capacity in the country.[52]
In short, battery storage systems are expensive regardless of their falling price.

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A 60 MW, 4-hour duration, 240 MWh system is estimated to cost $91 million total, but there are dozens of unknown variables that will impact the price, some of which are:

- How much solar and wind will make up the generation mix
- What will Colorado's peak demand look like at the point storage is introduced
- Will there be any newer technology/ other ways to store energy
- How much will the cost of storage systems decrease

The final battery cost is undetermined, but it will have a lot of zeros. To not provide a cost for the public to consider ahead of this transition is reckless at best. Perhaps, getting Coloradans used to electricity curtailment would be cheaper. This quote from Josh Quinnell, a senior research engineer at the Center for Energy and Environment, clarifies the financial consideration:

> *"Additional capacity coupled with energy curtailment is considerably less expensive than, and a viable alternative to, long-term or seasonal storage in a high renewables future. Essentially,*

Figure 3: U.S. Large-Scale Wind, Solar, and Battery Storage Capacity Projections (2020-2050)

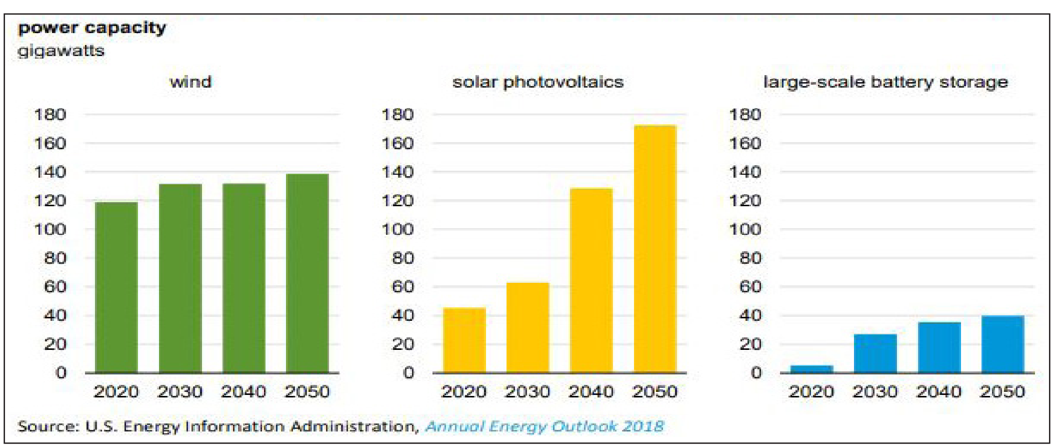


Figure 3 Projected wind, solar, and storage capacity in America from 2020-2050. **Source:** U.S. Energy Information Administration ***Annual Energy Outlook 2018 with projections to 2050***, February 2018.

it is cheaper to overbuild solar than it is to add enough storage to avoid curtailment."[53]

Curtailment and Cycling

One consequence of the current inadequate battery storage is curtailment. "Curtailment is the act of reducing or restricting energy delivery from a generator to the electrical grid."[54] There are two types of curtailment.

- Voluntary curtailment occurs when generators decide on their own to reduce their output. This typically happens in wholesale electricity markets in the form of negative pricing, when generators essentially have to pay to get their power onto the grid.[55]
- Involuntary curtailment occurs when "system operators faced with congestion overloads order wind producers to reduce their output or cease operations to preserve system reliability."[56] In other words, when there is more generation capacity than needed on the grid (low demand, high supply), system operators will typically ask wind (or solar) farms to stop producing power. This usually happens because baseload power plants such as coal cannot be turned on and off easily in comparison to renewable sources.

If the idea of curtailment sounds puzzling, that's because it is puzzling to pay wind and solar power generators not to generate power on top of all the subsidies they receive.[57] Striving for 100 percent renewables in Colorado will most likely require some form of curtailment until battery storage catches up because the combined generation from renewables cannot yet be stored economically using batteries. Thus, if there is an excess supply of wind or solar at any time, currently it will not be stored. The excess supply must be curtailed otherwise it can damage the grid.

Curtailment comes at a cost, typically the cost is included in the Power Purchase Agreement (PPA) between the renewable energy generator and grid operator. Data from Xcel (Table 5 and Table 6) show the potential costs for curtailing wind and solar:

Table 5 shows different scenarios and the anticipated costs of adding wind to the grid. For example, adding 300 MW of wind would result in a curtailment cost of $180,000 per year and adding 900 MW of wind would cost $1.7 million per year.

...if there is an excess supply of wind or solar at any time, currently it will not be stored. The excess supply must be curtailed otherwise it can damage the grid.

Table 5: Wind Power Curtailment Costs

			Incremental Over Baseline				
Scenario	Added Wind	Resource Zone	Wind Production (GWh/yr)	Cycling Cost Component ($Million)	Curtailment Cost Component ($Million)	Total Levelized Annual Cost ($Million)	Total Levelized Cost ($/MWh)
8	300 MW	North	1,070	$0.51	$0.18	$0.68	$0.64
9	600 MW	North	2,140	$1.19	$0.65	$1.84	$0.86
10	900 MW	North	3,211	$1.97	$1.69	$3.66	$1.14
11	300 MW	Central	1,022	$0.49	$0.18	$0.67	$0.66
12	600 MW	Central	2,043	$1.12	$0.64	$1.75	$0.86
13	900 MW	Central	3,065	$1.84	$1.66	$3.49	$1.14
14	300 MW	South	1,181	$0.47	$0.16	$0.64	$0.54
15	600 MW	South	2,363	$1.13	$0.62	$1.75	$0.74
16	900 MW	South	3,544	$1.96	$1.66	$3.62	$1.02

Table 5 Xcel Energy Services, Inc, ***Wind and Solar-Induced Coal Plant Cycling and Curtailment Costs on the Public Service Company of Colorado System***, May 2016.

> ...if Colorado has a surplus of renewable energy generation now (Appendix Four), when it accounts for only a fraction of the generation mix, it will be more challenging when wind and solar account for 100 percent of Colorado's generation mix.

In addition to curtailment, another cost involved is what is known as cycling. According to Xcel, "cycling is the operation of thermal electric generators at varying load levels, including on/off and low load variations, in response to system load requirements."[58] Besides curtailment, the other impact of excess renewable generation is cycling of baseload power plants (i.e., coal-powered generation) which are not designed for that purpose. In Xcel's own words:

> *"The inclusion of greater levels of variable generation sources such as wind and solar has forced a movement from the designed non-varying operation of the coal-fired generating units which can result in increased cycling-induced plant wear."*[59]

The cycling cost for adding 900 MW of additional wind to the grid is $1.97 million for a total annual cost (cycling and curtailment) of $3.66 million per year. Considering that Colorado will most likely require 9,087 MW of additional wind capacity, the cycling and curtailment costs add up quite significantly.

Table 6 shows different scenarios and the anticipated costs of adding fixed solar to the grid, which are significantly less than the costs of adding wind power. An additional 200 MW of solar would cost $90,000 per year (curtailment and cycling), a far cry from wind power's $3.66 million/year price tag.

There is no accurate way to predict how often and how much curtailment will occur in Colorado, but Table 7 gives a quick summary of the frequency and main reasons for curtailment from a sample of grid operators. In Colorado's case, one of the primary reasons for curtailment is oversupply, an issue which has already been discussed in the report. Logically, if Colorado has a surplus of renewable energy generation now (Appendix Four), when it accounts for only a fraction of the generation mix, it will be more challenging when wind and solar account for 100 percent of Colorado's generation mix.

Despite overgeneration often leading to curtailment, it is an issue that has not been explored as often as it should – especially when there are incentives for wind and solar farm owners to over generate. One such incentive is a federal subsidy known as the Production Tax Credit (PTC):

> *"The federal renewable electricity production tax credit (PTC) is an inflation-adjusted per-kilowatt-hour (kWh) tax credit for electricity generated by qualified energy resources and sold*

Table 6: Solar Power Curtailment Costs

			Incremental Over Baseline				
Scenario	Added Solar	Resource Zone	1st Year Solar Production (GWh)	Cycling Cost Component ($000)	Curtailment Cost Component ($000)	Total Levelized Annual Cost ($000)	Total Levelized Cost ($/MWh)
17	100 MW	NFR	137	$34	$9	$43	$0.33
18	200 MW	NFR	274	$69	$21	$90	$0.34
19	100 MW	SFR	161	$41	$11	$52	$0.34
20	200 MW	SFR	322	$84	$26	$109	$0.36
21	100 MW	SLV	169	$38	$10	$49	$0.30
22	200 MW	SLV	338	$72	$23	$95	$0.29
23	100 MW	WS	147	$28	$8	$37	$0.36
24	200 MW	WS	293	$62	$19	$81	$0.29

Table 6 Xcel Energy Services, Inc, ***Wind and Solar-Induced Coal Plant Cycling and Curtailment Costs on the Public Service Company of Colorado System***, May 2016.

Table 7: Reasons for Curtailment

Utility/Grid Operator	Wind and Solar Curtailment Levels Frequency	Primary Reasons for Curtailment
Alberta Electric System Operator (AESO)	Infrequent	Oversupply; transmission constraints, high wind ramps
Arizona Public Service (APS)	Infrequent	Local transmission outages or constraints
Bonneville Power Administration (BPA)	Varies by year; less than 2% of wind production	Balancing issues related to exhaustion of reserves; oversupply
California Independent System Operator (CAISO)	Infrequent; not tracked	Oversupply; transmission constraints, congestion
Electric Reliability Council of Texas (ERCOT)	Varies by year; 2% to 4% in 2012–2013, but higher in previous years	Transmission constraints; oversupply, new transmission lagged wind capacity
Southwest Power Pool (SPP)	Some wind generators report high levels	Local transmission constraints, expansion of wind outpaced new transmission build-out
Tucson Electric Power	Very infrequent	Local outages
Western Area Power Administration (WAPA)	None	None
Public Service Company of Colorado (PSCO)	1%–2% of wind generation	Oversupply; transmission constraints

Table 7 Table outlining the reasons for curtailment in North American electric grids. **Source:** Lori Bird, Jaquelin Cohran, Xi Wang, ***Wind and Solar Energy Curtailment: Experience and Practices in the United States,*** National Renewable Energy Laboratory, March 2014.

by the taxpayer to an unrelated person during the taxable year."[60]

Stated otherwise, wind farm operators get paid by the government to produce wind power. Currently, the credit is set at 1.9c/kWh for the first decade of the wind farm. Research by the Heartland Institute shows that more than half of a wind farm's capital costs are covered by the PTC and tax depreciation.[61]

Taxpayers including Colorado ratepayers pay for owners of industrial wind facilities to profit. The Heartland study found that one company, NextEra Energy received almost $5.7 billion in PTC's from 2007-2016.

Although curtailment costs are typically covered within a PPA, Colorado residents could be affected in two ways. First, the agreed upon price in the PPA could be higher in later years leading to higher electricity prices. And second, if output from wind farms is curtailed, ratepayers are effectively paying owners not to produce electricity.

Premature fossil fuel capacity retirement

The plan to achieve a 100 percent carbon free grid through a buildout of renewable energy sources also means all coal and natural gas power plants that are either built or in the process of being built will need to be shuttered by 2040. In many cases, closing them down before the end of their useful life. As of 2017, Xcel Energy had nine coal power plants with a dependable generating capacity of 6,991 MW and 22 natural gas plants with a dependable generating capacity of 7,360 MW.[62]

Xcel announced that it would be retiring two of its units at the Comanche power plant mid last year.[63] The utility's plan is to prematurely retire the two units with a generating capacity of 700 MW and replace them with new wind and solar farms. Xcel will retire Comanche 1 in 2022 (11 years before the end of its useful life) and Comanche 2 in 2025 (10 years before the end of its useful life).[64]

The plan to achieve a 100 percent carbon free grid through a buildout of renewable energy sources also means all coal and natural gas power plants that are either built or in the process of being built will need to be shuttered by 2040.

Table 8: 2017 Owned Generating Plants

Type	Plants	Units	Net Dependable Capacity (MW)
Coal	9	19	6,991
Natural Gas	22	68	7,360
Nuclear	2	3	1,657
Hydro	26	79	377
Wind	5	476	852
Solar	4	4	0.1
Other	4	20	416
Total	72	669	17,653

Table 8 Data from Xcel Energy Inc. **Source:** Xcel Energy, "Power Plants – Our Facilities – 2017 Owned Generating Plants," (https://www.xcelenergy.com/energy_portfolio/electricity/power_plants).

Xcel's rationale is that these plans will provide $213 million worth of savings for Colorado ratepayers. A Coalition of Ratepayers' report disproved the utility's numbers and instead argued that closing Comanche 1 and 2 will be financially detrimental to ratepayers. Through their expert witness, the Coalition found financial modeling errors and accounting gimmicks that will cost Colorado ratepayers nearly $300 million versus Xcel's claims that the premature retirement will save money.[65]

> ...the Coalition found financial modeling errors and accounting gimmicks that will cost Colorado ratepayers nearly $300 million versus Xcel's claims that the premature retirement will save money.

The Coalition of Ratepayers successfully argued their case in front of the Public Utilities Commission (PUC) and forced Xcel to rework its costs. Although the PUC eventually approved Xcel's plan, it's wise to be skeptical of any promised savings from such plans.

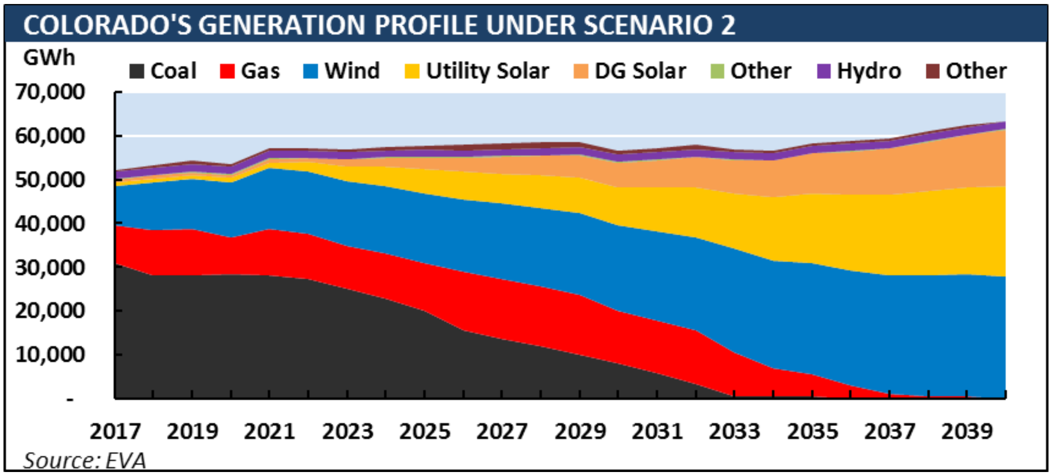
Of interest to Colorado is 9,200 MW of coal/natural gas capacity and 168 MW of oil that will have to be retired by 2040. The EVA study modelled a retirement schedule that assessed all fossil fuel plants respective retirement ages.[66] The model predicts that many of the gas and coal plants will start going offline in the 2030's and continue until 2040 when they will be completely closed down. One of the biggest ironies is that fossil fuel power plants are typically used as backup generation for renewables.[67] Closing all these plants by 2040 means everything rests on plan A, otherwise known as utility-scale battery storage systems – certainly not a sound policy.

Conservative estimates from the EVA study show that premature closures will cost ratepayers at least $7.6 billion. This figure considers how much utilities invested in the various power plants and their expected retirement dates. These stranded costs have five main categories, one of which is the unrecoverable costs of generation related assets. Unrecoverable costs are those investments that will not be paid via the operation of coal fired/natural gas fired power plants till the end of their useful life. Therefore, the utility must be repaid the money they put into those plants. This is because electric utilities (regulated by the PUC in Colorado) are entitled to what is known as a fair rate of return: "A 'fair' rate of return is one that allows the utility to raise whatever capital it needs to make needed investments in infrastructure."[68]

Unfortunately for Colorado ratepayers, they pick up the tab for an electric utility's stranded costs.

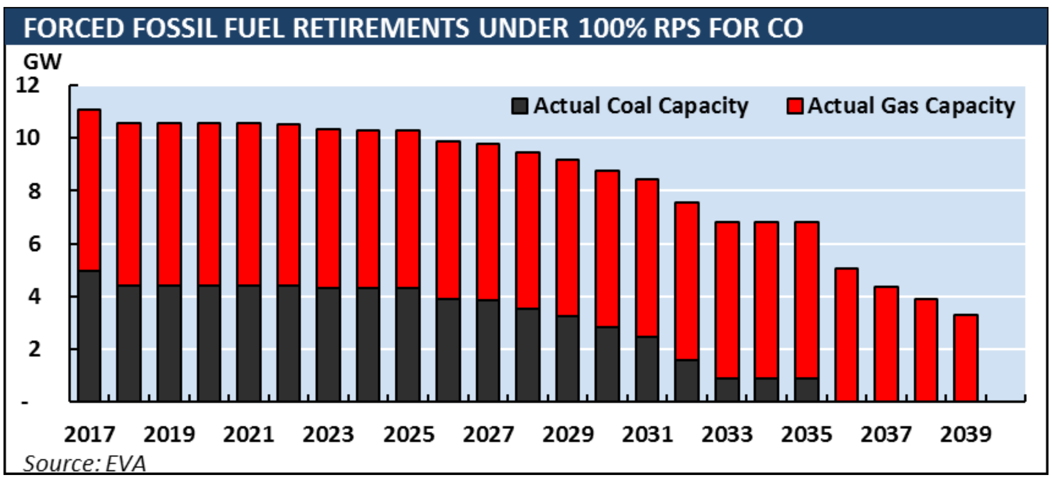
> *"Most legislators, utilities, regulators, and economists have generally agreed that it is important to honor the regulatory compact made in the past between*

Figure 4: Breakdown of generation under the 100 percent RPS



Source: Energy Ventures Analysis, ***Cost and Impact of a 100 Percent Renewable Energy Portfolio Standard for the State of Colorado,*** Independence Institute IP-6-2017, December 2017.

Figure 5 Breakdown of fossil fuel retirement under the 100 percent RPS



Source: Energy Ventures Analysis, ***Cost and Impact of a 100 Percent Renewable Energy Portfolio Standard for the State of Colorado,*** Independence Institute IP-6-2017, December 2017.

> *the utilities and the stakeholders they serve. This, along with many other considerations, has led legislatures to assign to consumers the responsibility to cover the stranded costs.'*"[69]

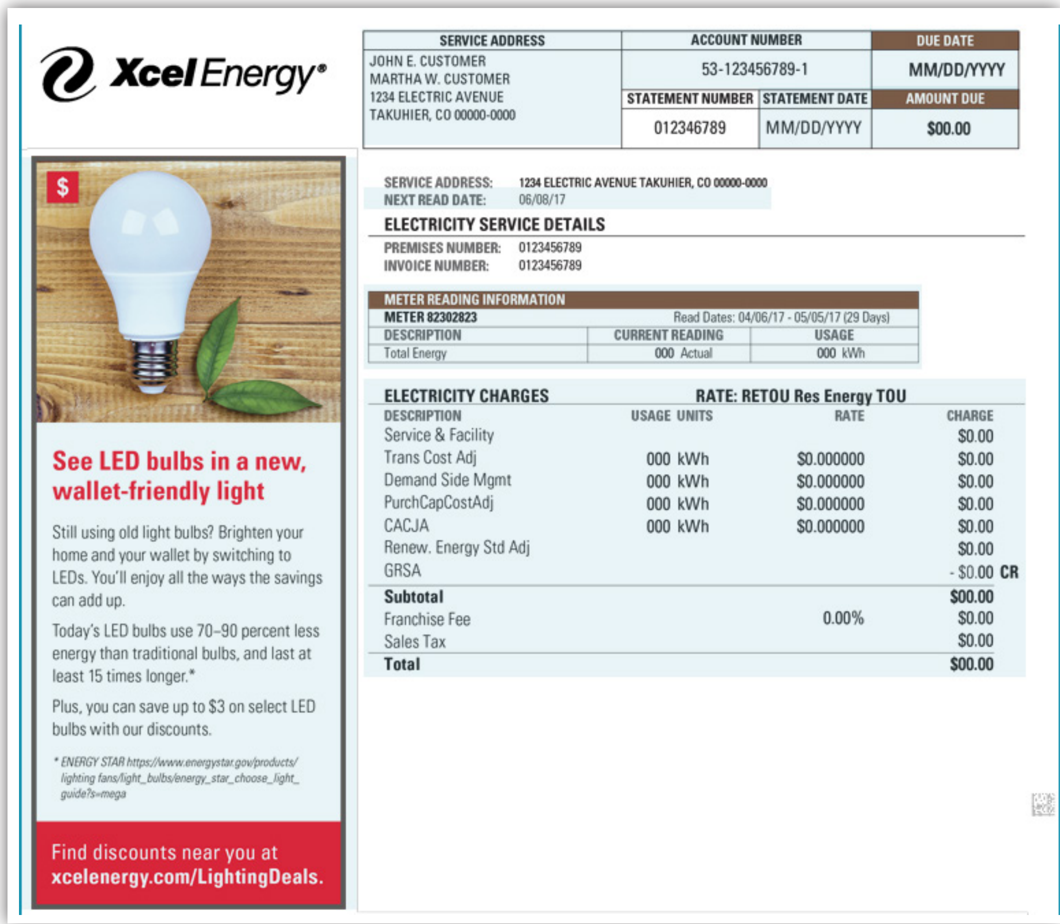
One of several ways these costs can be recovered is by including a fixed or variable (based on consumption) monthly surcharge for a set amount of time on ratepayers' electricity bills.[70] That means utility customers would pay an extra amount every single month for a set period (in addition to their electricity bill) until the utility has recovered its costs.

Examples of how the monthly surcharge could appear on a consumer's bill is included in the Xcel bill (Figure 6) under the Clean Air Clean Jobs Act (CACJA): "The CACJA Rider recovers the capital costs and expenses of new investments Xcel Energy is undertaking pursuant to its approved emissions reduction plan under the CACJA."[71]

There are other ways that the stranded costs can be recovered, but all of them involve consumers paying regardless of how the utility labels the line item on electricity bills. A comment by

There are other ways that the stranded costs can be recovered, but all of them involve consumers paying regardless of how the utility labels the line item on electricity bills.

Figure 6: Copy of Xcel Energy Bill



Xcel Energy®

SERVICE ADDRESS	ACCOUNT NUMBER		DUE DATE
JOHN E. CUSTOMER MARTHA W. CUSTOMER 1234 ELECTRIC AVENUE TAKUHIER, CO 00000-0000	53-123456789-1		MM/DD/YYYY
	STATEMENT NUMBER	STATEMENT DATE	AMOUNT DUE
	012346789	MM/DD/YYYY	$00.00

SERVICE ADDRESS: 1234 ELECTRIC AVENUE TAKUHIER, CO 00000-0000
NEXT READ DATE: 06/08/17

ELECTRICITY SERVICE DETAILS

PREMISES NUMBER: 0123456789
INVOICE NUMBER: 0123456789

METER READING INFORMATION
METER 82302823 Read Dates: 04/06/17 - 05/05/17 (29 Days)

DESCRIPTION	CURRENT READING	USAGE
Total Energy	000 Actual	000 kWh

ELECTRICITY CHARGES RATE: RETOU Res Energy TOU

DESCRIPTION	USAGE UNITS	RATE	CHARGE
Service & Facility			$0.00
Trans Cost Adj	000 kWh	$0.000000	$0.00
Demand Side Mgmt	000 kWh	$0.000000	$0.00
PurchCapCostAdj	000 kWh	$0.000000	$0.00
CACJA	000 kWh	$0.000000	$0.00
Renew. Energy Std Adj			$0.00
GRSA			- $0.00 CR
Subtotal			$00.00
Franchise Fee		0.00%	$0.00
Sales Tax			$0.00
Total			$00.00

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* ENERGY STAR https://www.energystar.gov/products/lighting fans/light_bulbs/energy_star_choose_light_guide?s=mega

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Source: Xcel Energy, "How to Read Your Bill, Here's a breakdown of each portion of your bill."

"Xcel is not going to pay for this. The customers of Xcel Energy will pay for the retirement of these plants and will pay for the accelerated depreciation and it will show up in rates in terms of the full costs of what we do with these plants. So, don't think this is free and it's going to be borne by somebody else.

Commissioner Wendy Moser of the Colorado Public Utilities Commission puts this in plain language:

> *"Xcel is not going to pay for this. The customers of Xcel Energy will pay for the retirement of these plants and will pay for the accelerated depreciation and it will show up in rates in terms of the full costs of what we do with these plants. So, don't think this is free and it's going to be borne by somebody else."*[72]

For households already struggling with high electricity bills and living in energy poverty, paying extra will further strain their monthly budgets – possibly forcing them to forgo necessities like food and healthcare.[73]

So far, the costs discussed in this report have been direct costs. However, Colorado will also face a significant indirect cost: job loss.

Impacts on Employment

Advocates for a transition to a 100 percent renewable grid often cite job creation as an economic reason for fuel switching. However, many jobs in renewables are short term in nature, lasting only during the construction of solar and wind facilities.[74] Advocates for and the articles supporting fuel switching tend to focus on the number of jobs that renewables create and have created without assessing the type of job. These distortions on the surface show more jobs being created in renewables, but they fail to show that

many of these jobs will disappear once the construction is over.

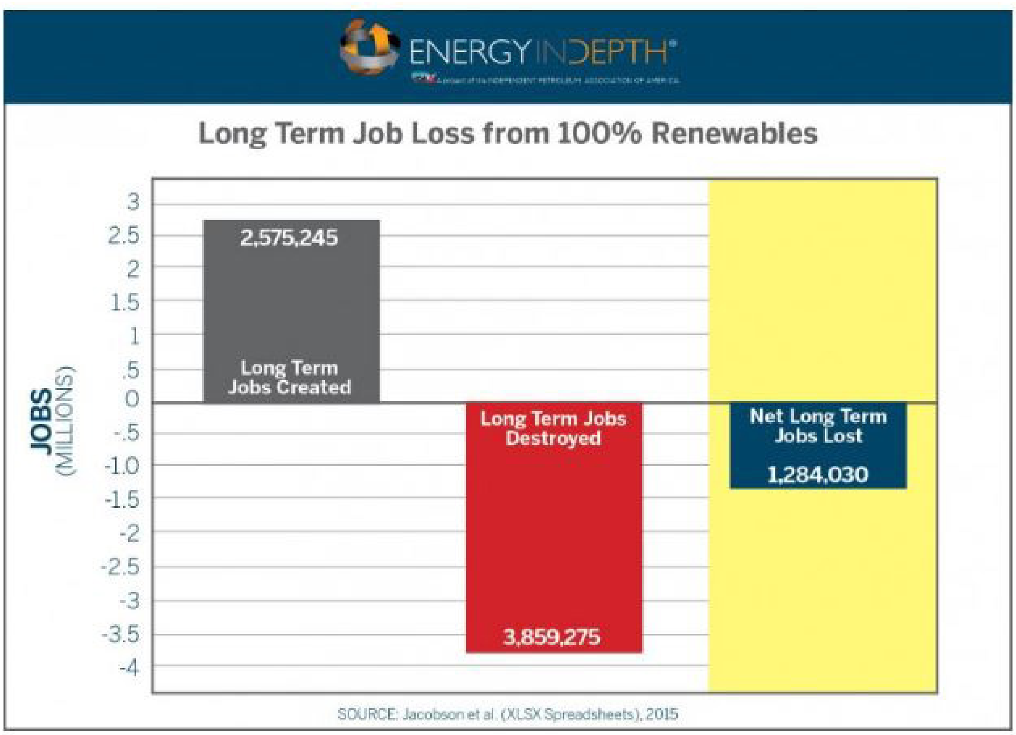
A study from Stanford professor and climate activist Mark Jacobson predicts that while 2.5 million long term jobs would be created by transitioning to 100 percent renewables, 3.8 million long term jobs will be lost across the country for a net loss of 1.28 million long-term jobs.[75]

The same study found that by 2050, Colorado would lose 49,308 long term jobs. Ultimately, this means Colorado would lose more jobs than it would gain, contradicting renewable advocates claims of a net gain of long-term jobs.

Simply put, studies and advocates present a severely flawed and skewed view of employment in the renewable energy sphere because of their lack of emphasis on long-term employment.

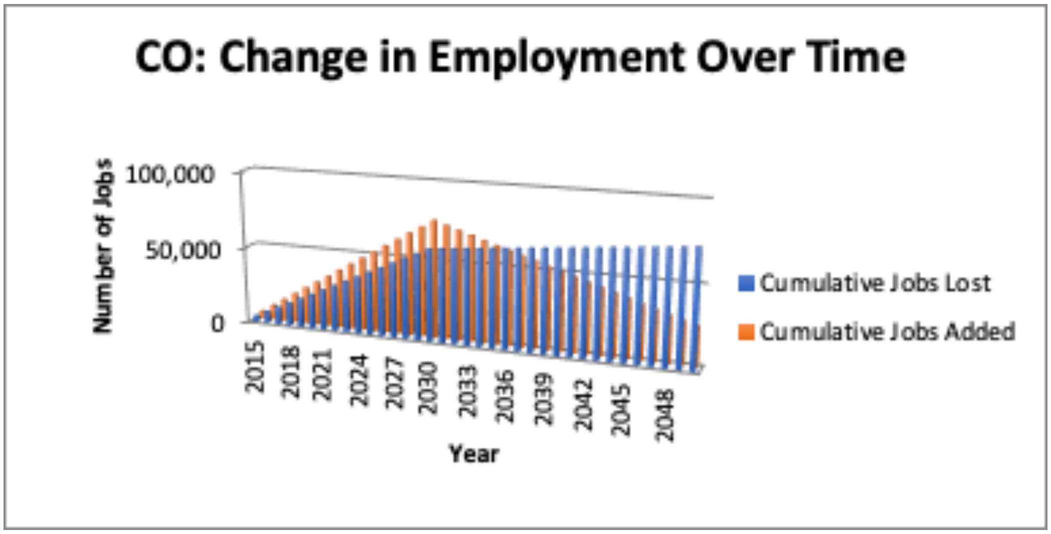
The same study found that by 2050, Colorado would lose 49,308 long term jobs. Ultimately, this means Colorado would lose more jobs than it would gain, contradicting renewable advocates claims of a net gain of long-term jobs.

Figure 7: Graph depicting anticipated employment impact as the U.S. transitions to a grid powered by renewable energy



Source: Steve Everly, "Climate Activists Push Study Showing 3.8 Million Lost Jobs from Renewable Energy Transition," Energy In Depth, January 2016.

Figure 8: 100 percent RPS impact on Colorado employment



Source: Mark Jacobson, "100% Wind, Water, and Solar (WWS) All-Sector Energy Roadmaps for Countries, States, Cities, and Towns," Stanford University, February 2019.

Other Options

... nuclear power is a zero-carbon option. If Colorado wants to reduce emissions, it should consider transitioning to a nuclear-powered electric grid.

Nuclear alternative

If the goal is a reduction in carbon emissions, then nuclear should be considered and clean natural gas should remain in the source mix to ensure reliability. Natural gas and nuclear are two obvious options. Colorado already has the sixth largest natural gas reserves in the country and burning natural gas to produce electricity releases 50 percent less carbon dioxide than using coal.[76]

Similarly, nuclear power is a zero-carbon option. If Colorado wants to reduce emissions, it should consider transitioning to a nuclear-powered electric grid.[77]

Nuclear has several advantages including:

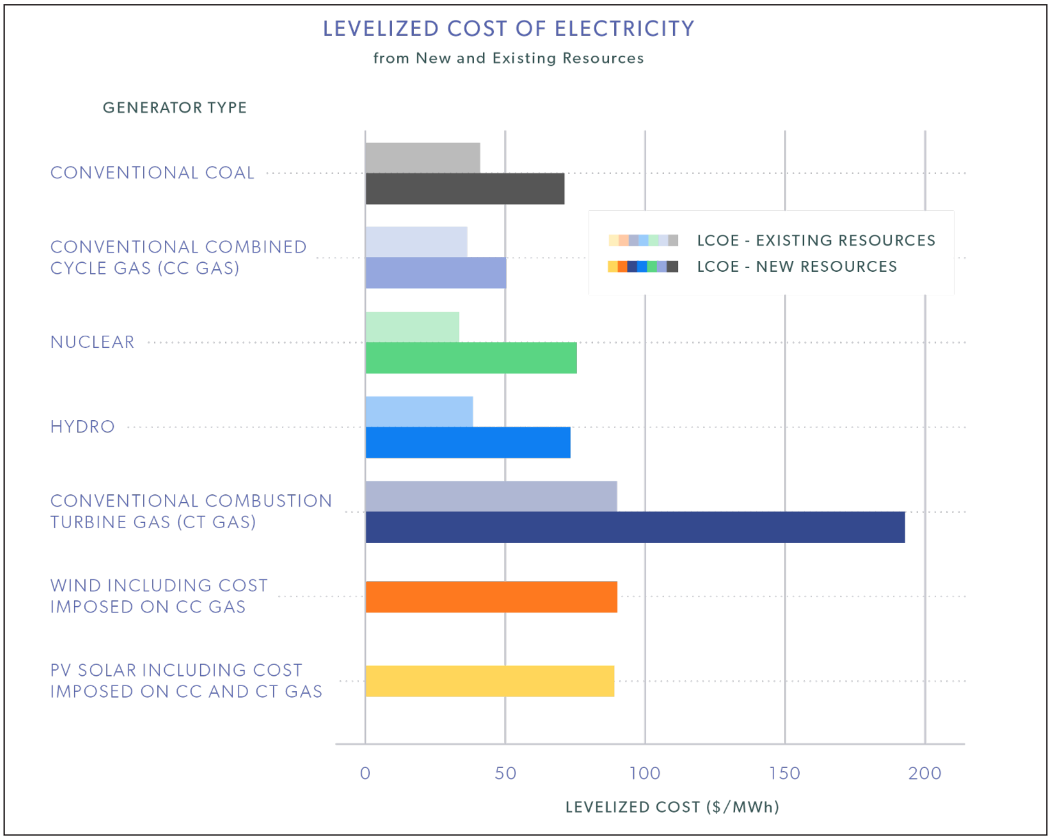
- Levelized cost of electricity (LCOE)
- Capacity factor/reliability
- Lower emissions
- Economic benefits
- Land usage

The "levelized cost of electricity (LCOE) represents the average revenue per unit of electricity generated that would be required to recover the costs of building and operating a generating plant during an assumed financial life and duty cycle."[78] LCOE is typically used to compare the cost of generating electricity from different energy sources as seen in Figure 9.

To provide accurate cost comparisons, the true cost of Governor Polis's choice of wind and solar must include back-up generation typically needed. Wind comes in at a cost of $90/MWh and Solar PV at $89/MWh.[79] The Polis plan won't allow the back-up generation to come from natural gas, instead it will be from utility-scale storage systems. Having seen the cost of utility-scale storage earlier in this report, it's hard to imagine that the true LCOE of wind/solar plus batteries will be lower than that of wind/solar plus natural gas.

Conventional coal, Combined Cycle (CC) natural gas, hydro, and nuclear are the most competitive options when looking at existing and new generation. Coal comes in at $70/MWh, gas at $50/MWh, hydro at $73/MWh, and nuclear at a cost of $75/MWh for new generation.[80]

Figure 9: Graph depicting the levelized cost of electricity per resource



Source: Thomas F. Stacy and George S. Taylor, ***The Levelized Cost of Electricity from Existing Generation Resources***, Institute for Energy Research and America's Power, June 2019.

A model built for the Independence Institute has a slightly lower LCOE for nuclear in Colorado at $74/MWh for new generation (See Appendix Six). The model finds that the LCOE of existing nuclear generation is $42.82/MWh. The big difference in price between new and existing generation is typical of nuclear, which has very high upfront capital costs, but once built, has low operation and maintenance costs (O&M).[81] An existing nuclear power plant's low LCOE makes transitioning to nuclear power an attractive option for Colorado and really any other state looking to achieve a reduction in carbon emissions.

Xcel Energy already has two nuclear power plants in its generation portfolio (Monticello and Prairie Island in Minnesota).[82] An option Colorado could consider is importing lower cost power from these two power plants instead of building new wind and solar. Doing so would enable Coloradans to reap the benefits of existing nuclear generation in the form of lower cost electricity (compared to the cost of electricity with wind and solar only).

Another big advantage of nuclear is its reliability. Nuclear power plants are used to provide baseload power because they can run 24 hours a day, seven days a week – which is not the case with solar and wind.[83] Electricity would be available on demand without having to build costly backup storage systems. A reliability comparison shows just how far superior nuclear is to any renewable source:

- Nuclear capacity factor: 92 percent of the time or 336 days out of 365 a year

An existing nuclear power plant's low LCOE makes transitioning to nuclear power an attractive option for Colorado and really any other state looking to achieve a reduction in carbon emissions.

- Hydro capacity factor: 38.2 percent of the time or 139 days per year
- Wind turbines: 34.5 percent of the time 126 days per year
- Solar electricity arrays: 25.1 percent of the time or 92 days per year.[84]

For example, assume a wind project and a nuclear project that both have a nameplate capacity of 500 MW. Using the above capacity factor of 34.5 percent, that means only a third of an industrial wind project's full output is generated during the year. In comparison, nuclear has a capacity factor of approximately 92 percent, and so generates power at its full nameplate capacity 9 times out of 10 – more than 2.5 times more generation. Colorado could save billions in backup generation costs and curtailment by using nuclear over wind and solar.

Nuclear is used even in parts of the country with strong environmental lobby groups opposed to fossil fuels such as New England as can be seen in Figure 10. Countries such as Germany and provinces such as Ontario in Canada also use nuclear with Ontario generating close to 60 percent of its power from nuclear energy.[85]

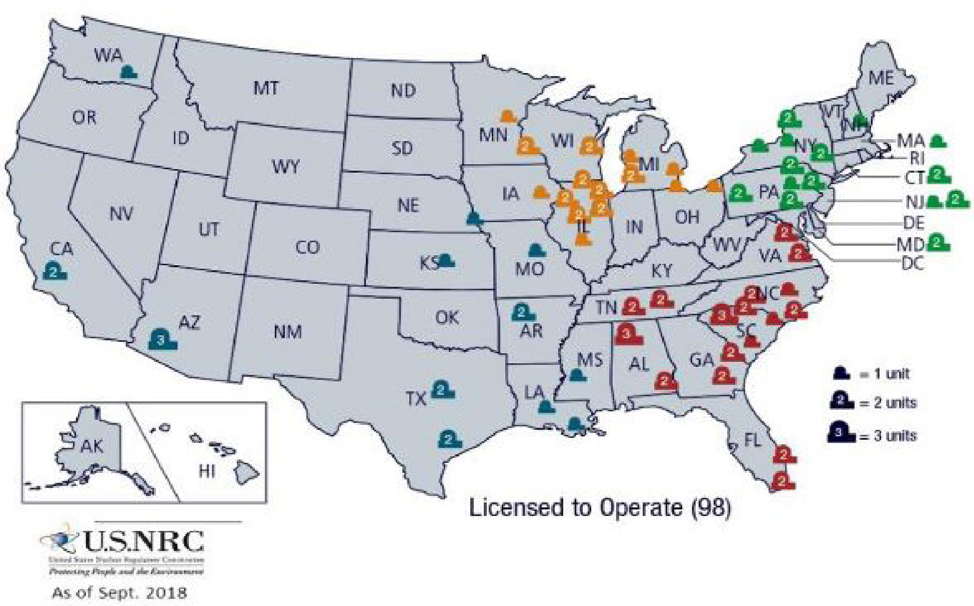
Nuclear is used in Ontario and New England not only because of its reliability, but also because of its zero carbon credentials.

Nuclear is used in Ontario and New England not only because of its reliability, but also because of its zero carbon cre-dentials.

> *"In 2018, Pennsylvania's nuclear power plants prevented more than 57 million metric tons of carbon emissions which is the equivalent of taking 12 million cars off the road. The saved social cost of carbon is more than $2.6 billion annually, according to the federal government's evaluation."*[86]

Using a nuclear model (created by Isaac Orr and Mitch Rolling), adding just 6,400 MW of nuclear capacity from 2023-2050 would result in 89,339,271 or 89 million metric tons of averted CO_2 emissions by 2030 and 671,585,568 or 671 million metric tons of averted CO_2 emissions by 2050. Nuclear is a bona fide option in the fight against greenhouse gases; there is no reason why it can't be used to ensure

Figure 10: U.S. Operating Commercial Nuclear Power Reactors



Source: ***"Map of Power Reactor Sites,"*** U.S. Nuclear Regulatory Commission, May 10, 2018, https://www.nrc.gov/reactors/operating/map-power-reactors.html.

Colorado has a 100 percent carbon free grid.

A common and credible critique of renewable energy generation is that the jobs it creates are typically short term – mainly during the construction phase.[87] This is not the case with nuclear. For example, Xcel Energy's two nuclear plants in Minnesota employ 1,400 full time employees as well as additional skilled labor.[88] The nuclear power plants generate over $1 billion annually to the economy, with $35 million paid in state and local tax and over $320 million in local procurement.

Lastly, nuclear energy is more concentrated in comparison to either solar or wind or any other fossil fuel: "A single uranium pellet the size of a pencil eraser contains the same amount of energy as 17,000 cubic feet of natural gas, 1,780 pounds of coal, or 149 gallons of oil."[89] The scale impacts the amount of land required to build a nuclear plant compared to a solar or wind farm. Solar farms can take up to 450 times more land than a nuclear power plant.[90] Xcel's Rush Creek wind farm uses 95,000 acres of land for 600 MW. [91] Xcel's Monticello nuclear plant uses 215 acres for its 671 MW of power.[92]

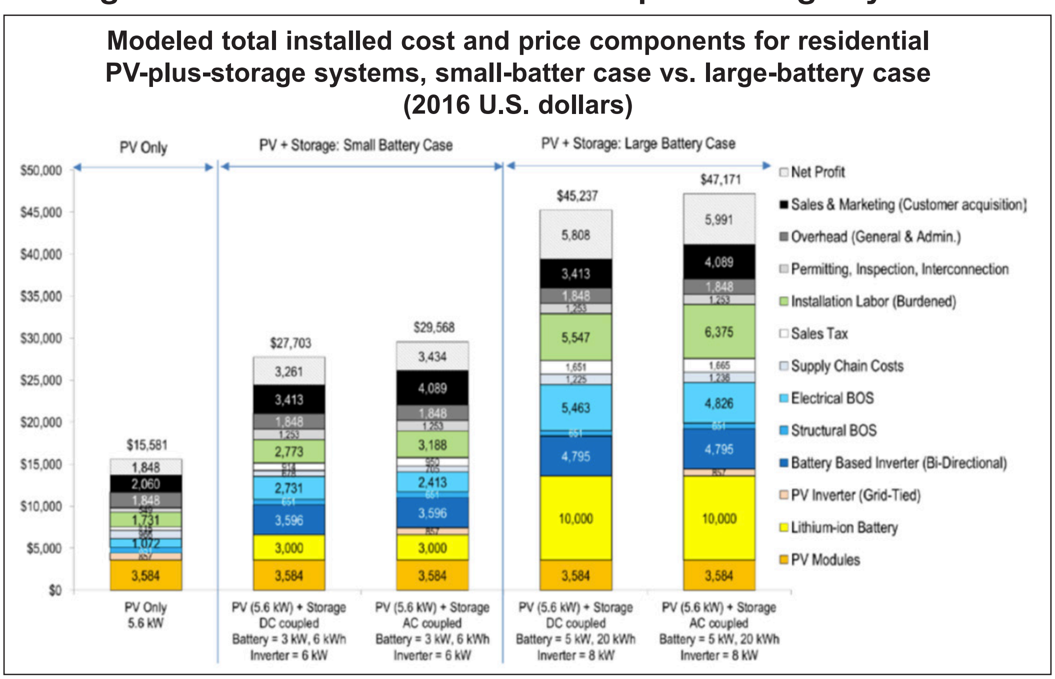
Nuclear clearly offers many advantages over wind and solar. It is more reliable, helps to lower emissions, is less costly over the long term, and uses less land while employing more people in long term jobs. Instead of saddling Coloradans with unaffordable and unreliable renewables, Colorado would be wise to consider nuclear as an energy source.

Microgrid & Distributed Energy Alternative

Nuclear is not the only alternative, and industrial grade, stand-alone batteries are not the only type of storage systems on the market. There is also behind the meter residential storage, which can be coupled with distributed PV (i.e., rooftop solar). If multiple residential storage plus solar systems are linked, these can island off from the main electric grid and function as a microgrid, but these systems are not cheap. According to NREL, while coupling

Solar farms can take up to 450 times more land than a nuclear power plant.

Figure 11: Price of residential solar plus storage systems



Source: Kristen Ardani, Eric O'Shaughnessy, Ran Fu, Chris McClurg, Joshua Huneycutt, and Robert Margolis, ***Installed Cost Benchmarks and Deployment Barriers for Residential Solar Photovoltaics with Energy Storage: Q1 2016***, National Renewable Energy Laboratory, February 2017.

residential solar and storage may reduce costs associated with site preparation and land acquisition, individuals still face high upfront capital and installation costs as well as hurdles regarding permitting and connecting with the electric grid.[93]

Compared to installing a PV system only ($16,656 in 2019 U.S. dollars), PV + storage can be two to three times more expensive ($31,609-$50,427 in 2019 U.S. dollars). Price differential depends primarily on the size and type of the system. Figure 11 breaks the pricing of these systems down.

Currently, distributed solar generation plus storage (microgrid technology) is in its infancy. According to our calculations, even after isolating the systems price from the cost of installing solar panels and accounting for the expected drop in battery storage prices, the total cost is higher than the $900 billion price tag of installing only utility-scale storage (Appendix Two).

Using NREL's system costs, EVA's projected distributed solar generation capacity (42 percent of all installed solar) and applying that to Wojick's 360,000,000 kWh of required storage capacity for solar power, there are three scenarios. The first calculated the total cost of the required storage capacity assuming AC coupled 20 kWh battery systems would account for 42 percent of the required solar storage capacity (151,000,000 kWh); the second calculated the total cost of the required storage assuming AC coupled 20 kWh battery systems would account for 21 percent (75,600,000 kWh) of the required solar power storage capacity; the third and final scenario calculated the total costs of required storage assuming AC coupled 20 kWh battery systems would account for a little over 10.5 percent (33,800,000 kWh) of the solar power storage capacity. Under all three scenarios, the total cost equaled $15 to $62 billion dollars more than building only utility-scale battery storage.

However, there are positive aspects of microgrids and self-generation; namely, the avoided costs of building new transmission lines and not having to factor in energy curtailment at the utility level, and that they are private investments, like purchasing a home and building equity instead of renting an apartment or house. It is the individual investment that has peaked the most interest, since instead of purchasing electricity from a regulated electric utility, a homeowner would be able invest in equipment and in their own home. Admittedly, it is a metric that currently cannot be quantified, but one that should be considered if Colorado is serious about reducing its electric grid's carbon emissions.

If Coloradans are going to be forced to spend money on reorganizing how they power their lives, they may prefer to spend it on themselves.

If Coloradans are going to be forced to spend money on reorganizing how they power their lives, they may prefer to spend it on themselves.

Environmental Benefits vs. Costs

Transitioning to 100 percent renewable energy by 2040 is an ambitious, expensive goal, with a price tag ranging from billions to possibly trillions of dollars, depending on battery pricing. It stands to reason then, that Coloradans should expect to enormously benefit the global climate from their financial generosity of hundreds of thousands of dollars per household. But that's unlikely. If Colorado attempts to transition to 100 percent renewable energy, its residents' efforts to alleviate climate change would most likely be in vain.

A Heritage Foundation study found that even if the entire United States would

eliminate all its carbon emissions, the resulting effects on the global climate are insignificant. The authors found that by the year 2100, the expected rise in global temperatures would be decreased by less than .2 degree Celsius and sea-level rise would be slowed by less than 2 centimeters.[94]

To put these figures in perspective, the Fourth National Climate Assessment projected that global sea-level is likely to rise between 25-80 cm by 2100, and global temperatures are projected to increase, according to the United Nations World Meteorological Organization, by 3-5 degrees Celsius by 2100.[95] Even if America neutralized its carbon footprint, projected sea-level and temperature rise would be the same. These results simply do not warrant radically reorganizing how America and Colorado are powered.

This is in part because of the carbon emissions from countries with emerging economies like China and India. Both of these nations' combined carbon footprint dwarf Colorado's. In 2015, for example, China and India released a total of 12 billion metric tons of only CO_2, whereas Colorado released 127 million metric tons of CO_2-equivalent (CO_2-equivalent considers all greenhouse gases).[96] To put these numbers into context, Colorado's total GHG emissions equaled a mere one percent of China and India's CO_2 emissions in 2015.

Knowing the findings in the Heritage Foundation study then begs the question: If the United States eliminating its entire carbon emissions has relatively no impact on the global climate, why should Colorado possibly bankrupt itself for even less of an impact? Said a different way, the global benefits gained by Colorado transitioning to 100 percent renewable energy are not worth the costs of doing so.

By our calculations the direct cost of the entire plan is at least $941 billion, but the true cost is likely in the trillions, nearly a half million dollars or more for a Colorado family of four with virtually no global benefit in emissions.

Conclusion

Governor Polis and Democrats have passed and will continue to pass energy reorganization bills that will cost Colorado ratepayers for generations to come, long after those elected officials are out of office. For Coloradans already struggling to keep their lights on, these costs will be a killer blow.

By our calculations the direct cost of the entire plan is at least $941 billion, but the true cost is likely in the trillions, nearly a half million dollars or more for a Colorado family of four with virtually no global benefit in emissions.

The first alternative option: nuclear, while also costly, would at the very least provide reliable electricity and create permanent jobs. Its environmental footprint would also be significantly less. Instead of a hundred thousand acres for a 500 MW wind farm, which has a capacity factor of 30 percent, a 500 MW nuclear plant would sit on 215 acres and generate 500 MW of electricity 90 percent of the time.

The second alternative option: microgrid technology, while costly as well, would at least give individuals an opportunity to invest in themselves. It would also avoid building new transmission lines and electricity curtailment at the utility level.

If lawmakers are serious about reducing energy related carbon emissions and forcing Coloradans to spend nearly a trillion dollars to build a zero emissions

electric grid, nuclear and microgrids must at least be considered as alternative options. If they are not, lawmakers are doing ratepayers a huge disservice and virtue signaling at an enormous expense. That's no way to keep the lights on in Colorado.

Table 9 Cost Breakdown of Transitioning to 100% Renewable Energy

Item	Description	Total Cost
Wind capacity	Capital cost for addition of 9087 MW to the grid	$9.6 billion
Utility Solar and Rooftop PV capacity	Capital cost for addition of 16440 MW to the grid	$23.9 billion
Additional costs	Transmission lines/substations, legal costs associated with eminent domain,	Unknown/variable
Battery storage capacity	Battery storage required for new wind and solar capacity once fossil fuel backup is phased out	$900 billion-$4 trillion
Curtailment/cycling	Cost of curtailing renewables and cycling baseload power plants	Unclear
Premature fossil fuel capacity retirement	Cost of shutting down fossil fuel plants before the end of their useful life	$7.6 billion
	Total per household cost	**$475,000**
	TOTAL COST	**$941.1 billion**

Appendix

Appendix One

Bill	Description
SB18-064	The bill updates the renewable energy standard to require that all electric utilities, including cooperative electric associations and municipally owned utilities, derive their energy from 100% renewable sources by 2035
SB 181	Potentially bans oil and gas development in Colorado
SB 19-077	Requires utilities to file an application for a program to support transportation electrification every 3 years starting in 2020 that may include investments or incentives, rates or programs, and customer outreach and education
SB19-239	Requires Colorado Department of Transportation (CDOT) to convene a group of stakeholders affected by the adoption of new and emerging transportation technologies and business models to develop policy recommendations to address resulting impacts
SB19-181	Protects public safety, health, welfare and the environment in the regulation of the oil and gas industry by modifying the oil and gas statute and clarifying, reinforcing and establishing local governments' regulatory authority over the surface impacts of oil and gas development
HB19-1231	Updates and adopts standards for new equipment sold in Colorado and requires that certain appliances, plumbing fixtures and other products sold for residential or commercial use meet energy efficiency and water efficiency standards that will be phased in over 3 years.
HB19-1313	100 % elimination of carbon emissions by 2050
SB 19 236	The act continues the functions of the commission for 7 years, until 2026.
HB19-1261	Sets Colorado statewide goals to reduce 2025 greenhouse gas emissions by at least 26%, 2030 greenhouse gas emissions by at least 50% and 2050 greenhouse gas emissions by at least 90% of the levels of greenhouse gas emissions that existed in 2005
HB 19-1314	The creation of a 'just transition' office to assist coal transition workers

Appendix Two

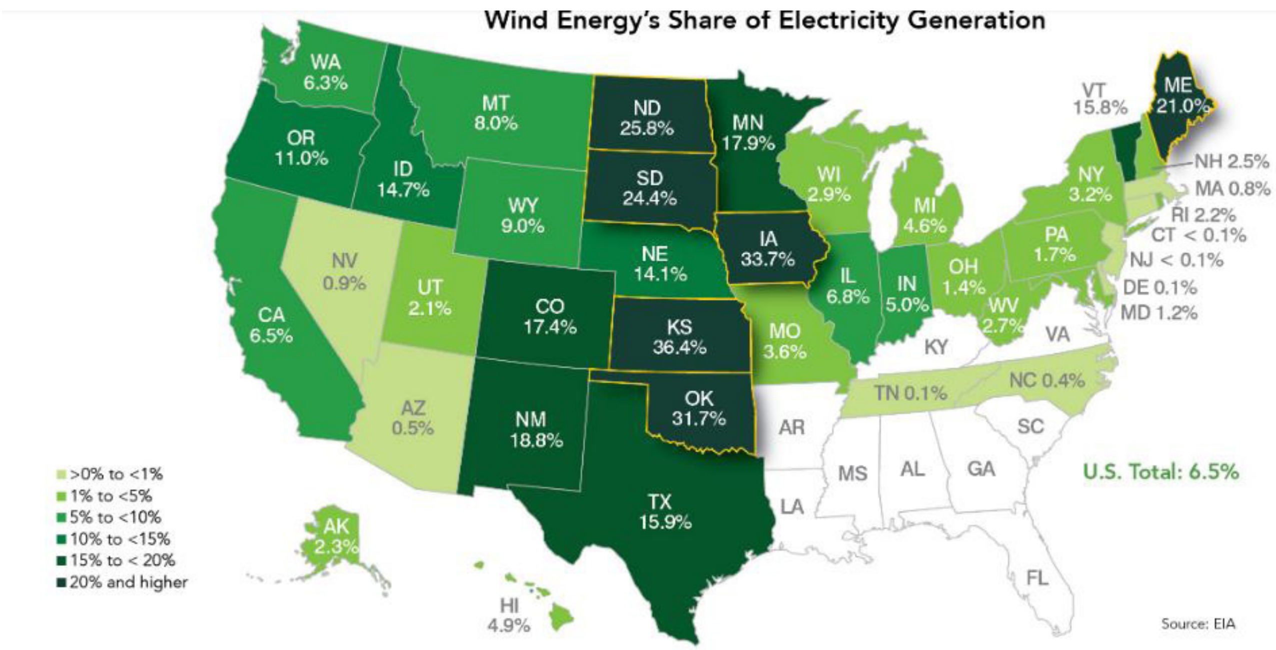
Industrial Scale Storage Costs:

1. Assuming 50 percent of Colorado's energy comes from solar: Solar energy will meet 50 percent of peak demand which is 5000 MW. Assuming it is required 24 hours a day, 3 days a week then 5000 x 24 x 3 = 360,000 MWh
2. Assuming 50 percent of Colorado's energy comes from wind: Wind energy will meet 50 percent of peak demand which is 5000 MW. Assuming it is required 24 hours per day, 7 days a week then 5000 x 24 x 7 = 840,000 MWh.
3. Thus, for both solar and wind the total battery storage capacity Colorado requires is at least 1.2 million MWh: 1.2 million MWh x $1.5 million MWh/ 2 (to account for estimated 50 percent drop in battery storage costs over 10 years) = $900 billion

Residential Scale Storage Costs:

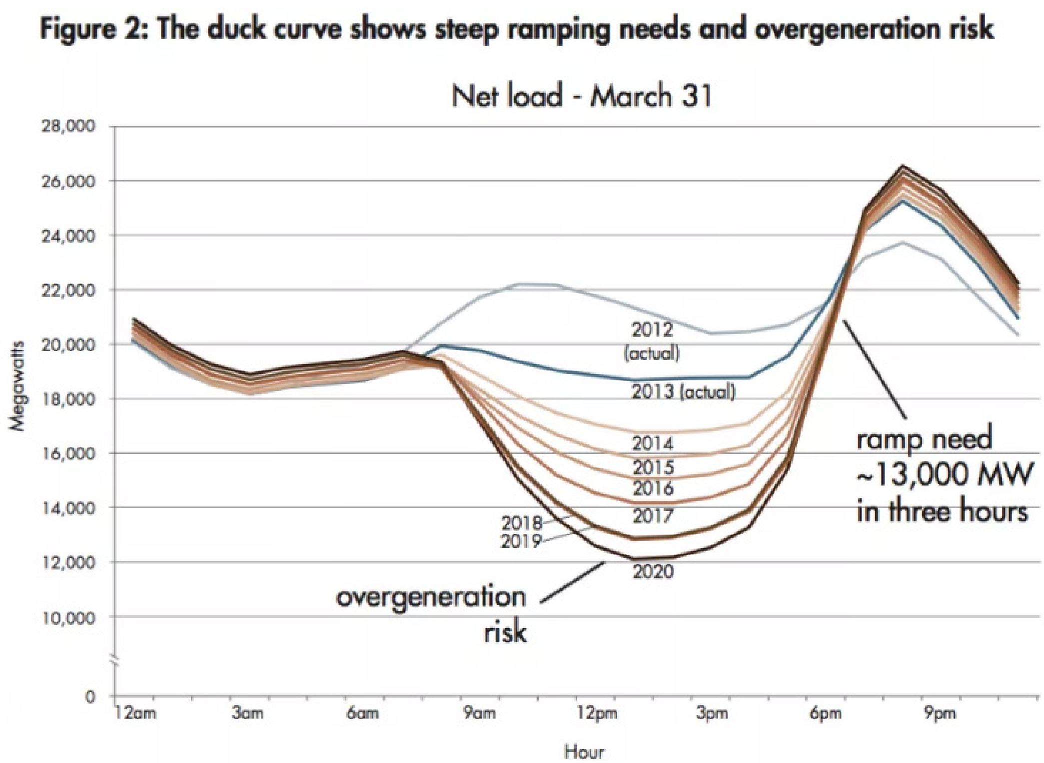
1. Assuming AC coupled 20 kWh battery systems account for 42 percent of the required solar power storage(151,000,000 kWh/20) x $46,596 / 2 (to account for estimated 50 percent drop in battery storage costs over 10 years) + (1,048,800 x 1,500,000) / 2 (required utility-scale storage) = $962,733,000,000
1. Assuming AC coupled 20 kWh battery systems account for 21 percent of the required solar power storage: (75,600,000 kWh/20) x $46,596 / 2 (to account for estimated 50 percent drop in battery storage costs over 10 years) + (1,124,400 x 1,500,000) / 2 (required utility-scale storage) = $931,366,000,000
1. Assuming AC coupled 20 kWh battery systems account for 10.5 percent of the required solar power storage: (37,800,000 kWh/20) x $46,596 / 2 (to account for estimated 50 percent drop in battery storage costs over 10 years) + (1,162,200 x 1,500,000) / 2 (required utility-scale storage) = $915,683,300,000

Appendix Three



Source: Curtis Walter, "New EIA report shows wind pulls its weight," Into the Wind, October 2018, https://www.aweablog.org/new-eia-report-shows-wind-pulls-weight/

Appendix Four



Source: Michael Burnett, "Energy Storage and the California 'Duck Curve'," Stanford University, June 2016, http://large.stanford.edu/courses/2015/ph240/burnett2/

Appendix Five

Revenue Streams in Colorado

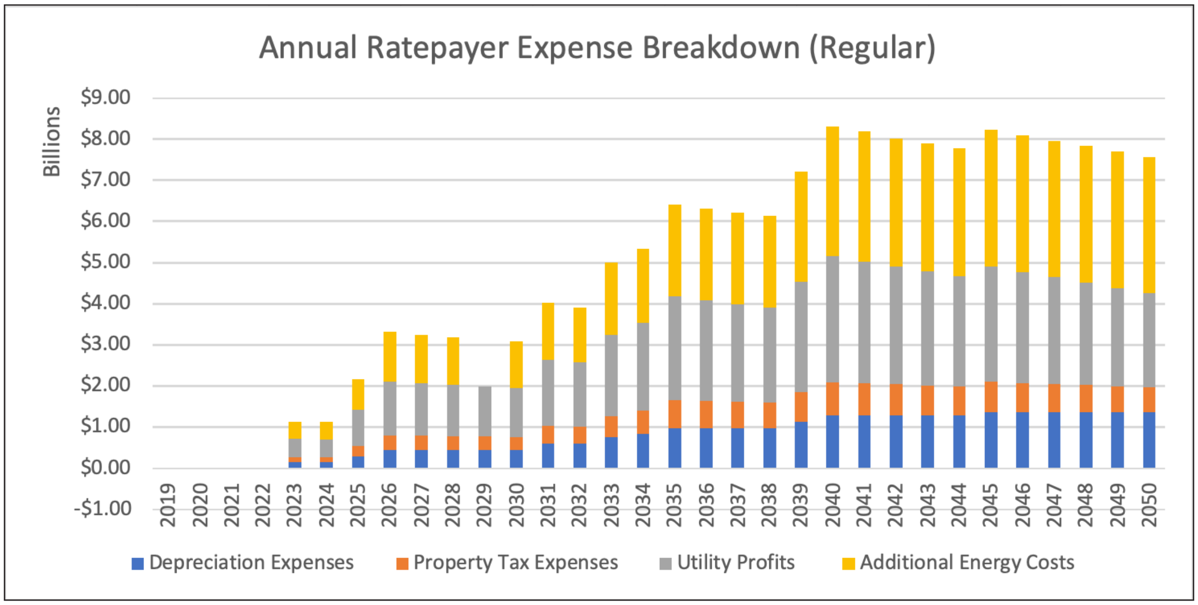
Commodity / Revenue Category	State and County Assessed Taxes *On Federal, State, and Private Land*			Rents, Bonuses, and Royalties *On State Land*			Federal Revenue Streams	
	Severance and License Taxes	*Ad Valorem Taxes*	*Surcharges*	*Securing a Lease or Claim*	*Pre or Postponed Production*	*During or Post Production*	*Abandoned Mine Land (AML) Fees*	*U.S. Mineral Royalties*
Oil and Gas	**Oil and Gas Severance Tax:** • Gross income under $25,000: 2% • From $25,000-$99,000: $500 and 3% of excess over $24,999 • From: $100,000-$299,999: $2,750 and 4% of excess over $99,999 • $300,000 and above: $10,750 and 5% of excess over $299,999 **Oil Shale Severance Tax:** 1-4% of gross production beginning 180 days after commercial viability, with an exemption of 15,000 tons of oil shale or 10,000 barrels of shale oil per day, whichever is greater	**Oil and Gas Property Tax**: Oil and Gas properties are assessed at 87.5% of production value if primary well and 75% of production value if secondary well. The ad valorem tax rate itself varies from county to county, ranging from 4-15%	**COGCC Levy:** A rate not to exceed 0.17% (currently 0.07%) is imposed on the market value of all oil and natural gas produced, saved, sold, or transported to address environmental response needs	**Mining Exploration Permit:** Negotiated at a line mile rate **Bonus:** Bids made above the annual rate are referred to as a lease bonus. The amount will vary from lease to lease	**Annual Rent:** Annual rental rate of $2.50 per acre for the life of lease. State land and board oil and gas leases contain a five year term **Bonding Requirements**: Performance bond requirement ranges from $25,000 per lease to a $100,000 blanket bond	**Royalties**: Standard royalty rate of 20% with additional deductions allowed for post-production costs		**Federal Royalties:** The royalty rate for: • Onshore oil and gas production is 12.5% • Surface mining is also 12.5% • Underground mining is 8%
Coal	**Coal Severance Tax:** The tax rate is based on changes in the producer price index, with an exemption for the first 300,000 tons produced each quarter. Underground production is allowed a 50% tax credit, and lignite coal is given a further 50% credit			**Bonus:** Bids made above the annual rate are referred to as a lease bonus. The amount will vary from lease to lease	**Rents:** Annual rentals are $3.00 per acre per year **Advanced Minimum Royalty:** Leases will require AMR payments based on amount per acre/estimated production volumes. Any AMR paid but not utilized will be surrendered	**Minimum Royalty Pricing**: 8% of Gross Sales Price (GSP) for underground mining, 12.5% of GSP for surface mining	**AML Fees:** Companies pay a per-ton fee to OSMRE • $0.28/ton on surface mined coal • $0.12/ton on subsurface • $0.08/ton on lignite	
Non-Energy Minerals	**Metallic Mineral Severance Tax:** 2.25% of gross income that exceeds $19 million. A credit for county ad valorem taxes is allowed for up to 50% of severance tax liability **Molybdenum (Ore) Severance Tax:** 5 cents per ton, with an exemption for the first 625,000 tons produced each quarter			**Mining Exploration Permit:** $100.00 **Bonus:** Bids made above the annual rate are referred to as a lease bonus. The amount will vary from lease to lease	**Rents:** Annual rentals are $3.00 per acre per year **Advanced Minimum Royalty:** Leases will require AMR payments based on amount per acre/estimated production volumes. Any AMR paid but not utilized will be surrendered	**Minimum Royalty Pricing**: • Precious metals: 10% of Gross Sales Price (GSP) • Base Metals: 8% of GSP • Fissionable Minerals: 5-10% of GSP		
Renewables				**Planning Lease:** Intended for due diligence phase, and does not allow for surface disturbance. Generally 1-2 years in length **Exploration Permit:** Provides permission to disturb surface, a bond is required to ensure remediation	**Production Lease:** Covers the construction and long term operation (typically 20-40 years) **Rents:** For utility scale projects there is a per acre ground rent, plus a minimum annual payment	**Royalty:** Structure based on Power Purchase Agreement and annual revenue the developer generates from sale of electricity		

Source: U.S. Department of the Interior, "Colorado Revenue Streams (2016)," https://revenuedata.doi.gov/downloads/USEITI_Colorado_revenue_streams.pdf

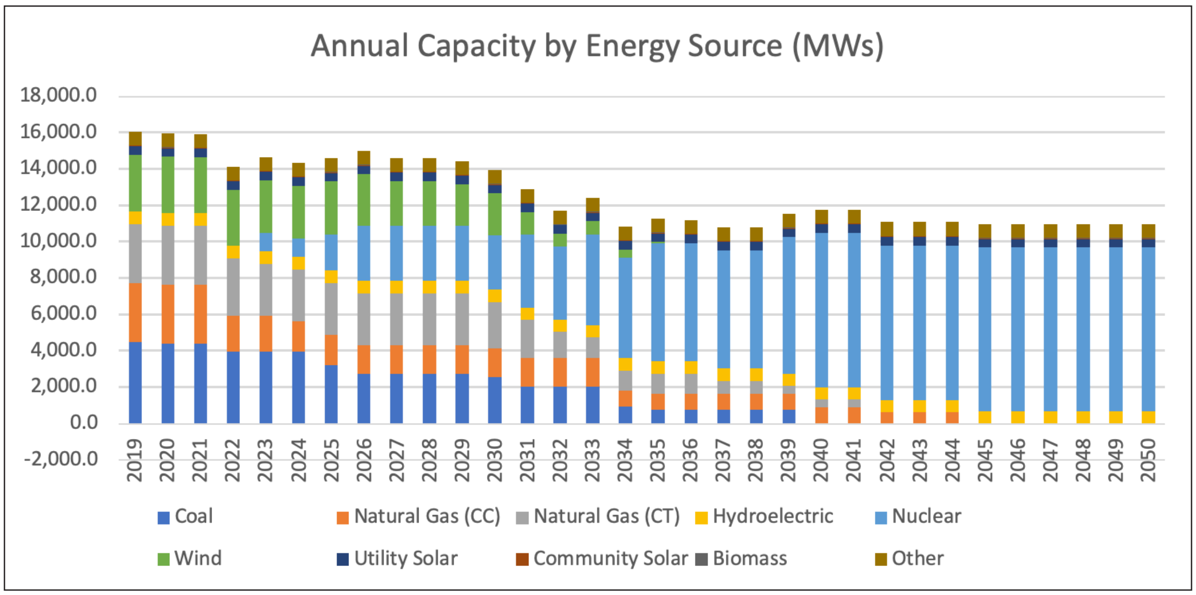
Appendix Six (Results of Nuclear Cost Model)

		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
Levelized Cost of Energy for Old Facilities	Coal	$27.82	$27.92	$27.92	$27.79	$27.82	$27.82	$27.99	$27.82	$27.82	$27.82	$27.82	$27.82	$27.82	$27.76	$27.82	$27.67
	Natural Gas (CC)	$40.66	$40.12	$40.12	$38.18	$38.92	$38.33	$38.92	$39.79	$39.31	$39.31	$39.31	$38.72	$38.72	$38.33	$39.79	$38.33
	Natural Gas (CT)	$64.59	$59.92	$59.92	$54.58	$56.81	$54.58	$59.92	$64.59	$59.92	$64.59	$59.92	$59.92	$64.59	$56.81	$64.59	$56.81
	Hydroelectric	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08
	Nuclear	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82
	Wind	$61.03	$61.03	$61.03	$61.03	$61.03	$61.03	$61.03	$61.03	$61.03	$57.00	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65
	Solar	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00
	Community Solar	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00
	Biomass	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00
	Biofuels	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00
Levelized Cost of Energy for New Facilities	Natural Gas (CC)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Natural Gas (CT)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Nuclear	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08
	Wind	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Solar	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00		$0.00	$0.00	$0.00	$0.00	$0.00
	Community Solar																

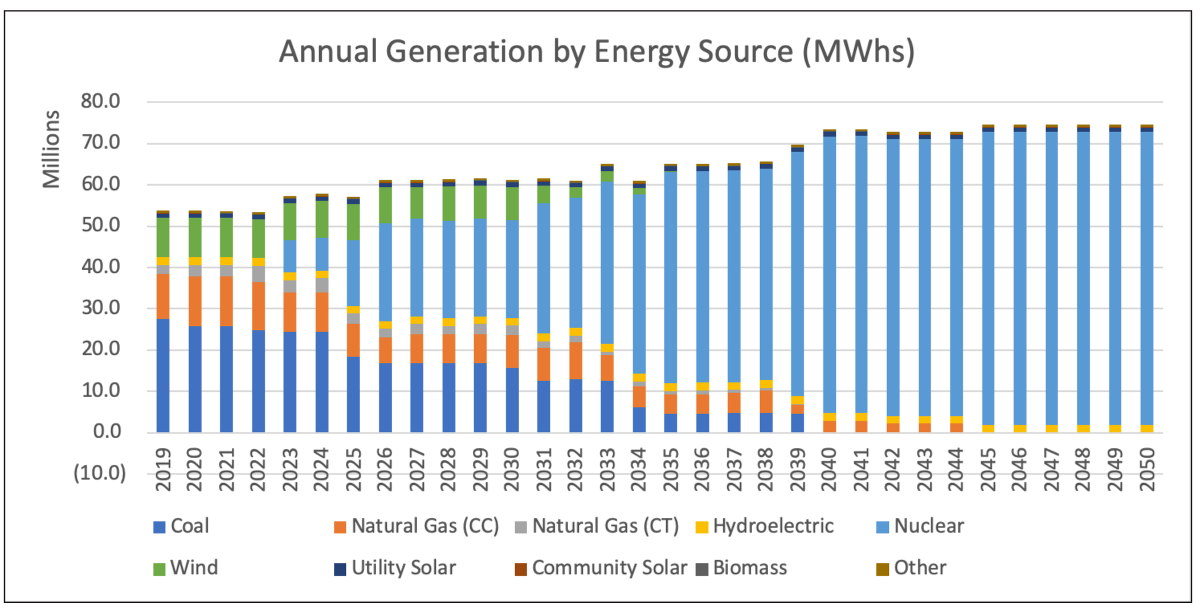
		2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Levelized Cost of Energy for Old Facilities	Coal	$27.82	$27.82	$27.76	$27.76	$27.82	$27.85	$27.99	$27.85	$27.85	$27.85	$27.67	$27.85	$27.85	$27.85	$27.85	$27.85
	Natural Gas (CC)	$38.60	$38.60	$38.48	$38.09	$42.67	$41.14	$41.14	$40.38	$40.38	$40.38	$41.14	$40.38	$40.38	$40.38	$40.38	$40.38
	Natural Gas (CT)	$64.59	$59.92	$56.81	$59.92	$87.94	$87.94	$78.60	$72.37	$72.37	$72.37	$87.94	$72.37	$72.37	$72.37	$72.37	$72.37
	Hydroelectric	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08	$13.08
	Nuclear	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82	$42.82
	Wind	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65	$54.65
	Solar	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00	$88.00
	Community Solar	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00	$135.00
	Biomass	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00
	Biofuels	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00	$85.00
Levelized Cost of Energy for New Facilities	Natural Gas (CC)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Natural Gas (CT)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Nuclear	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08	$74.08
	Wind	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Solar	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	Community Solar																



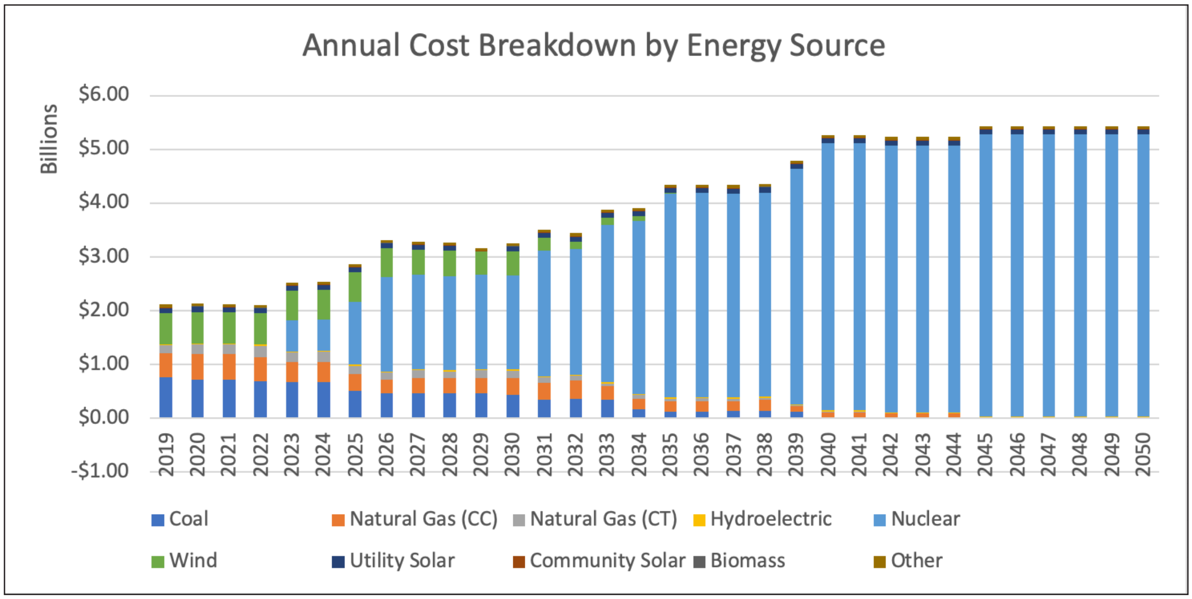
Annual Ratepayer Expense Breakdown (Regular)
Billions
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
-$1.00
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
Depreciation Expenses
Property Tax Expenses
Utility Profits
Additional Energy Costs

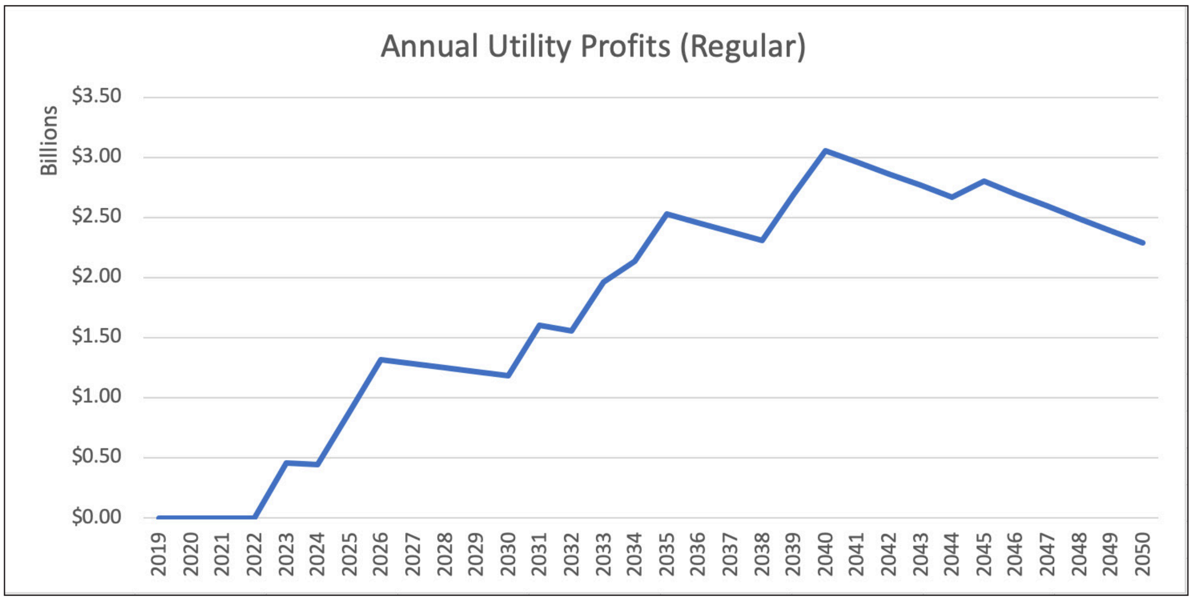


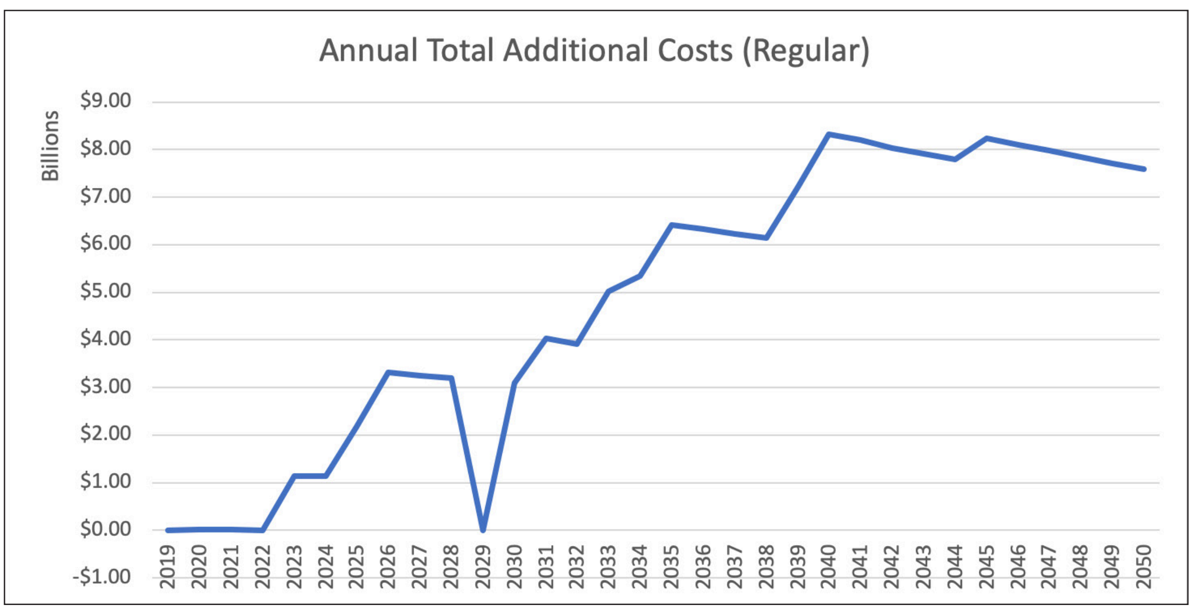
Annual Capacity by Energy Source (MWs)
18,000.0
16,000.0
14,000.0
12,000.0
10,000.0
8,000.0
6,000.0
4,000.0
2,000.0
0.0
-2,000.0
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other

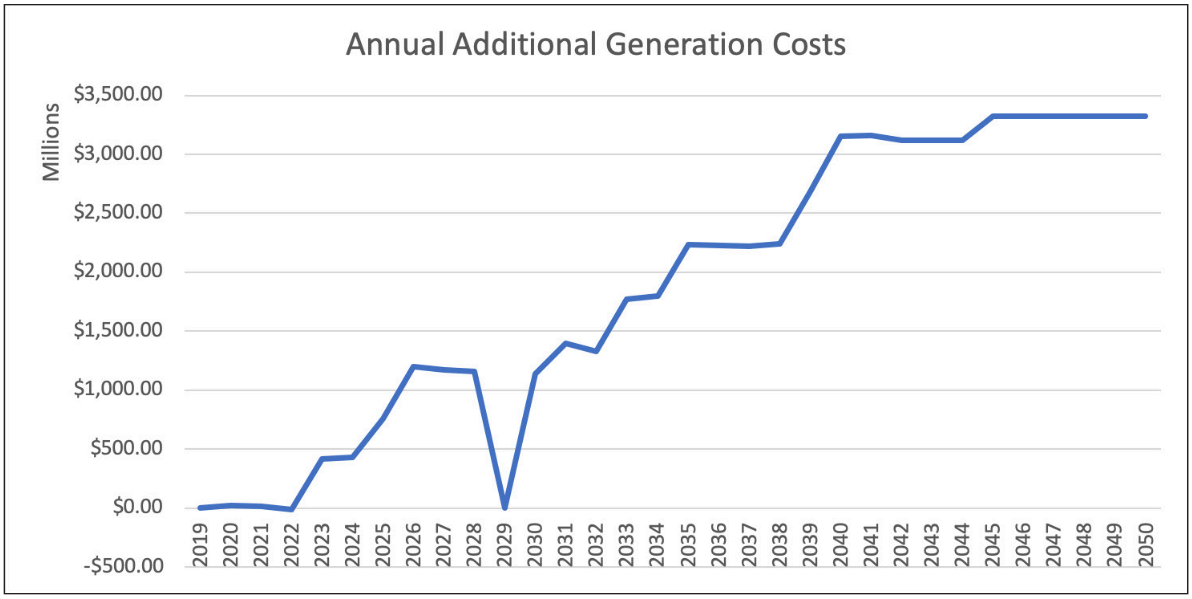


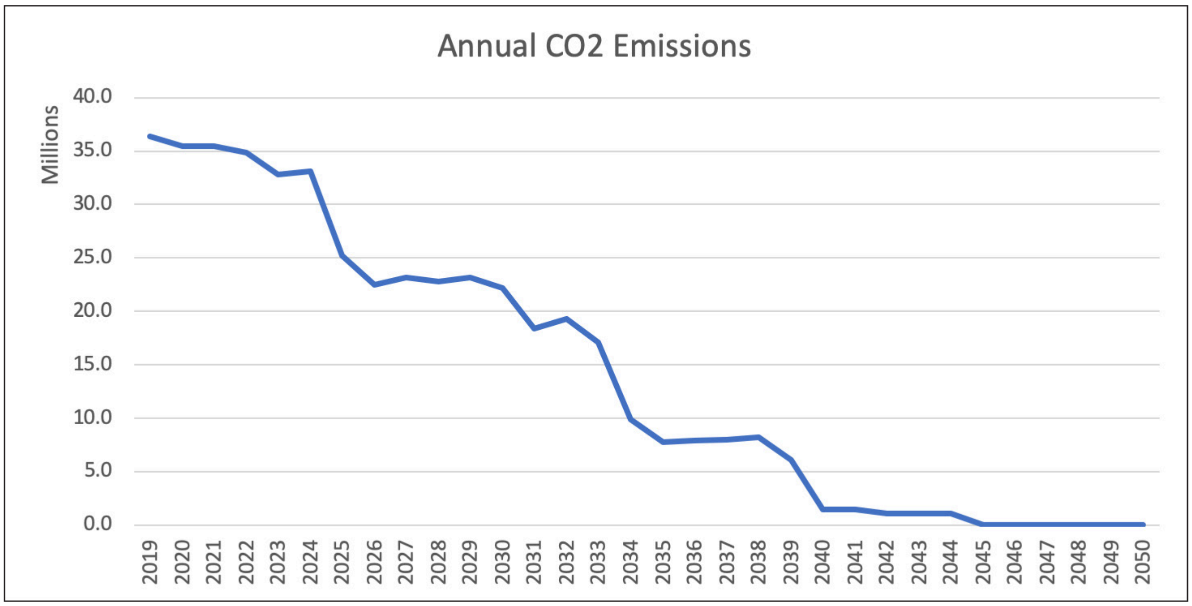
Annual Generation by Energy Source (MWhs)
Millions
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
(10.0)
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other

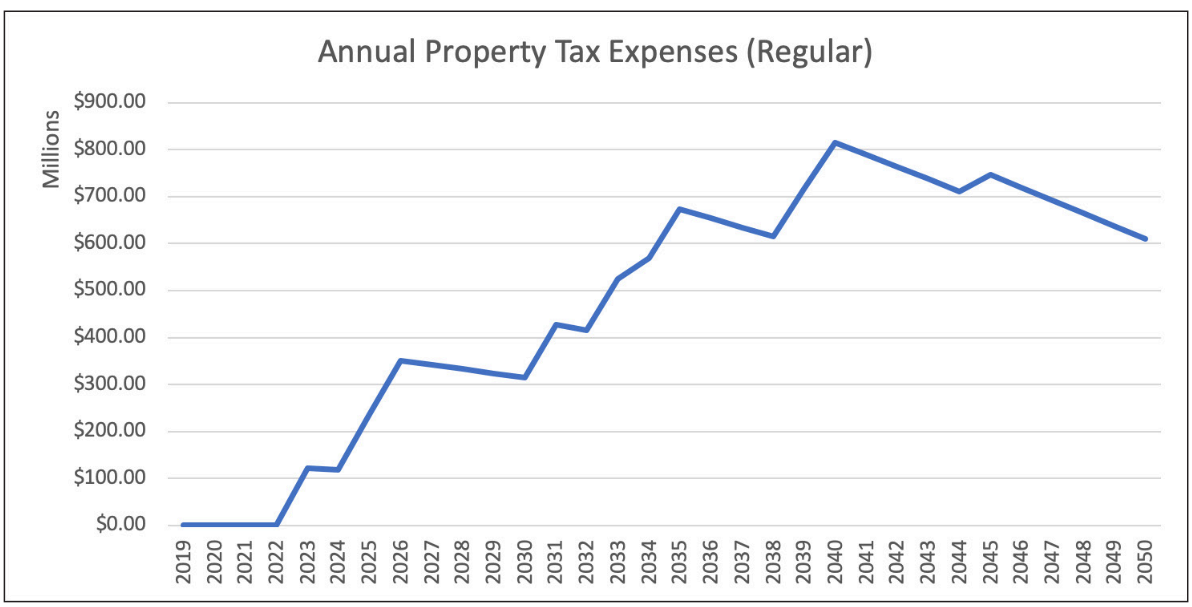

Annual Cost Breakdown by Energy Source
Billions
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
-$1.00
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other

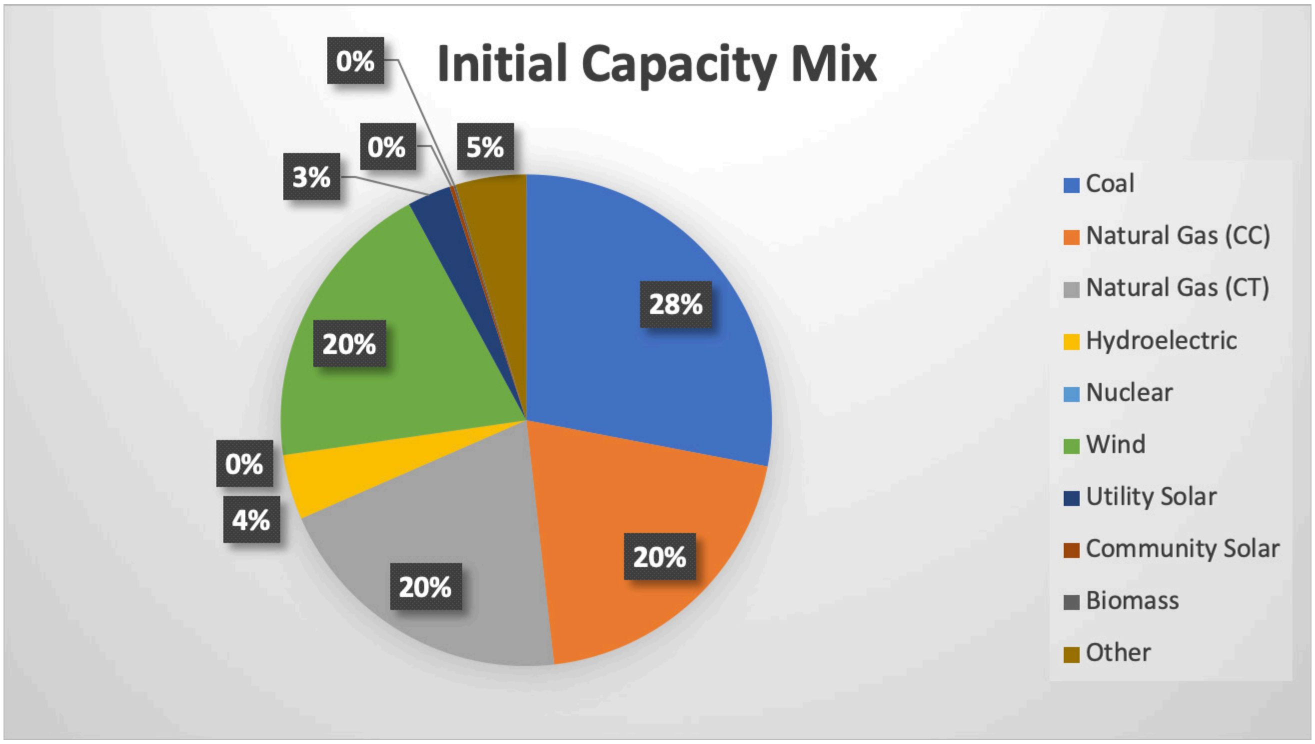

Annual Utility Profits (Regular)
Billions
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050

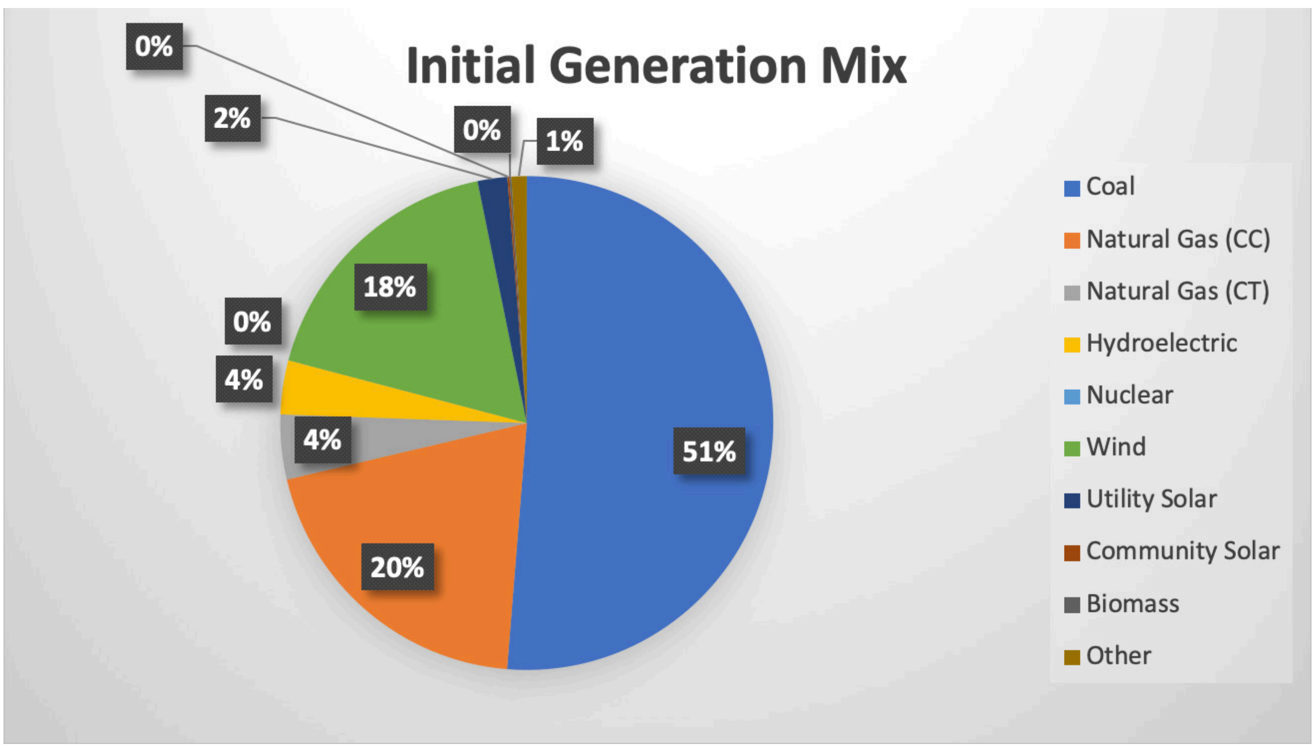

Annual Total Additional Costs (Regular)
Billions
$9.00
$8.00
$7.00
$6.00
$5.00
$4.00
$3.00
$2.00
$1.00
$0.00
-$1.00
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050

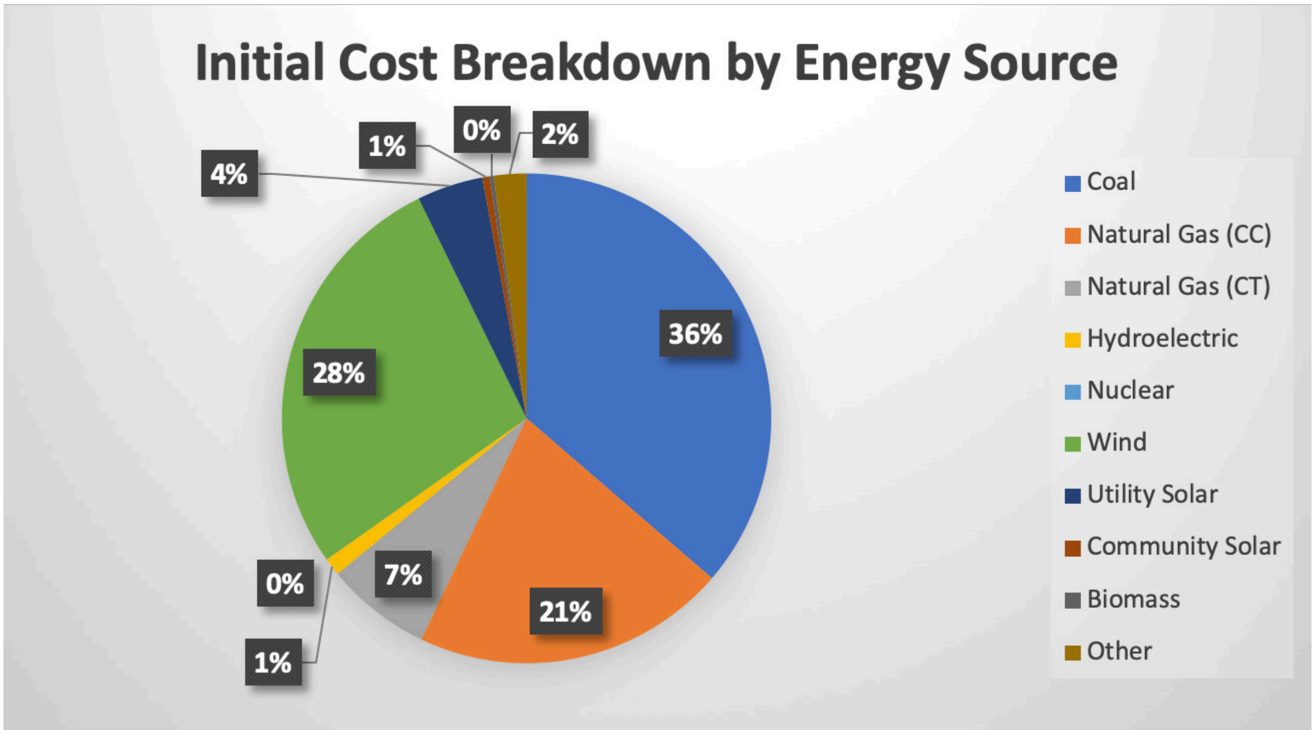

Annual Additional Generation Costs
Millions
$3,500.00
$3,000.00
$2,500.00
$2,000.00
$1,500.00
$1,000.00
$500.00
$0.00
-$500.00
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050

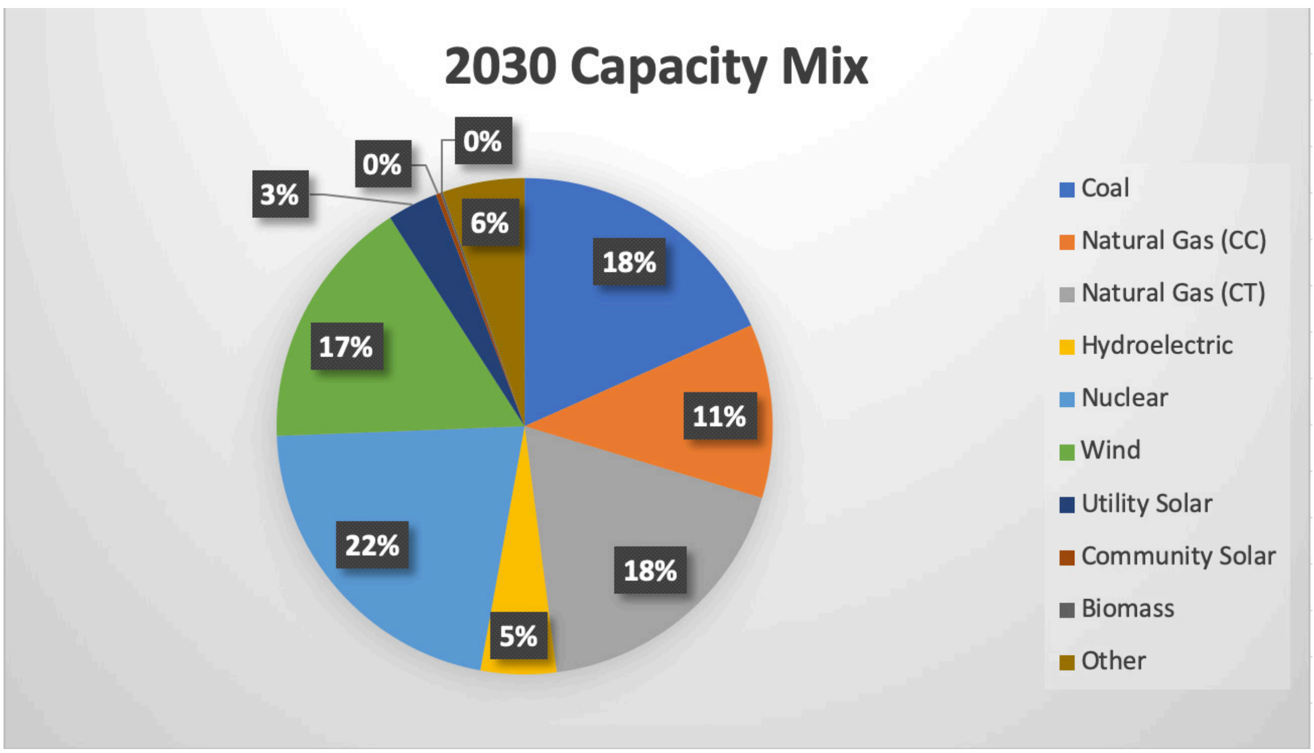

Annual CO2 Emissions
Millions
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050

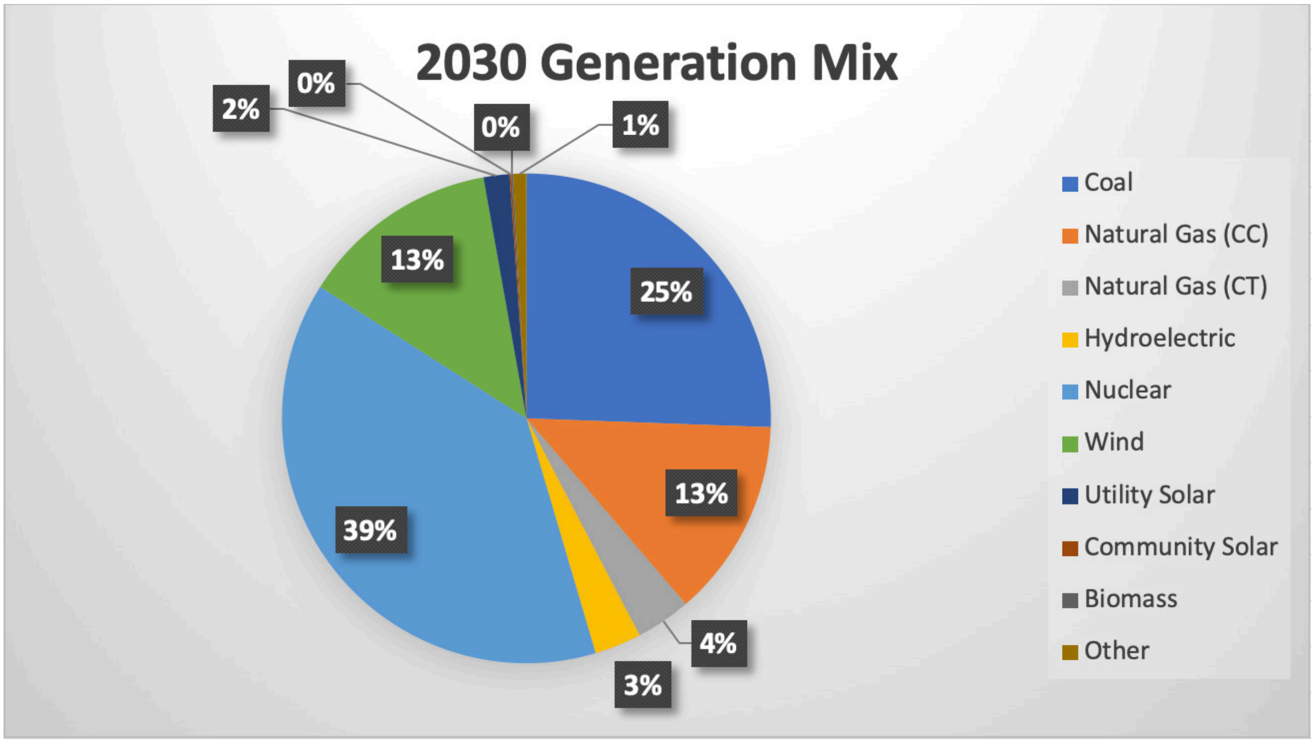

Annual Property Tax Expenses (Regular)
Millions
$900.00
$800.00
$700.00
$600.00
$500.00
$400.00
$300.00
$200.00
$100.00
$0.00
2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050

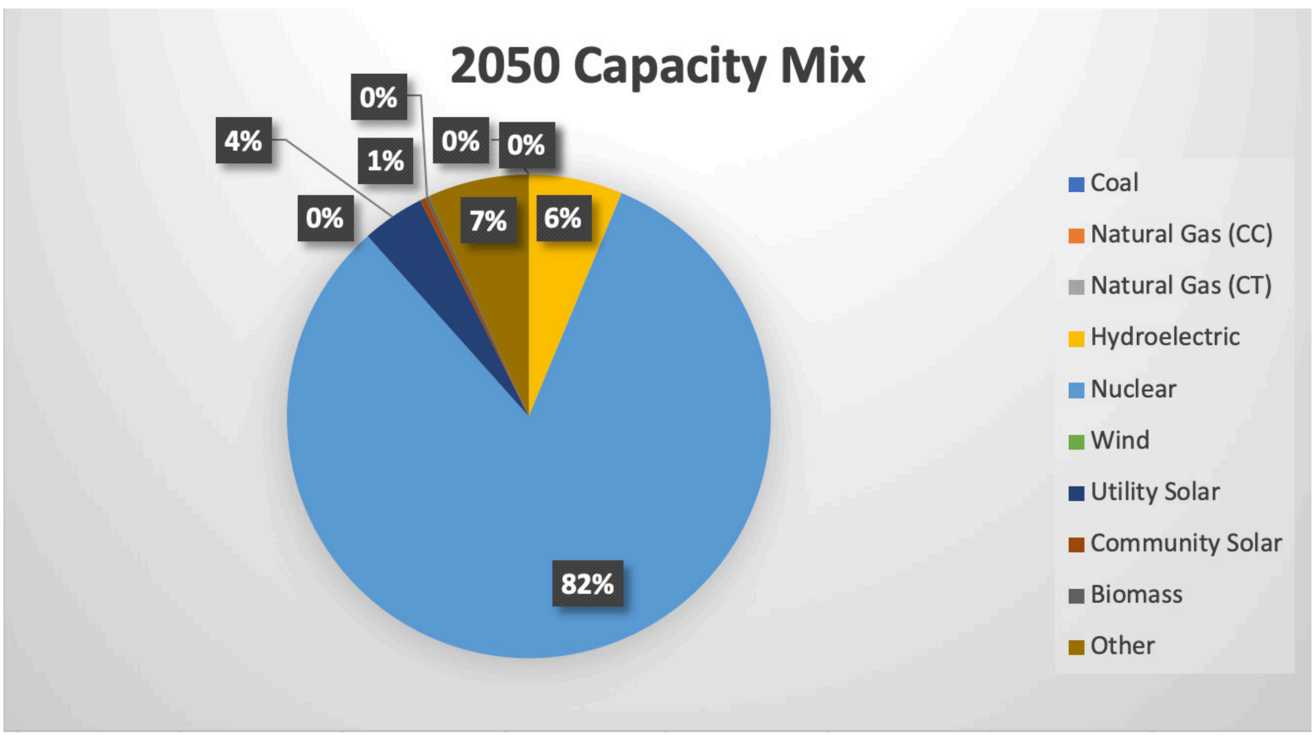

Initial Capacity Mix
0%
0%
5%
3%
28%
20%
0%
4%
20%
20%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other

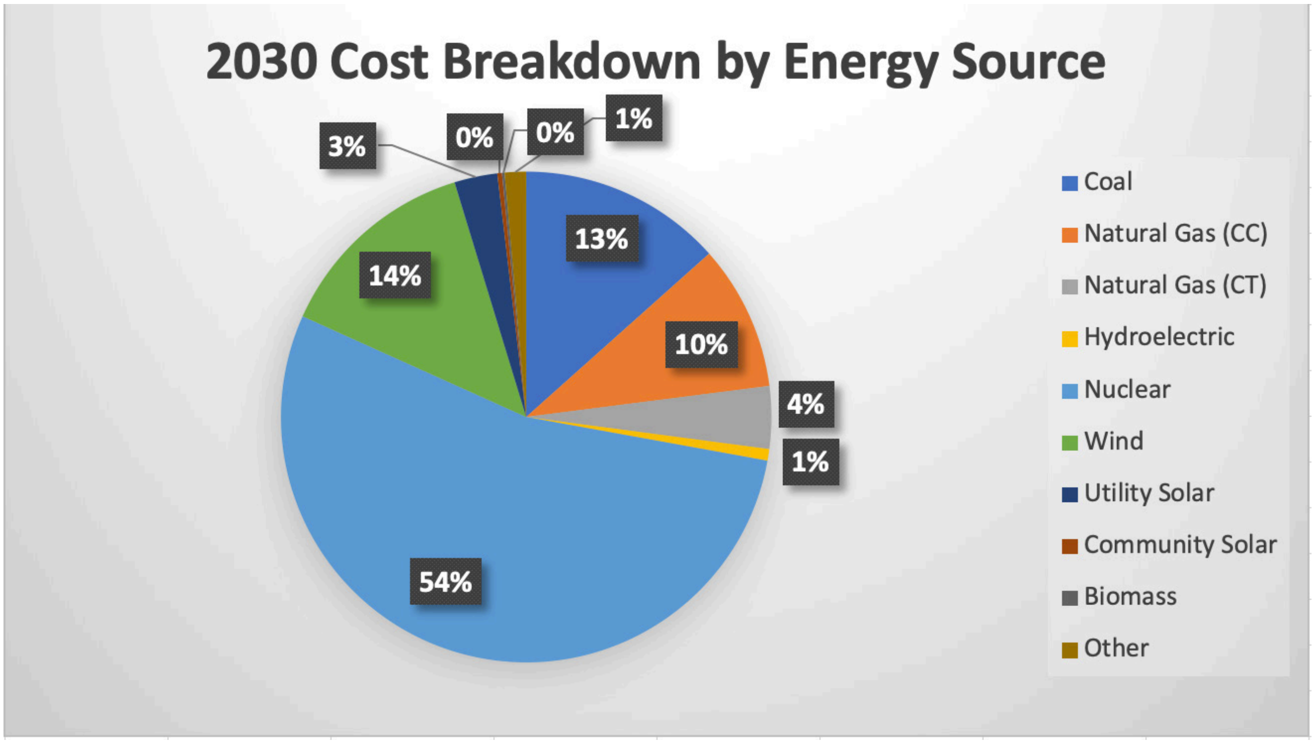

Initial Generation Mix
0%
2%
0%
1%
18%
0%
4%
4%
51%
20%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other

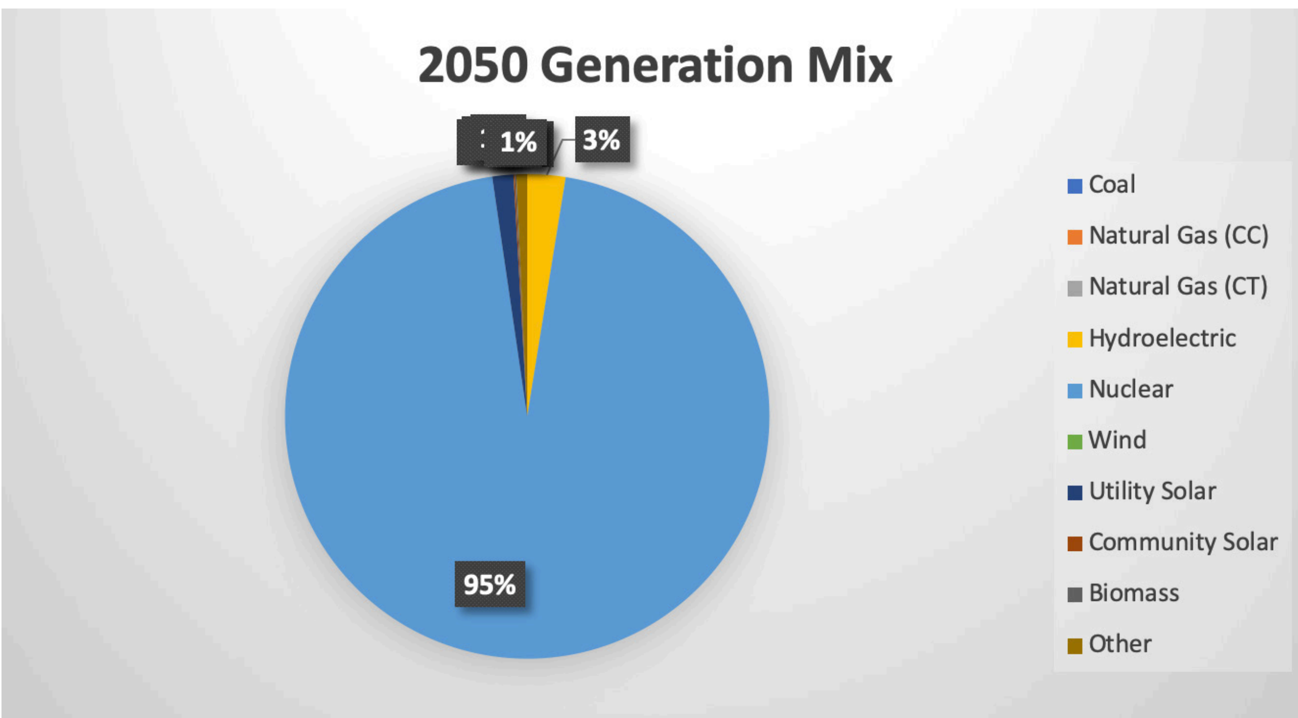

Initial Cost Breakdown by Energy Source
36%
21%
7%
1%
0%
28%
4%
1%
0%
2%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other

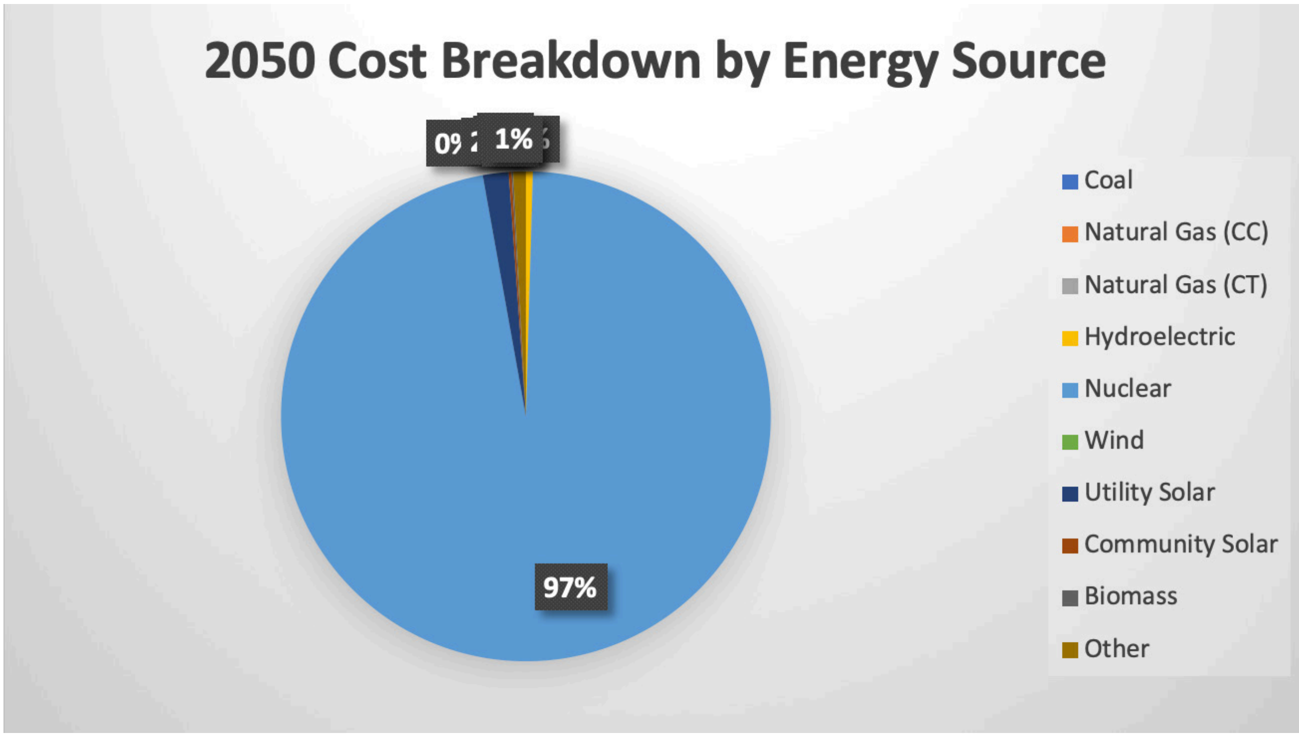

2030 Capacity Mix
18%
11%
18%
5%
22%
17%
3%
0%
0%
6%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other


2030 Generation Mix
0%
2%
0%
1%
13%
25%
13%
39%
4%
3%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other


2050 Capacity Mix
0%
4%
1%
0%
0%
0%
7%
6%
82%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other


2030 Cost Breakdown by Energy Source
3%
0%
0%
1%
13%
14%
10%
4%
1%
54%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other


2050 Generation Mix
1%
3%
95%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other


2050 Cost Breakdown by Energy Source
1%
97%
Coal
Natural Gas (CC)
Natural Gas (CT)
Hydroelectric
Nuclear
Wind
Utility Solar
Community Solar
Biomass
Other

Endnote

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