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Colorado's Energy Future:
The High Cost of 100% Renewable Electricity by 2040

A Joint Analysis by Independence Institute and Center of the American Experiment
Part 1 of 3

by Jake Fogleman
With Isaac Orr and Mitch Rolling

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Authors' Note: This report is the first in a series of three reports analyzing the costs and reliability impacts of Colorado's climate change mitigation policies. It is a continuation of the work performed by Center of the American Experiment modeling the cost of renewable energy mandates in states throughout the country.

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EXECUTIVE SUMMARY

- Colorado Governor Jared Polis's goal of a 100 percent renewable (wind, solar, and batteries) electric grid by 2040 (hereafter, the "Polis Plan") would cost the state $318.8 billion through 2050.
- Colorado electricity customers (residential, commercial, and industrial) would see their average monthly electricity bills increase to $628 by 2040.
- The transition would reduce the reliability of the grid by making the state more vulnerable to fluctuations in electricity output from weather-dependent energy sources like wind and solar.
- Under the Polis Plan, the electric grid would experience capacity shortfalls, which means there is not enough electricity on the grid to prevent blackouts, due to weather-driven fluctuations in electricity generation from wind and solar facilities.
- Colorado would experience 25 hours of blackouts spread across three separate events in January and early February 2040 if electricity demand and wind and solar output are the same as they were in the year 2021.
- Alternatively, Colorado could meet Polis's electric-sector decarbonization goals on the same timeline, without reliability issues and at just over a quarter of the cost, by transitioning the state's generating assets to nuclear energy.

INTRODUCTION

Colorado's electric grid stands at the precipice.

For nearly two decades, heavy-handed policymakers, well-funded environmental NGOs, and many of the state's electric utilities have been conducting a long-running experiment of picking winners and losers in the power sector without regard for the costs of doing so.

> ...the electricity that powers Colorado homes and businesses has only become more expensive.

Under the banner of environmentalism, increasing amounts of wind and solar energy have been shoehorned into the state's electricity mix at every opportunity, while the state's affordable fossil fuel plants have been forced to manage ever-increasing regulatory strictures imposed by policymakers who would see them shuttered.

As a result, the electricity that powers Colorado homes and businesses has only become more expensive.

Since 2004, when the state enacted its first renewable portfolio standard,[1] all-sector electricity prices in Colorado have increased by more than 70 percent, from an average of 6.95 to 11.85 cents per kilowatt hour (kWh) through 2022.[2],[3] Colorado's prices are now the highest on average in the entire Mountain West region.

Former Independence Institute Energy and Environmental Policy Center Director Amy Cooke warned Coloradans this would happen back in December 2010, following the Public Utilities Commission's (PUC) final decision on the controversial Clean Air, Clean Jobs Act:

It's a bad day for Colorado energy users, and that's pretty much everyone. The ethically-challenged Public Utilities Commission just gave a final thumbs up to Xcel's fuel-switching plan as mandated by HB 1365….

Losers in this deal include consumers who will see their utility costs go up. Of course, the negative impact won't just be felt at home but also on Coloradans' total cost of living because businesses will have to raise their prices to cover their increased energy costs.

Also, the natural gas industry ultimately will be one of the biggest losers. Make no mistake. This is not about cleaner-burning natural gas; the real goal is to switch to renewable energy — expensive, unreliable renewable energy. The precedence for fuel switching has been set. We are just one more legislative "fix" away from ridding Colorado of fossil fuel-fired plants and replacing them with thousands of acres of windmills.[4]

To be fair, the state has made significant strides in reducing power sector emissions. According to federal data from the Energy Information Administration (EIA), Colorado's electricity sector has slashed more than 12 million metric tons of annual CO2 emissions since its peak in 2007, thanks to an increase in natural gas-fired electricity generation brought about by the shale revolution as well as increased wind capacity in the state.[5]

Yet that progress has not been enough to dissuade the state's elected officials from pressing the accelerator on the state's forced energy transition.

Colorado Governor Jared Polis (D.) campaigned for his first term in office on a platform of transitioning the state to 100 percent renewable energy by 2040. In his first year in office, Polis unveiled an official government "roadmap" to do just that.[6] Since then, he has signed into law no fewer than 55 climate bills and directed his executive agencies to craft at least a dozen new regulations aimed at making his roadmap a reality.[7] Perhaps most consequential among those is the recent PUC decision to completely phase-out coal-fired generation in the state no later than January 1, 2031.[8]

Colorado Governor Jared Polis (D.) campaigned for his first term in office on a platform of transitioning the state to 100 percent renewable energy by 2040. In his first year in office, Polis unveiled an official government "roadmap" to do just that.

This three-part study does what no one else has been willing to attempt thus far. With the help of detailed modeling commissioned by the Independence Institute and conducted by energy researchers at the Center of the American Experiment, it aims to put a total price tag on the state's energy transition while evaluating the reliability implications that come with it.

Part One of the study assesses the costs and grid reliability impacts of Governor Polis' proposal to mandate the transition of Colorado's electric grid to 100 percent renewable by 2040 (hereafter, the "Polis Plan").

Part Two will examine the cost of transitioning Colorado's residential natural gas home heating usage to electric home heating, using a combination of heat pumps and electric resistance heating, on a 100 percent renewable electric grid.

Part Three will analyze the added costs and reliability impacts of meeting the increased demand of transitioning Colorado's internal combustion vehicle fleet to all-electric.

Each part of the study also assesses an alternative scenario, referred to as the "Lower Cost Decarbonization" (LCD) scenario. Here, emissions reductions are achieved by utilizing reliable, clean technologies such as new nuclear power plants — including traditional, large nuclear power plants that have already demonstrated their viability at scale in other jurisdictions, and innovative small-modular reactors (SMRs).

These technologies offer superior value to wind and solar because they are dispatchable, meaning they can provide power whenever called upon to do so. As a result, the LCD Scenario delivers 100 percent emissions reductions from the status quo in each case, at a lower price than under the Polis Plan, and without sacrificing the reliability of the electric grid.

Ultimately this report aims to show that the state has more options than are currently being considered. Colorado policymakers can continue to embark down the road of California-style climate policy, causing Coloradans to face skyrocketing costs and reliability risks, or they can prioritize reliability and lower costs while still providing clean, abundant power to help minimize our state's climate impact.

THE POLIS PLAN

On May 30, 2019, Governor Jared Polis unveiled his administration's "Roadmap to 100% Renewable Energy by 2040 and Bold Climate Action."[9] The roadmap formalized an ambitious campaign promise by then-candidate Polis before securing his first term, and he has routinely doubled down on its central tenets throughout his tenure in office.

> A "100 percent renewable" standard is not synonymous with a "100 percent clean" or "carbon-free" standard...

While light on concrete details, the roadmap outlines a broad vision of completely transitioning the state's existing fossil fuel generation to renewables like wind and solar, promoting energy efficiency, and electrifying the state's building and transportation sectors. It was released in tandem with Polis' signing of a landmark climate bill, HB19-1261, which codified statewide greenhouse gas (GHG) reduction benchmarks of six percent reduction by 2025, 50 percent by 2030, and 90 percent reduction by 2050.[10]

The particular phrasing of the Governor's goal is both intentional and key to its execution. A "100 percent renewable" standard is not synonymous with a "100 percent clean" or "carbon-free" standard, though their impacts on the fight against climate change would be comparable. Instead, the former definitionally excludes the United States' current single-largest source of zero-carbon electricity generation in nuclear energy.[11] It also precludes the inclusion of more novel yet promising technologies like carbon capture attached to existing fossil fuel plants.

Indeed, the state's statutory definition of renewable energy resources explicitly carves out such resources, stating, "fossil and nuclear fuels and their derivatives are not eligible energy resources." Instead, only the following resources are granted eligibility under the state's definition of renewable:

> *solar, wind, geothermal, biomass that is greenhouse gas neutral, and new hydroelectricity with a nameplate rating of ten megawatts or less and hydroelectricity in existence on January 1, 2005, with a nameplate rating of thirty*

megawatts or less and that does not require the construction of any new dams or reservoirs.[12]

As such, the Polis Plan calling for "100 percent renewable energy" amounts in practice to a 100 percent wind, solar, and battery storage mandate that also utilizes existing small hydroelectric power plants located in Colorado.

The Polis Plan would require all the state's coal, natural gas, and petroleum-burning power plants, which together generated 66 percent of Colorado's electricity in 2021, to be retired no later than December 31, 2039.

This analysis examines the cost and reliability implications of complying with the Polis Plan. It compares it to the LCD Scenario, which prioritizes providing the most reliable, carbon-free electricity for Colorado ratepayers regardless of categorization under any definition of renewable.

We conclude that complying with the Polis Plan will add substantial cost and complexity to the task of maintaining a reliable electric grid compared with the LCD Scenario, which will provide similar emissions reductions and improved reliability outcomes at a lower cost.

It is important to note that the model does not incorporate any federal or state subsidies paid to wind and solar facilities, nor does it include federal subsidies available for new nuclear plants. The exclusion of various subsidies is appropriate because, as energy researchers Isaac Orr and Mitch Rolling point out, "subsidies do not reduce the cost of producing energy using these resources. They simply shift who pays for it."[13]

This analysis also assumes that electricity consumption in Colorado will remain constant at 2022 demand levels through 2050. This assumption is conservative because Governor Polis and other like-minded Colorado policymakers are promoting and, at times, mandating the widespread adoption of electric vehicles and the broader electrification of Colorado's economy for purposes such as home and water heating. Doing so would dramatically increase demand on the grid and, thus, the need for more electricity generation. It would require even more capacity additions to comply with the Polis Plan.

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

The Polis Plan would require all the state's coal, natural gas, and petroleum-burning power plants, which together generated 66 percent of Colorado's electricity in 2021, to be retired no later than December 31, 2039.

THE LCD SCENARIO

The Lower Cost Decarbonization (LCD) Scenario seeks to provide a more reliable and affordable path to reducing carbon dioxide emissions from the electricity sector at the same pace and scale envisioned by the Polis Plan—100 percent by 2040.

Under the LCD Scenario, electric companies in Colorado would continue to utilize existing coal, natural gas, petroleum, wind, and solar capacity through their scheduled retirement dates—except for the Comanche generating station, which would be retired in 2040 rather than the accelerated date currently set for the end of 2030. The state's existing hydroelectric capacity would be kept constant through 2050.

Xcel's coal plants are kept online longer in this scenario to provide reliable electricity while new nuclear power plants are being constructed, substantially reducing the costs associated with the transition.

Nuclear power plants were selected as the modeled choice for the LCD Scenario because nuclear power is a clean firm resource, meaning it is zero-carbon and can be relied upon to supply electricity whenever it is needed for as long as it is needed. It was also selected because real-world examples have demonstrated that every single grid of any meaningful scale that has ever achieved deep decarbonization has done so using nuclear power, hydroelectric power, or both (with the exception of Iceland, which has abundant geothermal resources).[14]

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This analysis did not model increased hydroelectric capacity because Colorado has limited potential to expand its hydropower resources due to geographic, political, and persistent drought-related constraints. The model also excluded geothermal generation because it has yet to be demonstrated at scale in the U.S.

New nuclear facilities would take two primary forms: APR-1400s, which are large-scale pressurized water reactors currently built and deployed by South Korea, and small modular reactors (SMRs).

The APR-1400 is a 1,400 MW power plant built by the Korea Electric Power Corporation (KEPCO). This particular reactor was selected because it has a track record of being built at scale on time and on budget[15]—something other reactor designs have struggled with in recent years.[16]

It also has the advantage of having already been certified for use in the United States by the U.S. Nuclear Regulatory Commission.[17]

SMRs are used because they have the potential to offer improved flexibility compared with traditional nuclear plants and baseload fossil fuel plants with carbon capture. That allows them to be used as peaking assets to meet fluctuations in electricity demand throughout the course of a given day.[18]

The LCD Scenario also includes 500 MW of battery storage to help firm up the grid during periods of peak demand. These batteries are charged using the excess generation from the newly built nuclear fleet.

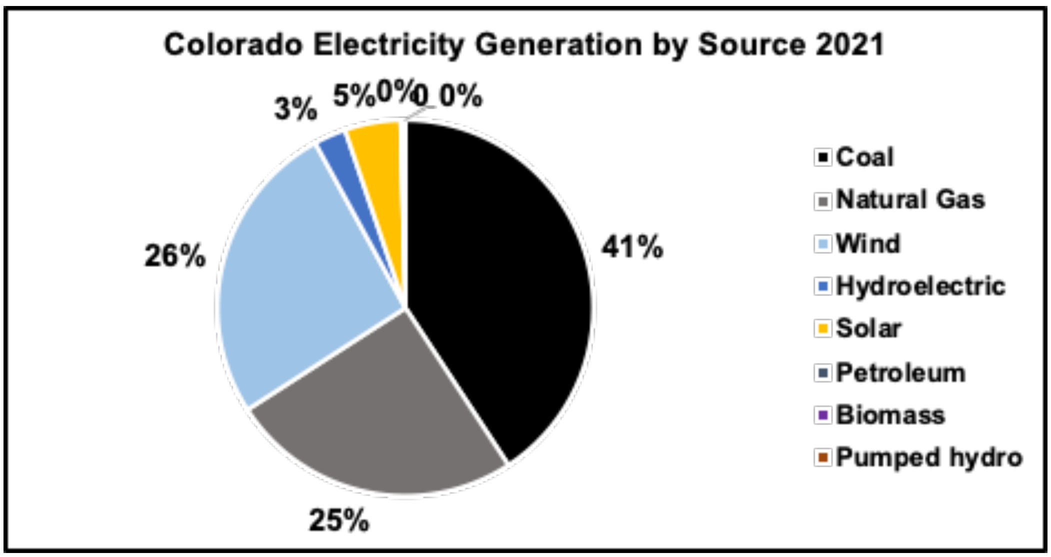
Because solar panels and wind turbines depend upon favorable weather conditions and certain times of day to produce electricity, they are at best redundant and, at worst, deadweight on a grid with abundant dispatchable energy resources. For the purposes of the LCD Scenario, Colorado's existing wind and solar facilities are allowed to operate through the end of their useful lives (up to 25 years) and then are replaced by new nuclear generation.

COLORADO'S ELECTRICITY MIX BEFORE AND AFTER THE POLIS PLAN

In 2021, Colorado derived approximately 41 percent of its electricity from coal, 26 percent of its electricity from wind, 25 percent from natural gas, five percent from solar, three percent from hydroelectric (excluding pumped storage), and less than one percent from a combination of biomass, petroleum, and pumped storage hydropower (see Figure 1).[19]

This analysis uses 2021 data for a baseline because complete 2022 data were not yet available at the time of this report.

Figure 1.



Coal, Natural Gas, and Wind accounted for 92 percent of the electricity generated in Colorado in 2021. Fossil fuel generation alone accounted for roughly two-thirds of the state's electricity generation

Under the Polis Plan, Colorado's electricity mix would be required to shift radically.

To meet the Governor's goal of 100 percent renewable energy by 2040, all utility companies operating in the state will be required to replace electricity currently generated with coal, natural gas, and petroleum with qualifying renewable energy resources such as wind turbines, solar panels, and battery storage facilities by 2040.

> Maintaining grid reliability and resource adequacy would be much more affordable if natural gas were used instead of battery storage, but these facilities would not be allowed under the Governor's renewables-only proposal.

Maintaining grid reliability and resource adequacy would be much more affordable if natural gas were used instead of battery storage, but these facilities would not be allowed under the Governor's renewables-only proposal. Furthermore, because natural gas plants have lifespans of 30 or more years, any new gas plant built between now and 2040 would be forced into early retirement. This would require Colorado ratepayers to pay millions of dollars to cover utilities' stranded asset costs for power plants they would no longer benefit from.

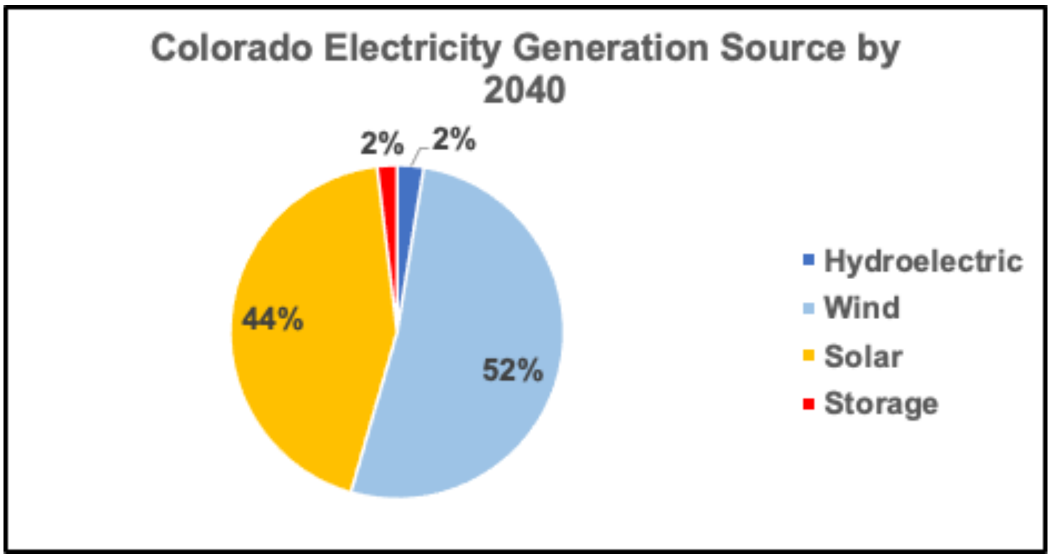
Therefore, this analysis excludes the possibility of new natural gas additions. Instead, it calculates the cost of using battery storage technology to provide electricity to the grid when the wind is not blowing, and the sun is not shining.

COLORADO'S ELECTRICITY MIX UNDER THE POLIS PLAN

American Experiment's model calculates Colorado's new generation mix resulting from compliance with the Polis Plan using wind and solar generation with battery storage. Figure 2 shows Colorado's electricity mix in 2040, and Figure 3 shows the annual share each source of electricity contributes to the state's total electricity consumption.

To meet a 100 percent renewable electricity generation standard, the state's electric utilities would have to invest heavily in new wind, solar, and battery storage facilities to meet demand.

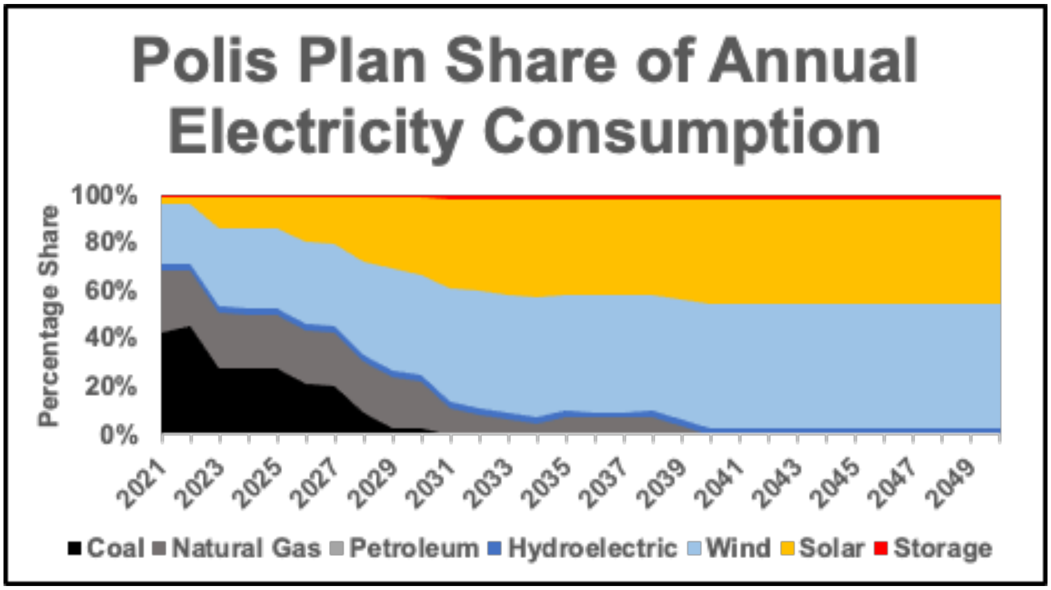
Figure 2.



Wind would become the state's single largest source of electricity, generating most of the power consumed in Colorado in 2040. Solar would make up a slightly smaller share, while hydropower and battery storage would provide a modest share of the electricity mix.

To meet a 100 percent renewable electricity generation standard, the state's electric utilities would have to invest heavily in new wind, solar, and battery storage facilities to meet demand. We project that by 2040, 52 percent of Colorado's electricity would come from wind, 44 percent would come from solar, two percent would come from hydroelectric resources, and two percent would be supplied by battery storage. All of the state's existing fossil fuel generation would be retired and thus would not produce any of the state's electricity in 2040.

Figure 3.



Coal's share of the state's electricity consumption shrinks dramatically as wind and solar grow to 96 percent of electricity consumption.

COLORADO'S ELECTRICITY MIX UNDER THE LCD SCENARIO

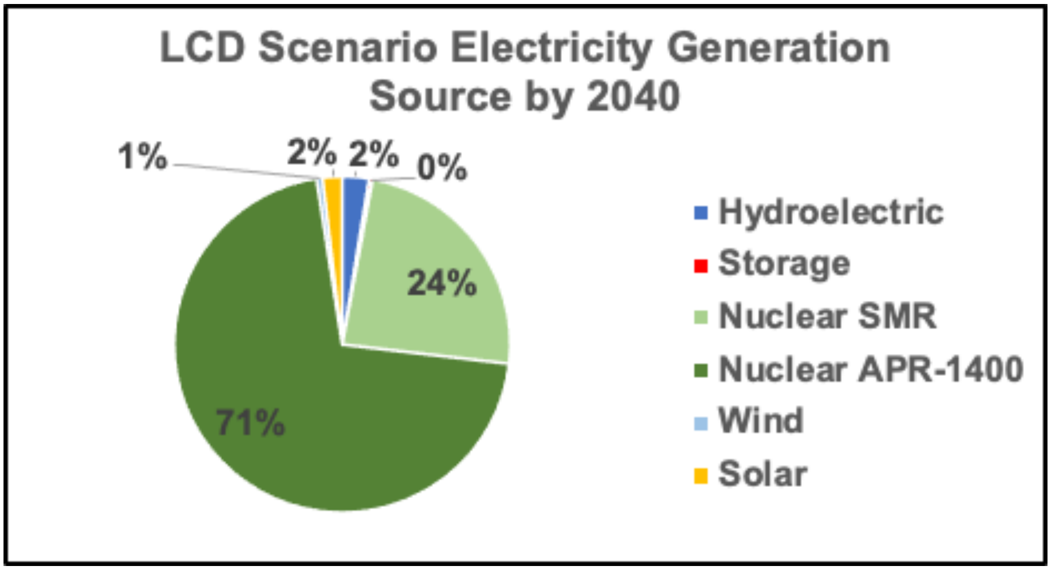
Under the LCD Scenario, Colorado would receive 71 percent of its electricity from new build APR-1400 nuclear plants, 24 percent from new SMR nuclear plants, two percent from in-state hydroelectric generation, two percent from solar, one percent from wind, and less than one percent from battery storage (See Figure 4).

The changing resource mix under this scenario can be seen in Figure 5. Unlike the Polis Plan, Colorado's coal generation is allowed to run until 2040 under the LCD Scenario rather than facing a more aggressive phase-out of 2031. Likewise, the state's natural gas generation is decreased to zero by 2040, and output from in-state renewables shrinks considerably as older installations are allowed to retire. Meanwhile, nuclear power makes up an increasing share of the state's generation mix starting in the early 2030s.

Figure 5 shows the annual share of total electricity consumption provided by each source of electricity through 2050 under the LCD Scenario.

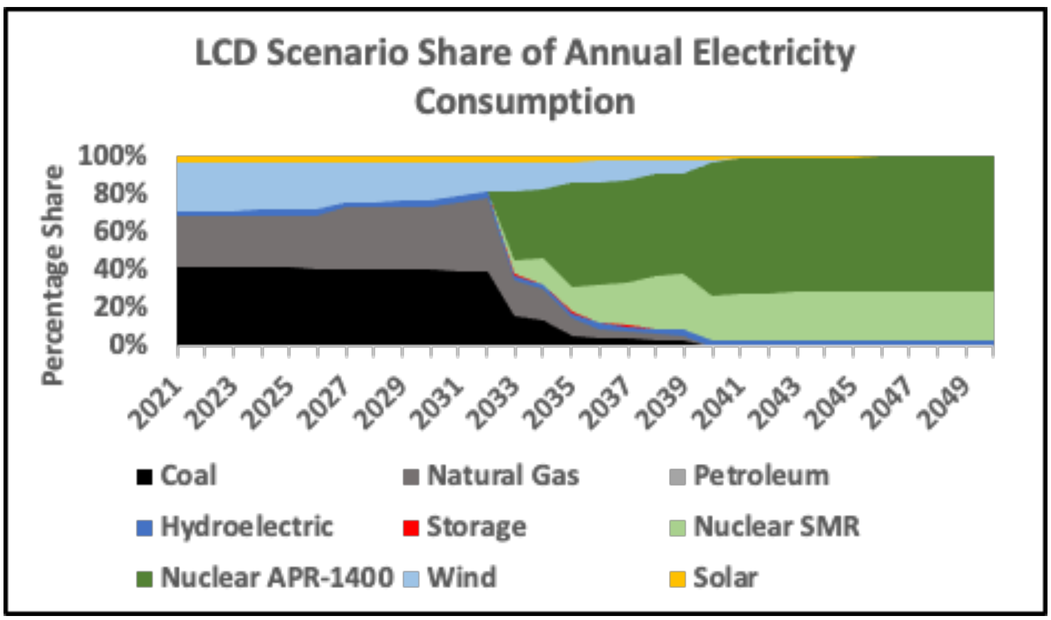
Under the LCD Scenario, Colorado would receive 71 percent of its electricity from new build APR-1400 nuclear plants, 24 percent from new SMR nuclear plants, two percent from in-state hydroelectric generation, two percent from solar, one percent from wind, and less than one percent from battery storage.

Figure 4.



Under the LCD Scenario, Nuclear becomes the single largest source of electricity generation in Colorado by 2040, contributing around 95 percent of the state's power.

Figure 5.



Nuclear power would be deployed rapidly beginning in 2033 to offset declining fossil generation.

HOW REALISTIC ARE EITHER OF THESE PLANS?

The changing electricity generation mix under the Polis Plan will have profound impacts on the cost of electricity for Colorado ratepayers and on the reliability of the electric grid. In contrast, the LCD Scenario would maintain reliability and reduce emissions at a still substantial, but far lower cost.

Both proposals would require aggressive timelines for retiring existing power plants, and both proposals call for a massive build out of new replacement generating capacity on an abbreviated time schedule.

Supporters of the renewables-only strategy will likely claim that the buildout of roughly 12,600 MW of new nuclear capacity envisioned by the LCD Scenario is unrealistic given the recent track record of legacy nuclear projects in the U.S. and the stifling regulatory environment that currently exists at the federal level for next-generation plant designs.[20]

At the same time, the massive capacity buildouts required to implement the Polis Plan total nearly 117,729 MW, more than nine times the capacity needed for the LCD Scenario. Such a massive capacity buildout is unprecedented and is unlikely to occur by 2040.

For example, between 2004—when Colorado's first renewable portfolio standard was enacted—and the end of 2021, Colorado installed just 4,991 MW of new wind capacity. The Polis Plan would require a total wind capacity of 37,603 MW to be operating in the next 17 years. This means Colorado would need to build 7.5 times more wind facilities in the next 17 years than it has built in the previous 19 years.

The required solar buildout is even more daunting. Required solar capacity under the Polis Plan totals approximately 56,276 MW. The state had roughly 1,060 MW installed as of the end of 2021, nearly 53 times less capacity than the plan's 2040 deadline calls for.

Finally, the battery storage requirements of the Polis Plan pose an even more extreme challenge. The plan would require roughly 23,850 MW of four-hour battery capacity, up from the 10.2 MW of utility-scale battery storage the state had installed as of the end of 2021. That's more than 2,000 times the current amount of battery capacity being built in one state in under two decades—a tall task, to put it mildly.

While we can model the theoretical cost of attempting to power a grid with the Polis Plan and the LCD Scenario, that does not mean either plan will materialize in the real world. The most likely scenario is that the complete decarbonization of the electricity sector envisioned by both proposals is unlikely to be technically or economically feasible by 2040 without a major paradigm shift in technological innovation, the existing regulatory environment, and widespread public buy-in to help speed up power plant construction at reduced costs.

Furthermore, much will depend on the future operational nature of Colorado's electric grid. In 2021, the Colorado General Assembly passed a bill requiring the state's

The changing electricity generation mix under the Polis Plan will have profound impacts on the cost of electricity for Colorado ratepayers and on the reliability of the electric grid.

electric utilities to join an organized wholesale market, otherwise known as a regional transmission organization (RTO), by 2030.[21]

The state currently operates under a traditional, vertically-integrated monopoly utility model whereby individual utilities own and operate the generation, transmission, and distribution of electricity to their customers and are regulated by individual states themselves. By contrast, RTOs are independent non-profit organizations that oversee competitive wholesale markets for electricity across multiple states. They are regulated by the Federal Energy Regulatory Commission (FERC).

Colorado's participation in an RTO would greatly impact the calculus and timeframe of this analysis. Participation in an RTO would transfer a great deal of control over Colorado's electric utility assets to a broader regional process, and it would pool Colorado's resources with those of out-of-state utilities and independent power producers, introducing new cost and reliability considerations.[22]

None of Colorado's electric utilities have committed to joining any existing RTO yet, nor have they decided whether they will join with other vertically integrated western utilities to form a brand-new RTO. Additionally, the law leaves open the possibility for the Colorado Public Utilities Commission to decide against participating in an RTO if the regulators decide it is not in the public interest.[23]

Because so much uncertainty still exists about how Colorado's participation in an RTO will eventually work, and because Governor Polis' commitment to 100 percent renewable energy by 2040 predates Colorado's pledge to join an RTO by multiple years, an analysis of Colorado achieving the same goals using a wholesale market is not included in this report.

Regardless of the method chosen, completely overhauling the way Colorado generates electricity over the next 17 years will be costly.

COMPARING THE COSTS OF THE POLIS PLAN AND THE LCD SCENARIO

Regardless of the method chosen, completely overhauling the way Colorado generates electricity over the next 17 years will be costly.

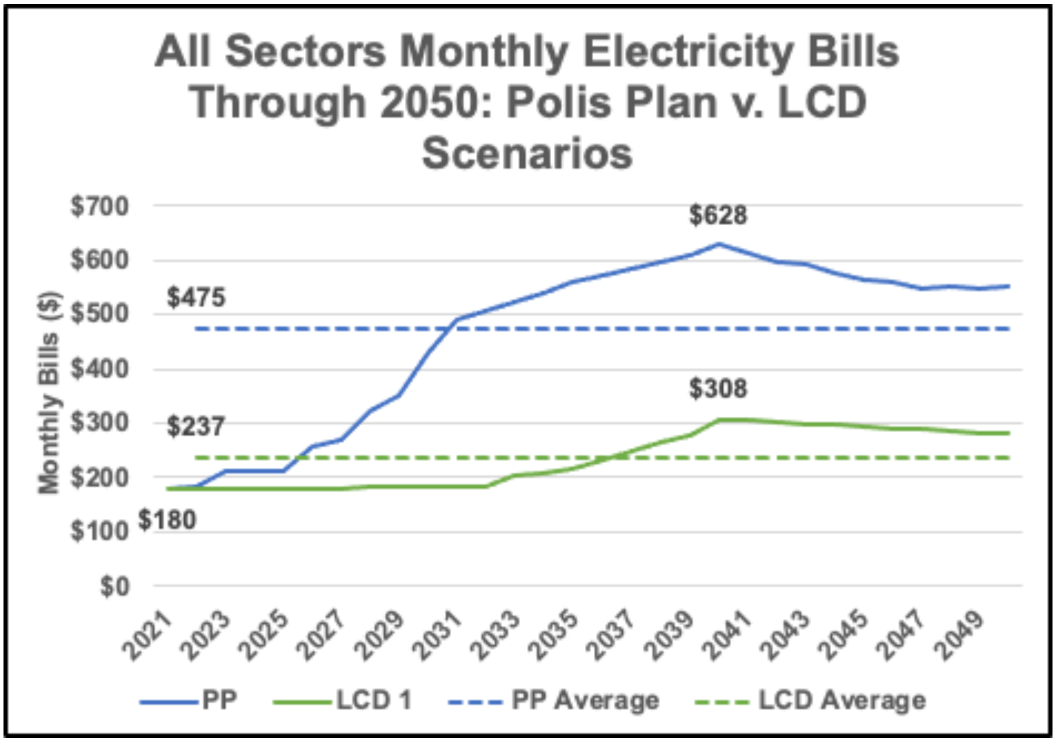
Both the Polis Plan and the LCD Scenario would increase electricity costs for Colorado ratepayers. However, the LCD Scenario would impose far fewer costs while achieving the same carbon reduction goals as the alternative.

Modeling conducted by the Center of the American Experiment indicates that complying with the Polis Plan will cost an additional $318.8 billion through 2050 using constant 2022 dollars. This would nearly quadruple existing average all-sector electricity rates from 10.90 cents per kilowatt hour (kWh) in 2021 to 38.12 cents per kWh in 2040. The resulting average monthly cost for each Colorado utility customer would increase by as much as $448 per month in 2040. (Figure 6).

By comparison, pursuing the LCD Scenario would cost an additional $88.4 billion, roughly $230 billion less than the Polis Plan through 2050. Under the LCD Scenario, average all-sector electricity rates would increase by roughly 8 cents per kWh, from 10.90 cents per kWh in 2021 to 18.70 cents per kWh by 2040. Average monthly electricity bills for all Colorado utility customers would increase $180 to as high as $308 in 2040—more than $300 per month cheaper than under the Polis Plan.

Figure 6 shows the average monthly costs borne by Colorado residential, commercial, and industrial ratepayers for complying with both the Polis Plan and LCD Scenario.

Figure 6.



Monthly electricity costs for Coloradans increase by $448 under the Polis Plan. Costs peak at $628 per month in 2040. The LCD Scenario would increase monthly electric costs by up to $128 per month, reaching a peak of $308 per month in 2040.

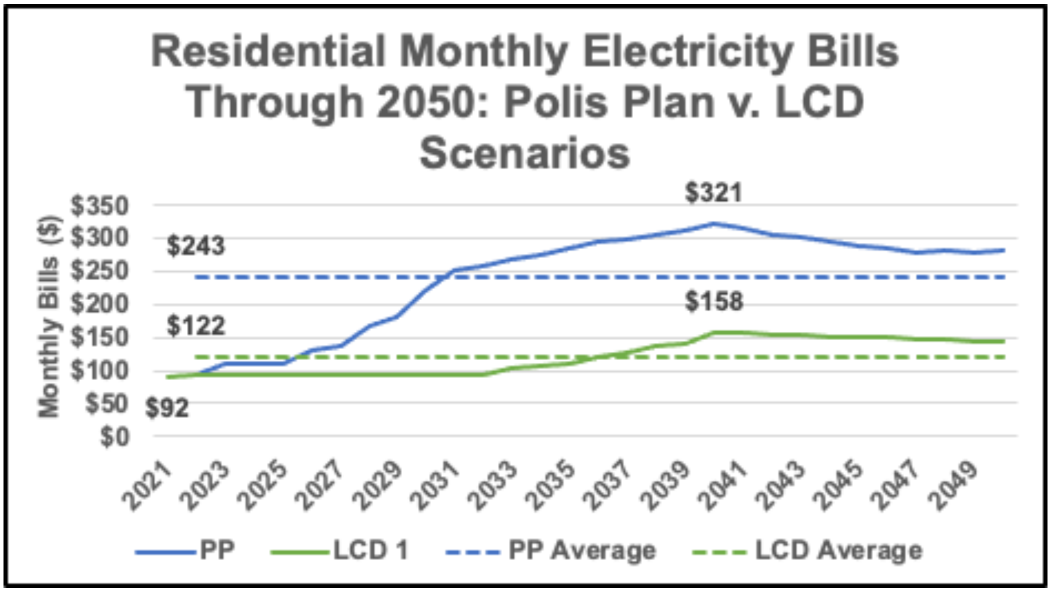
Under the Polis Plan, residential electricity rates would more than triple through 2040...

RESIDENTIAL COSTS

Under the Polis Plan, residential electricity rates would more than triple through 2040, increasing from 13.07 cents/kWh as of 2021 to a peak of 45.70 cents/kWh by 2040. Those residential rate increases would cause Colorado families to pay up to 3.5 times more per month on average than they do currently. To pay for the Polis Plan, Colorado residential electricity customers would see their monthly bills increase from an average of $92 per month in 2021 to $321 per month in 2040 (Figure 7).

Under the LCD Scenario, residential electric rates would increase by more than nine cents per kWh, peaking at 22.42 cents/kWh in 2040. That rate increase would cost residential customers an average of an additional $66 per month by 2040—a peak cost of $158 per month on average.

Figure 7.



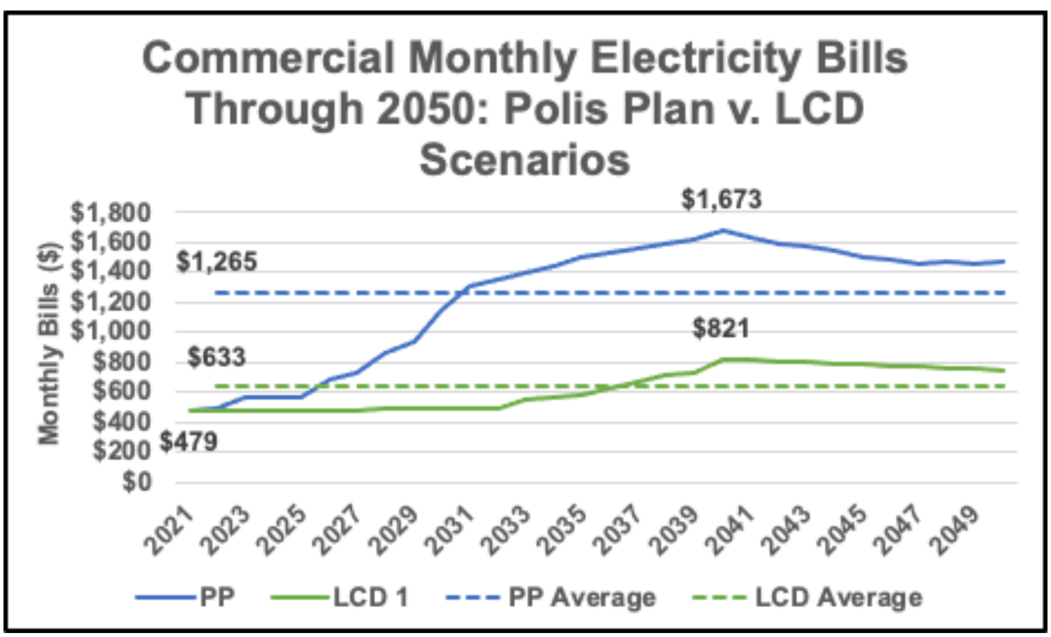
Costs begin rising immediately in the Polis Plan scenario to pay for the construction of new wind and solar facilities. Costs remain low in the initial years of the LCD Scenario while existing power plants are still in use. They begin climbing in the early 2030s as new nuclear facilities are built to replace retiring coal and gas.

> Commercial electricity customers would see their monthly electricity costs increase by up to $1,194 per month by 2040 under the Polis Plan.

COMMERCIAL COSTS

Commercial electricity customers would see their monthly electricity costs increase by up to $1,194 per month by 2040 under the Polis Plan. Under the LCD Scenario, the average commercial customer would end up paying an additional $342 per month in 2040 (see Figure 8).

Figure 8.



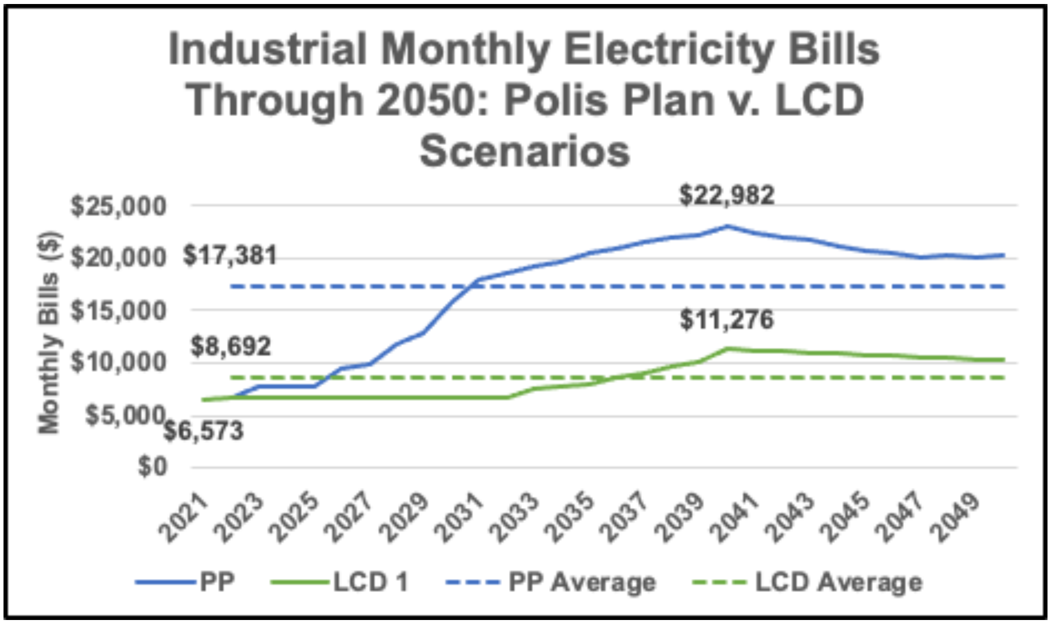
Electricity costs for Colorado businesses would peak at $1,673 per month in 2040 under the Polis Plan. They remain relatively stable through the next decade under the LCD Scenario before increasing more modestly to a peak of $821 per month on average in 2040.

INDUSTRIAL COSTS

Under the Polis Plan, industrial ratepayers would see their electricity rates increase an average of 20 cents per kWh by 2040. As a result, their monthly electricity costs would increase from an average of $6,573 per month in 2021 to $22,982 per month in 2040 (Figure 9). Under the LCD Scenario, the average Colorado industrial customer would pay $11,276 per month that same year.

Attempting to run a resilient electric grid while relying primarily upon variable resources like wind and solar, with the help of non-generating assets like battery storage for support, greatly increases the cost and complexity of providing stable power compared with a grid using reliable, firm power plants.

Figure 9.



Colorado industrial customers would see their average monthly electricity costs increase by more than $16,400 per month under the Polis Plan. Under the LCD Scenario, those same costs would increase by a little more than $4,700 per month.

The next section of the paper will explore why these costs would occur under each scenario and why such a disparity exists depending on which sources of electricity generation are chosen.

WHY THERE IS SUCH A LARGE COST GAP BETWEEN SCENARIOS

The primary factor driving the substantial cost difference between the Polis Plan and the LCD Scenario is the nature of the generation technologies being utilized in each proposal.

Attempting to run a resilient electric grid while relying primarily upon variable resources like wind and solar, with the help of non-generating assets like battery storage for support, greatly increases the cost and complexity of providing stable power compared with a grid using reliable, firm power plants.

In order to keep electric grid operations running smoothly, the supply and demand of electricity must be kept in perfect balance at all hours of the day. Unlike other commodities, electricity must be consumed the instant that it is produced. That means if electricity demand suddenly rises, say, on a hot Colorado summer day when millions of residents rely on air conditioning, the state's electric utilities must immediately increase the supply of electricity to meet that demand.

If the state's utilities are unable to meet that demand for whatever reason, grid operators are forced to cut power to certain consumers to keep the grid from crashing (an action known as "load shedding").

Quickly ramping up the supply of electricity is relatively easy to accomplish with dispatchable power plants—typically fuel based resources that can be depended on to adjust their output based on need. Natural gas plants are the quintessential dispatchable resources, as are coal and nuclear facilities (though they are more commonly used at a steady state of generation, known as "baseload").

...it is much more difficult to provide reliable power as greater quantities of wind and solar are used to meet our electricity needs.

On the other hand, non-dispatchable or "intermittent" resources like wind and solar are not able to reliably adjust to second-by-second fluctuations in electricity demand. Instead, the output of these resources is almost entirely dependent on changes in daily weather conditions. As a result, it is much more difficult to provide reliable power as greater quantities of wind and solar are used to meet our electricity needs. With that added complexity comes added expense.

In order to counteract some of the inherent unreliability of intermittent energy resources, power producers must install far more wind and solar capacity than is needed to meet demand at any given time—a concept known as "overbuilding."

The theory behind this strategy suggests that even if some of the installed wind and solar capacity is failing to produce due to unfavorable weather conditions (i.e. a cloudy, still day), with sufficient redundancy, enough of the installed wind and solar will be producing to meet demand. Then, when the weather is more favorable to wind and solar output, grid operators must shut down, or "curtail" much of this installed capacity to avoid overloading the grid with excess supply.

Other mitigation strategies include building more transmission lines to transmit power across further distances from new renewable installations, which are typically situated in more rural and remote locations, to the population centers where most power is consumed. Likewise, battery facilities can be installed either as standalone assets or alongside new wind and solar facilities to store excess electricity when renewables are generating and supply useable electricity to the grid when they are not.

Each of these mitigation strategies, however, is a major driver of cost for the entire electric system. They also, in turn, create other additional costs, including higher profits for investor-owned utilities like Xcel Energy and higher property taxes.

These added costs will be discussed in greater detail below.

OVERBUILDING GENERATION CAPACITY

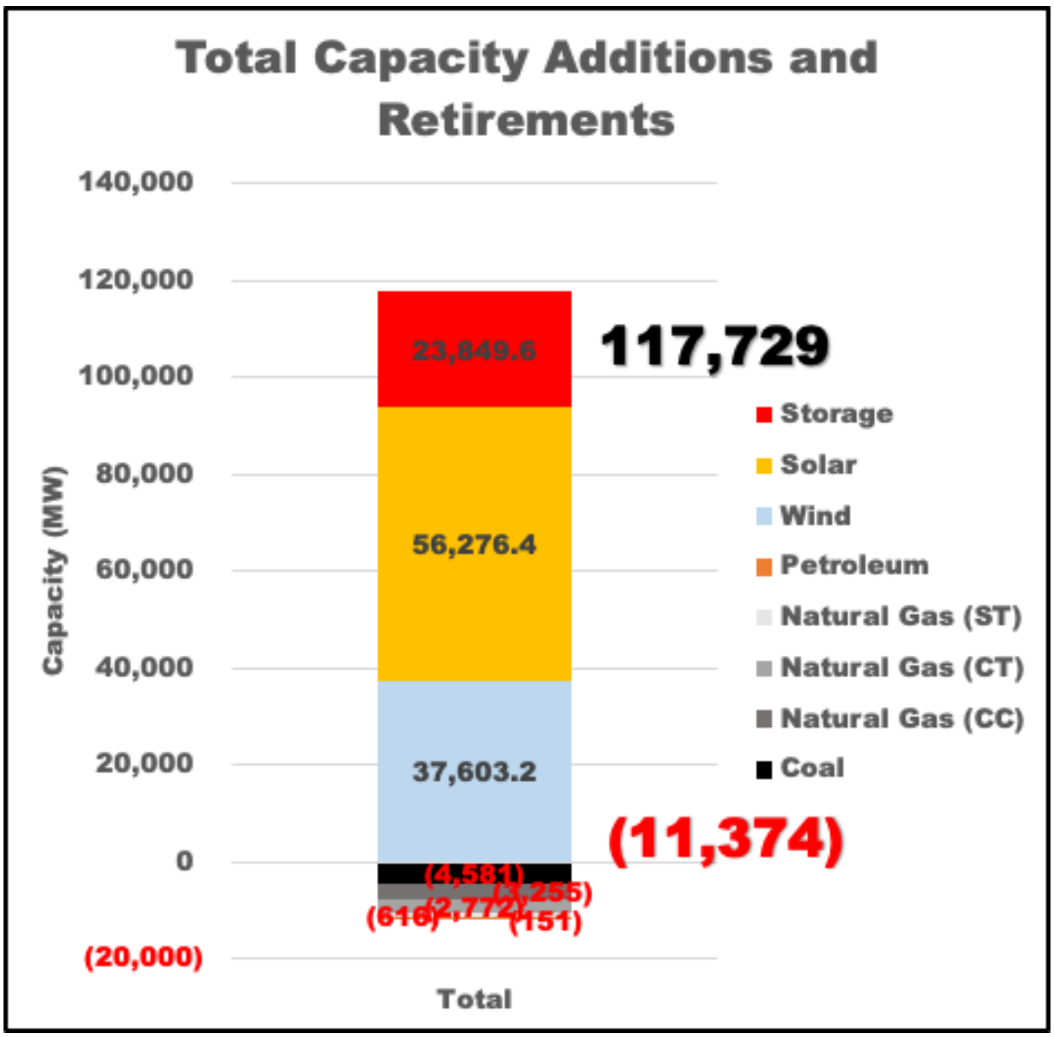
Building and operating new power plants is expensive. The Polis Plan would significantly increase the new power plant capacity on the state's electric grid to replace phased-out fossil fuel generation and overbuild the intermittent resources prioritized by Colorado policymakers. The LCD Scenario would build far less new capacity and, as a result, is a far less expensive option.

In 2021, Colorado had approximately 18,300 MW of total electric power industry capacity, more than 10,900 of which came from fossil fuel-based resources.[24]

In 2021, Colorado had approximately 18,300 MW of total electric power industry capacity, more than 10,900 of which came from fossil fuel-based resources.

Under the Polis Plan, that total capacity would increase to 117,729 MW of wind, solar, and battery storage by 2040. This would represent a nearly 6.5 times increase in the size of the state's current electric grid in terms of generation capacity (Figure 10).

Figure 10.



Complying with the Polis Plan would require nearly 6.5 times more installed capacity on the state's electric grid to maintain a reliable system based on 2021 wind and solar output.

While adding power plant capacity to the grid may sound beneficial, increasing capacity solely to meet renewable energy mandates rather than meeting real-world electricity demand is an inefficient use of resources and ratepayer money.

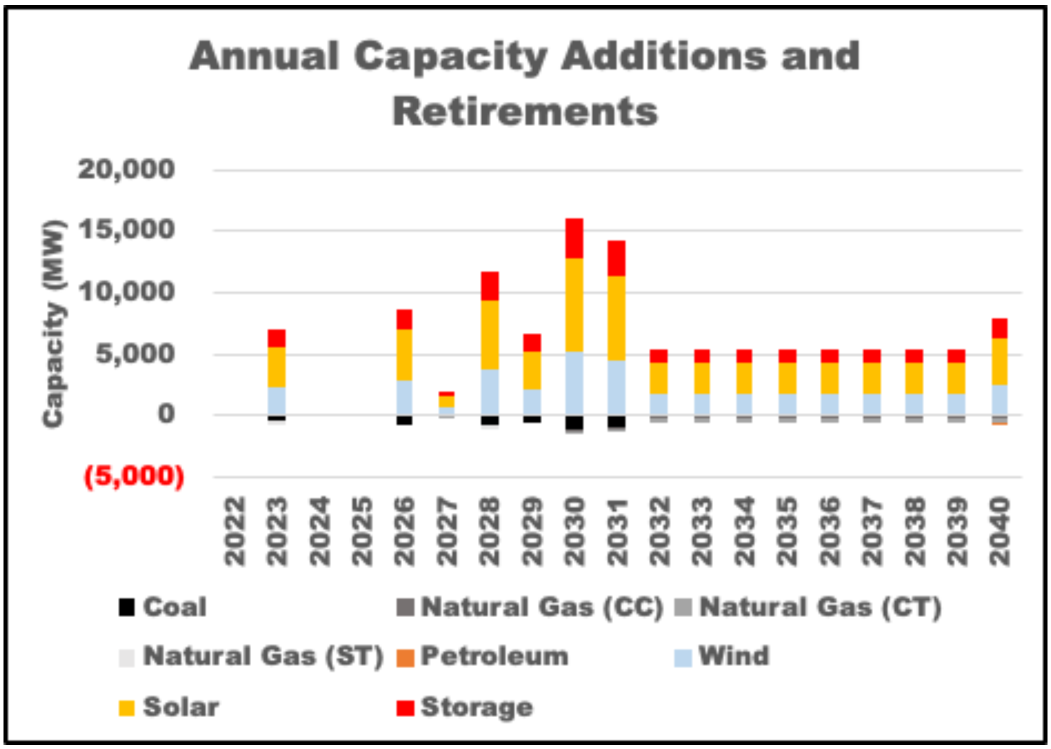
Solar installations would increase the most under the Polis Plan, from just 1,060 MW in 2021 to 56,276 MW in 2040. Wind capacity would grow from 4,991 MW to just over 36,603 MW in 2040. Finally, battery storage would increase from just 10 MW in 2021 to around 23,850 MW of four-hour storage by 2040.

...increasing capacity solely to meet renewable energy mandates rather than meeting real-world electricity demand is an inefficient use of resources and ratepayer money.

It is important to note that the model run by the Center of the American Experiment selected these specific quantities of solar, wind, and battery storage resources because they were the most cost-effective portfolio for meeting the goal of 100 percent renewables by 2040 set forth by Governor Polis while maintaining grid reliability under 2022 electricity demand and wind and solar generation conditions.

Figure 11 details the rate at which existing fossil fuel generation would be phased out and replaced by new renewable generation over the next 17 years under the Polis Plan.

Figure 11.



Installation of annual new renewable capacity would greatly accelerate over the next decade, peaking in 2030 with 16.1 GW of new capacity alone as the last of Colorado's coal fleet is retired. Installations would continue steadily through the rest of the decade.

KEEPING COSTS LOWER WITH DISPATCHABLE GENERATION

The LCD Scenario would require far fewer new capacity additions than the Polis Plan, which would keep costs lower for Colorado ratepayers.

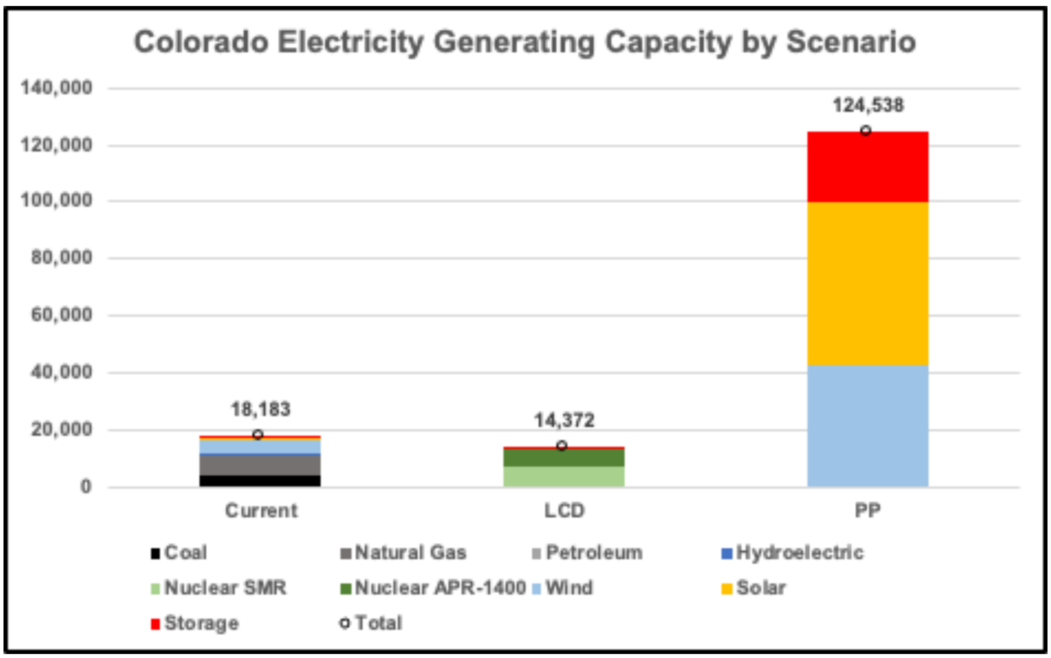
Unlike the Polis Plan, the LCD Scenario would allow coal to continue playing a role in the state's generation mix until 2040, a full decade longer than the alternative. This would help avoid much of the frontloaded costs of new renewable generation required under the Polis Plan and provide extra time for new nuclear generation to come onto the market and get installed on Colorado's grid. It would also provide an additional decade of relatively affordable and reliable electricity from the state's already paid for coal fleet before such generation is retired and replaced with carbon-free nuclear energy.

The LCD Scenario would also allow Colorado's current installed capacity of wind and solar resources to operate through the end of their useful lives before being retired. Some wind and solar capacity would remain on Colorado's grid through 2040 under this scenario, but new wind and solar would not be built once the existing capacity is retired as clean, dispatchable generation is prioritized.

> ...the LCD Scenario would actually involve less installed capacity than the status quo once existing wind and solar generation is allowed to retire.

As a result, the LCD Scenario would actually involve less installed capacity than the status quo once existing wind and solar generation is allowed to retire. The LCD Scenario would also require nearly nine times less installed capacity than the Polis Plan (Figure 12).

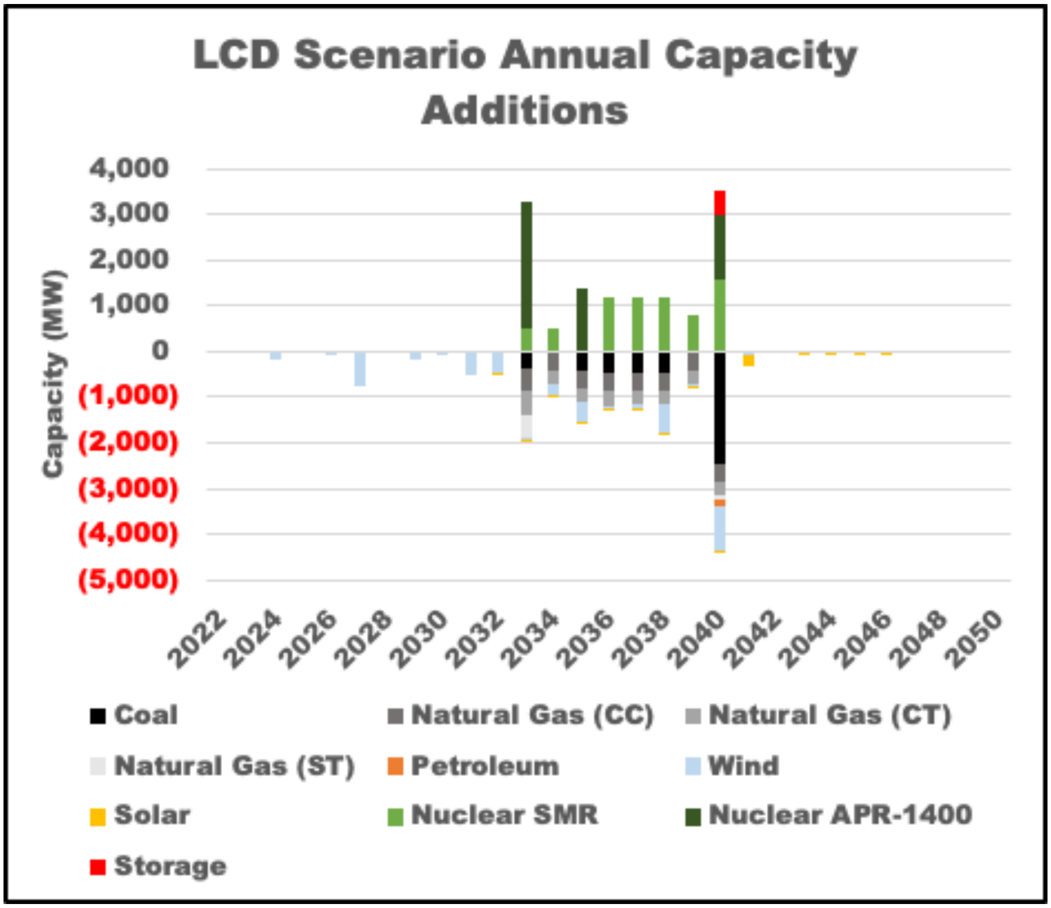
Figure 12.



This graph shows the amount of capacity serving Colorado in 2021 and in 2040 under both the LCD Scenario and the Polis Plan.

In the LCD Scenario, a total of 13,100 MW of new capacity is added to the grid through 2040. Of these additions, 5,600 MW would be APR-1400 nuclear reactors, 7,000 MW would be small modular reactors (SMRs), and 500 MW would be four-hour battery storage. Additionally, the LCD Scenario would see the retirement of nearly 17,000 MW of existing coal, natural gas, petroleum, wind, and solar capacity through 2046 (Figure 13).

Figure 13



Existing wind and solar would be allowed to retire on schedule, without refurbishment, under the LCD Scenario. New nuclear generation would begin to come online starting in 2033. Coal and gas-fired generation would be completely phased out in by 2040.

...the LCD Scenario achieves the same carbon reduction goals as the Polis Plan but at a much lower cost.

The amount of new power plant capacity added in the LCD Scenario is substantial, but it is far lower than would be required under the Polis Plan because the new power plants are dispatchable, meaning they are always available and can be ramped up or down as needed. This is critical because it means there is no need to overbuild for reliability. This, in turn, reduces the need for as many transmission line buildouts, and it reduces the costs associated with utility profits and property taxes as well.

As a result, the LCD Scenario achieves the same carbon reduction goals as the Polis Plan but at a much lower cost.

UTILITY PROFITS AND OTHER ADDITIONAL COSTS

Before detailing the other cost drivers of the Polis Plan and LCD Scenario, it is worth explaining how electric utilities make money in Colorado.

Colorado is a regulated electricity state, which means most Colorado residents are served by one of the state's vertically integrated, investor-owned utilities (IOU) for their electricity. The largest electric utility in Colorado is Xcel Energy, which serves more than 1.5 million ratepayers in the state with electricity.[25]

These utilities own each part of the electricity supply chain, from the generation facility producing electricity to the power lines used to transmit and distribute those electrons to each individual end-consumer.[26] They are also granted a government-sanctioned service territory and customer base, shielded from competition from other power providers by law. In exchange for monopoly status, IOUs are overseen by regulators at the Public Utilities Commission, who approve each utility's investments and set their prices.

Unlike most businesses, IOUs do not profit from the amount of product (in this case, electricity) they sell to their customers. Instead, they only make a profit, called a rate of return, on investments made in physical assets before they are fully depreciated. In other words, the more infrastructure a utility builds, the more profit it can earn as long as the PUC approves those investments.

Under this system, utilities stand to benefit considerably from an energy transition that forces the closure of still-useful power plants and encourages a major build out of brand-new generation facilities and transmission lines.

It should come as no surprise, then, that the single-largest driver of cost under both the Polis Plan and the LCD Scenario is utility profits, since both scenarios necessarily involve building a substantial amount of new electricity infrastructure over a short period of time.

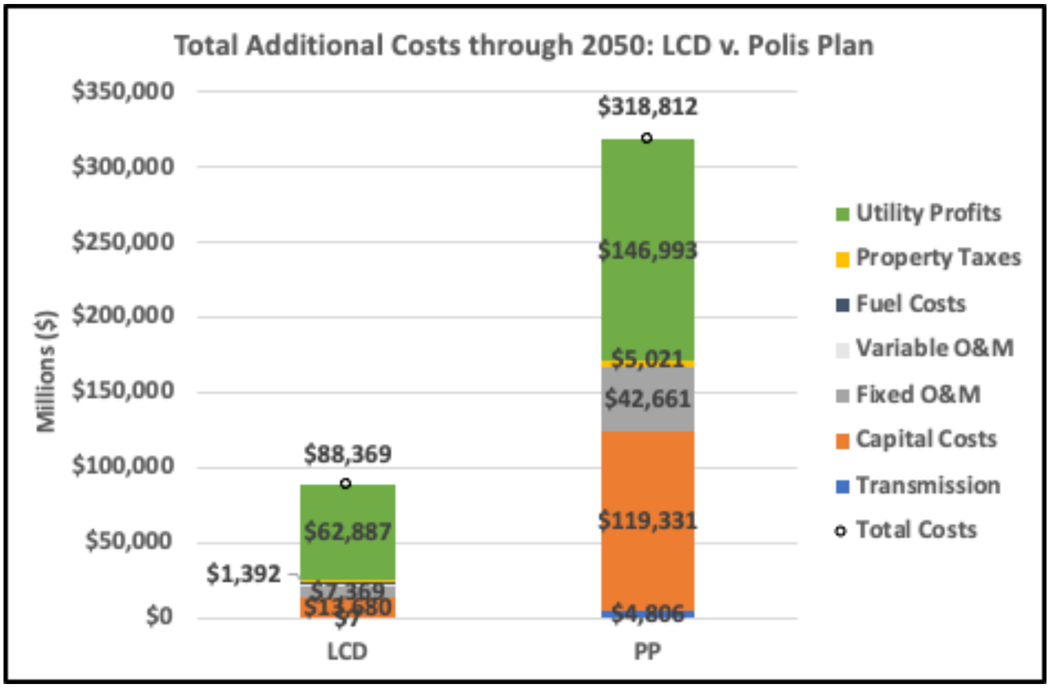
It should come as no surprise, then, that the single-largest driver of cost under both the Polis Plan and the LCD Scenario is utility profits, since both scenarios necessarily involve building a substantial amount of new electricity infrastructure over a short period of time.

Under the Polis Plan, utility profits account for $147 billion of the nearly $319 billion total cost. By comparison, utility profits account for $62.9 billion of the roughly $88 billion total cost of the LCD Scenario (Figure 14).

The other major cost drivers of the Polis Plan include $119.3 billion in additional capital costs required by the plan, $42.7 billion in operating and maintenance (O&M) expenses, $4.8 billion in transmission expenses, and $5 billion in additional property tax expenses.

In the LCD Scenario, other cost drivers include $13.7 billion in additional capital costs, $8 billion in O&M expenses, $2.3 billion in fuel expenses, $7.3 million in transmission expenses, and $1.4 billion in additional property tax expenses.

Figure 14.



The Polis Plan would cost roughly 3.5 times more than the LCD Scenario through 2050, driven primarily by higher capital costs for new generation and larger utility profits.

The accelerated retirement of Comanche 3—from 2040 to 2030—increased the cost of the Polis Plan by $8 billion alone, as the retired coal capacity needs to be replaced with wind, solar, and battery storage 10 years earlier than originally planned.

DISCUSSION OF THE ACCELERATED RETIREMENT OF COMANCHE 3.

At the time the model was first being run by Center of the American Experiment, Xcel Energy proposed closing its Comanche 3 coal facility—the newest coal unit on its fleet—to the Colorado Public Utilities Commission (PUC) by 2040, a full 30 years before it was originally slated to retire.[27] After facing backlash from several environmental advocacy groups and the commissioners on the PUC over the proposed closure date, Xcel later reached a new settlement to shutter the plant a decade earlier, no later than January of 2031.[28]

The accelerated retirement of Comanche 3–from 2040 to 2030–increased the cost of the Polis Plan by $8 billion alone, as the retired coal capacity needs to be replaced with wind, solar, and battery storage 10 years earlier than originally planned. The cost increase occurs because it accelerates the timeline in which investments must be made to replace the plant, which earn a rate of return for the utility paid for by ratepayers.

THE LEVELIZED COST OF ELECTRICITY (LCOE) VS. "ALL-IN" LCOE

Almost all attempts to quantify the costs associated with a given energy system rely on a metric known as the levelized cost of electricity (LCOE) to convey a cost estimate of a particular resource.

The LCOE of an energy-generating resource can be thought of as the average total cost of building and operating the resource per unit of total electricity it's expected to generate over its assumed lifetime.

It is typically calculated using the following formula:

> LCOE = {(overnight capital cost * capital recovery factor + fixed O&M cost)/ (8760 * capacity factor)} + (fuel cost * heat rate) + variable O&M cost.[29,30]

LCOE values, particularly those calculated by organizations like the financial advisory firm Lazard or the U.S. Energy Information Administration (EIA), are widely cited by energy professionals, utilities, and investors as convenient proxies for evaluating the overall cost competitiveness of various generating resources.[31,32] They provide a simplistic way to communicate the basic costs of a given energy project.

However, there are some serious limitations to typical LCOE calculations that tend to result in the misuse of those statistics. Those limitations can breed misuse of LCOE estimates by renewables advocates and policymakers to paint a misleading picture of the overall cost competitiveness of wind and solar generation.[33]

Most common LCOE estimates often exclude many necessary costs associated with renewables that can make their low values misleading from their real-world costs to ratepayers. Due to the intermittency of renewables like wind and solar, backup generation and/or battery storage is often necessary to accompany such projects to ensure grid stability. Yet those costs aren't included in the LCOE values of wind and solar, making them seem more cost-competitive by omission.

Likewise, transmission costs generally aren't accounted for either, under the assumption that such costs apply equally across all resource types. But this simply isn't true. The optimal siting for utility-scale renewables is often many miles away from where the electricity is most consumed—a distance generally much further than traditional fuel-based plants—requiring a far more extensive (and expensive) build out of transmission lines to connect them to the grid.

As such, attempting to use LCOE values to directly compare the "costs" of variable renewables to those of traditional fuel-driven plants winds up being more of an apples-to-oranges comparison than LCOE was originally designed to be used for.

Perhaps most importantly, because LCOE is typically used to convey the cost estimates of *individual* generation projects, it does not account for the *systemic* overbuilding and curtailment required to ensure that grids with high penetrations of wind, solar, and battery storage keep electricity supply and demand in perfect balance at all hours of the day.

This is critical to understanding the all-in system costs of integrating vast quantities of intermittent renewable generation. It's one thing to say that an individual solar installation theoretically generates cheaper electricity than a coal plant in a vacuum; it's quite another to argue that a grid-scale buildout of renewables is more affordable than continuing to generate electricity using dispatchable infrastructure.

It's one thing to say that an individual solar installation theoretically generates cheaper electricity than a coal plant in a vacuum; it's quite another to argue that a grid-scale buildout of renewables is more affordable than continuing to generate electricity using dispatchable infrastructure.

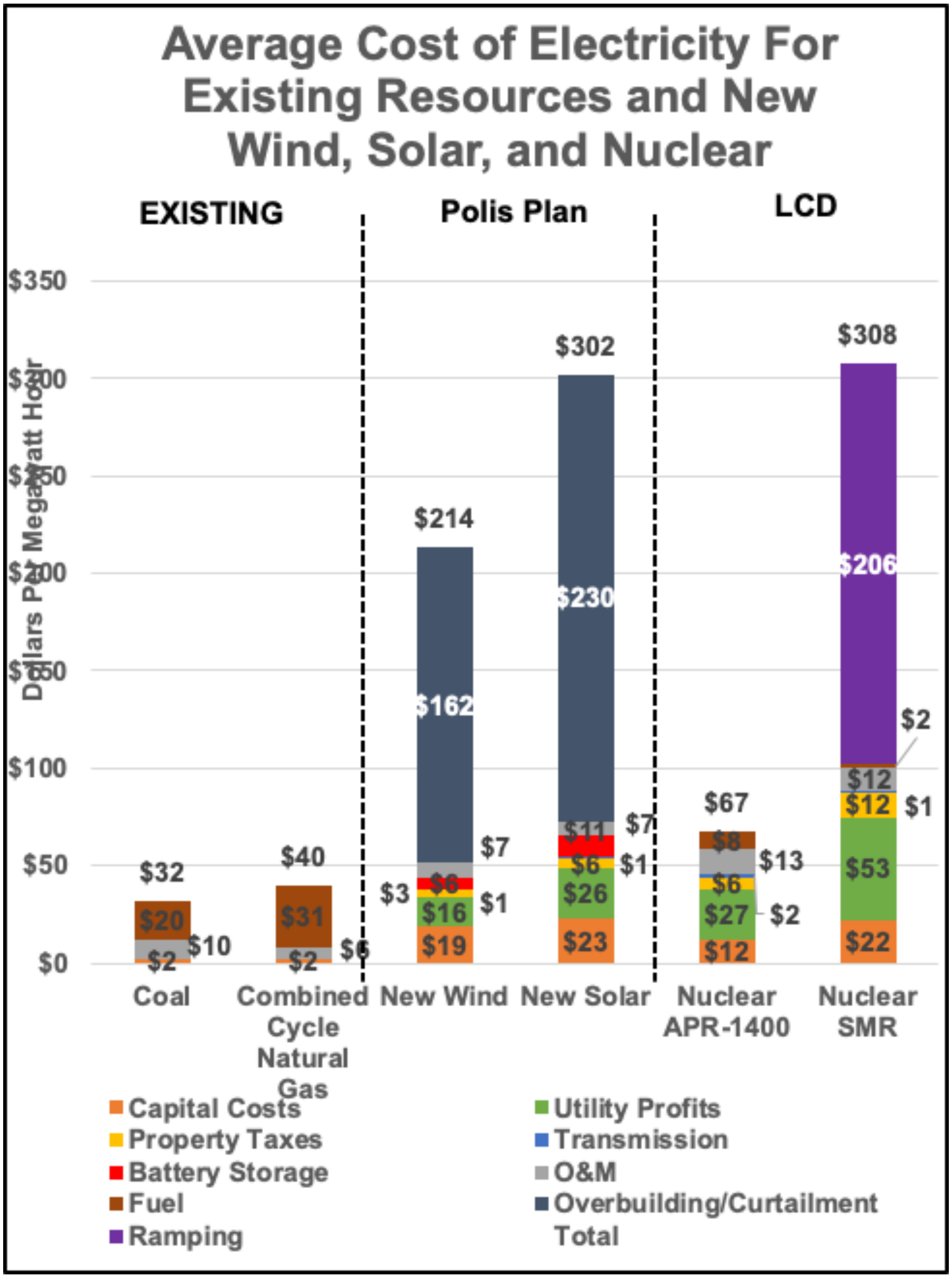
The model used in this report accounts for all these additional expenses and attributes them to the cost of wind and solar to get an "all-in" LCOE value. This all-in levelized cost is meant to represent the true cost of delivering the same reliability value of dispatchable generating technologies. This allows for a more appropriate apples-to-apples comparison between the cost of reliably meeting electricity demand with Colorado's existing energy mix, and with the new plants that would be built under the Polis Plan and LCD Scenario.

Under the Polis Plan, these affordable and reliable fossil fuel plants would be entirely replaced by wind, solar, and battery storage by 2040. Figure 15 shows the all-in LCOE of new wind and solar reaches $214 and $302 per MWh, respectively, on average throughout the model run.

Data from the most recent Federal Energy Regulatory Commission (FERC) form 1 filing show Colorado's combined cycle natural gas plants generated electricity for $39.56 per MWh, and coal plants in the state generated electricity for $31.50 per MWh, on average in 2020 (Figure 15).

Under the Polis Plan, these affordable and reliable fossil fuel plants would be entirely replaced by wind, solar, and battery storage by 2040. Figure 15 shows the all-in LCOE of new wind and solar reaches $214 and $302 per MWh, respectively, on average throughout the model run.

Figure 15.



By the end of the Polis Plan, new solar facilities are the most expensive form of new electricity generation built. Once costs such as property taxes, transmission, utility returns, battery storage, and overbuilding and curtailment are accounted for new wind costs $214 per MWh, and new solar costs $302 per MWh. Under the LCD Scenario, APR-1400s would become the lowest cost source of new carbon-free power. SMRs would be expensive due to use as a peaking resource.

The all-in costs of these resources increase due to the rise of curtailment over time as more capacity is overbuilt on the system. High rates of curtailment would force wind and solar energy sources to recover costs over fewer megawatt hours (MWh) generated.[34]

In the LCD Scenario, new SMRs, APR-1400s, and battery storage facilities have higher costs than Colorado's existing natural gas and coal power plants, but these costs are substantially lower than those of the overbuilt wind and solar capacity under the Polis Plan.

As discussed previously, costs are higher for wind and solar facilities under the Polis Plan because grids with high penetrations of intermittent wind and solar require much more total capacity and transmission to meet electricity demand than systems consisting largely of dispatchable power systems like traditional fossil fuel plants and nuclear.

Under the LCD Scenario, new build APR-1400 nuclear plants would have a levelized cost of $67 per MWh. New build nuclear SMRs would have the highest levelized cost of any resource modeled, driven primarily by a major increase in cost per MWh beginning in 2036 and peaking in 2040. This is due to SMRs becoming the primary load following or, "peaking", resource, forcing them to generate less electricity and recover costs over fewer megawatt hours of generation by the end of the model run.[35]

Electric grid reliability is crucial for the safety, economic stability, health, security, and quality of life of any society, and Colorado is no exception to that rule.

GRID RELIABILITY UNDER EACH SCENARIO

A reliable electric grid is a strictly necessary precondition for any advanced, prosperous society.

As technology has advanced, our lives have never been more dependent upon electronic devices. And new innovations, as well as policy concerns over climate change, will only accelerate how dependent we are on constantly flowing electrons over poles and wires. That means the consequences of an insufficiently reliable electric grid have never been higher. Indeed, it can truly mean the difference between life and death.

In February 2021, Texas suffered one of the worst energy crises in American history when a major ice storm—dubbed Winter Storm Uri—froze much of the state's wind, natural gas, and coal-fired generation just as the state's primarily electric-based heating demand skyrocketed. The result was widespread blackouts that cost the state hundreds of billions of dollars and led to the deaths of anywhere between 246-702 Texas residents.[36],[37]

Electric grid reliability is crucial for the safety, economic stability, health, security, and quality of life of any society, and Colorado is no exception to that rule.

THE POLIS PLAN

The Polis Plan would seriously undermine the reliability of the state's electric grid by greatly expanding the state's dependence on fluctuations in the weather to meet demand. So long as the weather cooperates, this is not a problem. When it does not, blackouts become inevitable.

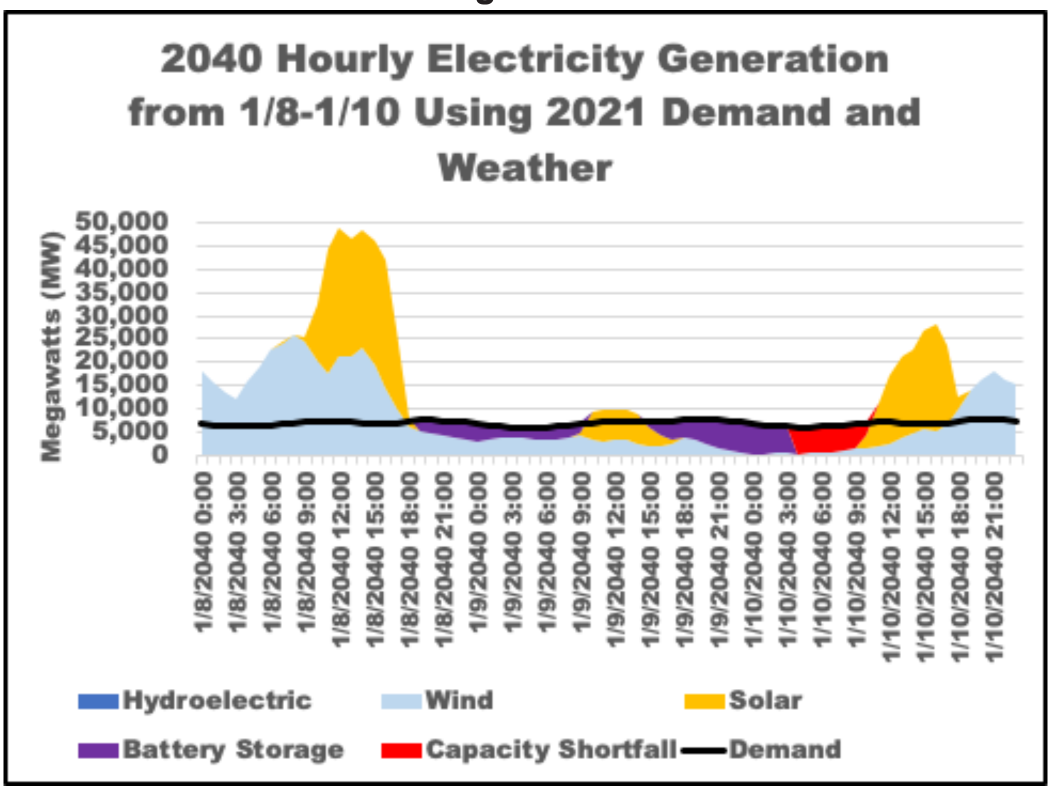
American Experiment's modeling determined the amount of wind, solar, and battery storage capacity needed for the Polis Plan by using hourly electricity demand data for

2022 provided by the U.S. Energy Information Administration and real-world wind and solar capacity factors from the same year.

Using these inputs, the model determined that the 37,603 MW of wind, 56,276 MW of solar, and 23,850 MW of batteries built under the Polis Plan would not be able to generate sufficient electricity to meet demand for a combined 25 hours over three capacity shortfall events in 2040 if demand and capacity factor conditions are similar to how they were in 2021 in Colorado.

Figure 16 shows electricity demand and supply by generation source for a hypothetical period in the future ranging from January 8, 2040, to January 10, 2040. Assuming 2021 demand and weather data from the same period (January capacity factors), there would be a nearly 5,800 MW capacity shortfall event for seven hours, starting in the afternoon and continuing into the evening of January 10.

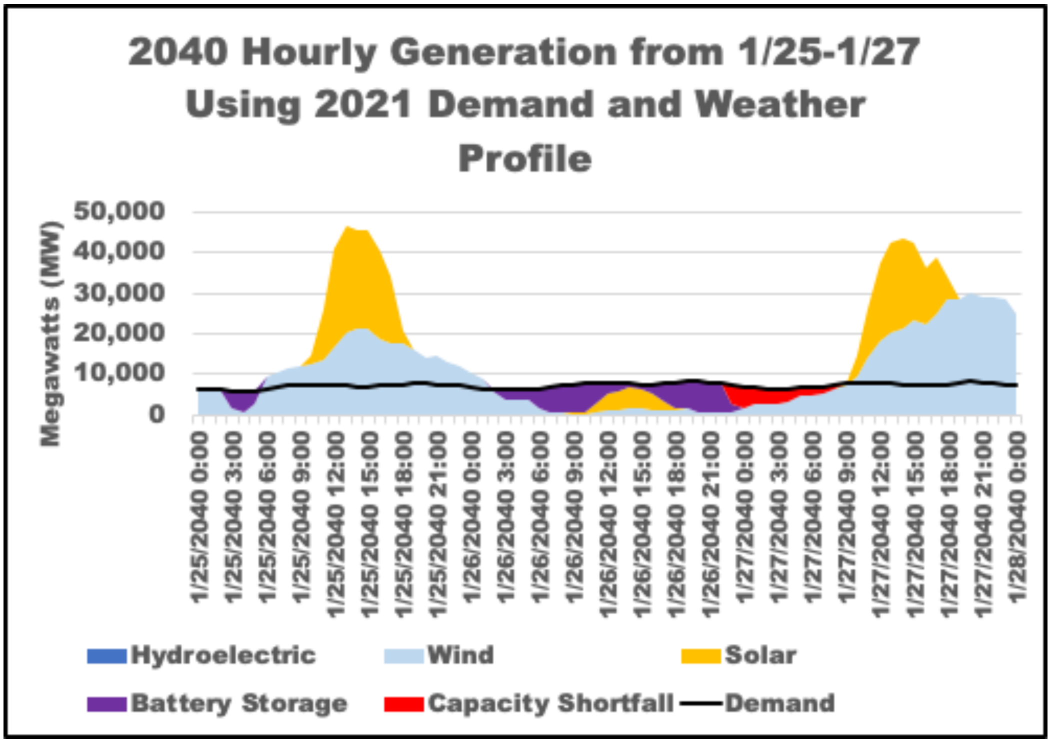
Figure 16.



Caused by a wind and solar drought occurring on the same day. Despite nearly 24,000 MW of four-hour storage on the grid, storage resources were unable to charge enough to prevent a 7-hour capacity shortfall event from 1/8-1/10 (shown in red).

Assuming the same exact demand and weather conditions, there would be another capacity shortfall event later that same month, from January 25, 2040, to January 27, 2040, lasting 11 hours (Figure 17).

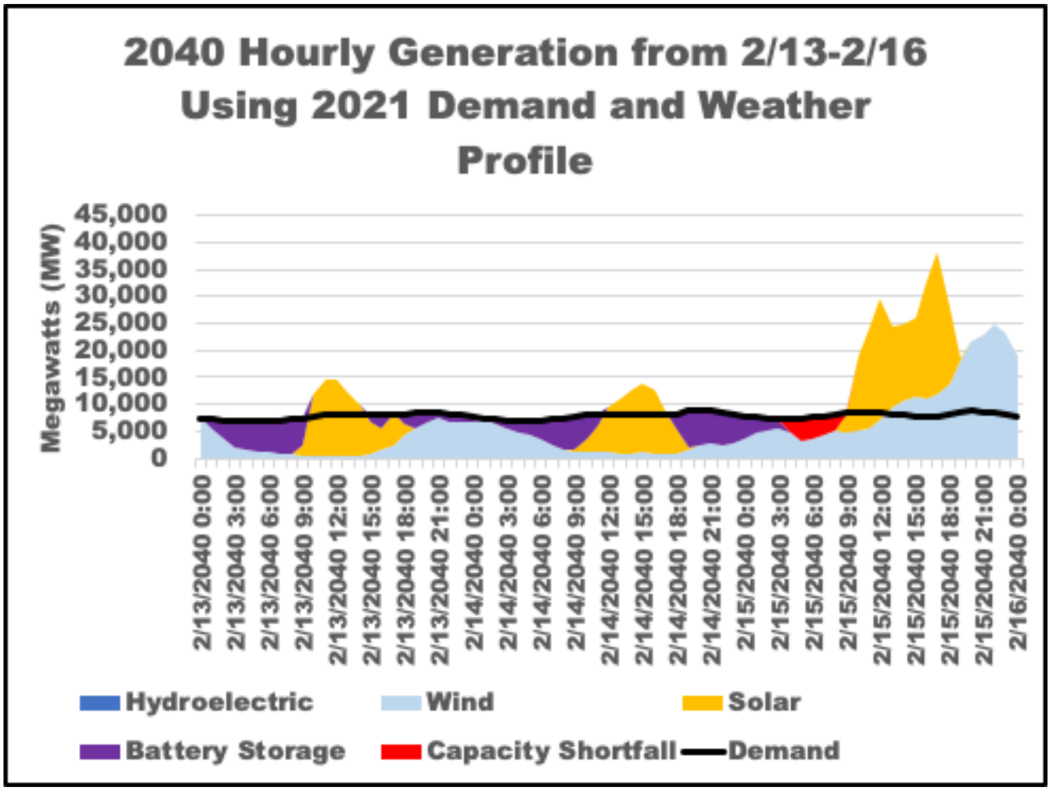
Figure 17.



Wind, solar, and battery storage are unable to meet electricity demand for every hour of the year under the Polis Plan, resulting in an additional 11-hour capacity shortfall in January, shown in red on the graph.

Finally, a third capacity shortfall would occur in mid-February under the same demand and weather conditions despite an extensive build out of wind, solar, and battery storage capacity on the grid by 2040. This shortfall would last seven hours, driven primarily by lower-than-expected wind generation (Figure 18).

Figure 18.



This capacity shortfall would last for seven hours in the early morning period of February 15, 2040, if demand and weather conditions are consistent with 2021 performance.

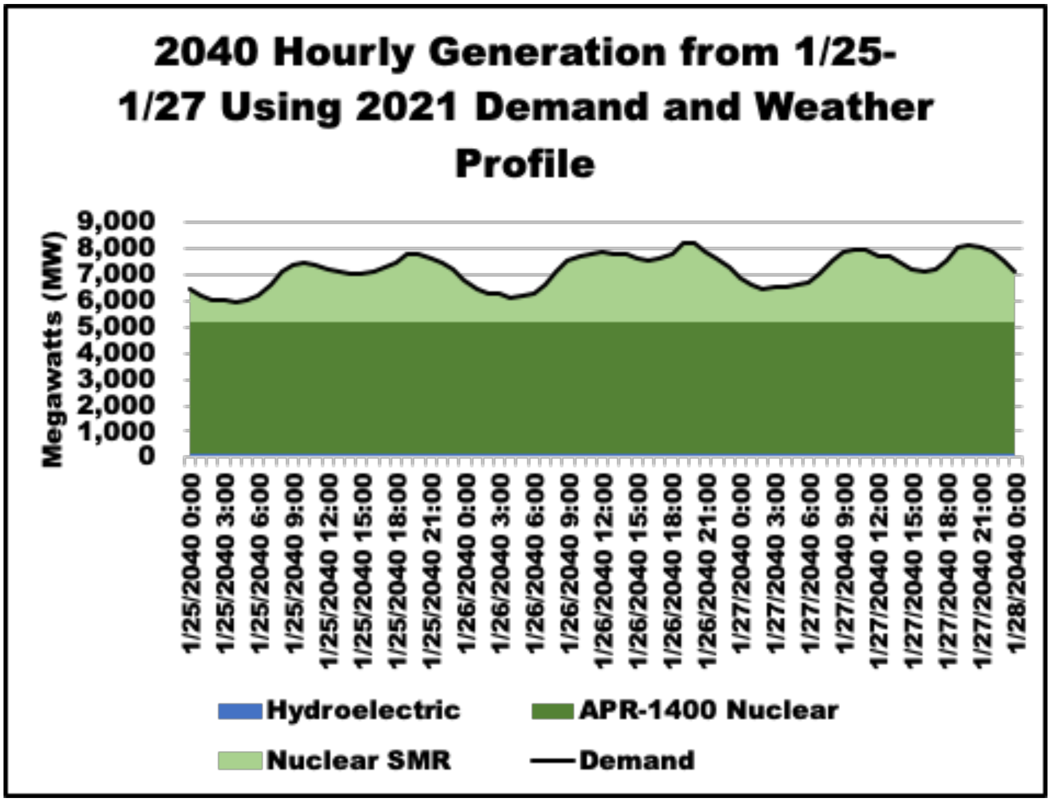
LCD SCENARIO

While the Polis Plan would result in three separate capacity shortfalls under conditions of 2021 level demand and weather patterns, resulting in blackouts totaling 25 hours between the frigid months of January and February, the state's grid would fare much better under the LCD Scenario.

Under the LCD Scenario, Colorado would maintain a reliable grid and increase the amount of dispatchable capacity at its disposal, resulting in zero hours of capacity shortfalls. Figure 19 shows there is enough dispatchable capacity on the Colorado electric grid in the LCD Scenario to reliably meet electricity demand every hour regardless of weather conditions, even during the period under which the Polis Plan suffered its longest blackout.

Under the LCD Scenario, Colorado would maintain a reliable grid and increase the amount of dispatchable capacity at its disposal, resulting in zero hours of capacity shortfalls.

Figure 19.



This the same period that the wind, solar, and battery storage scenario saw an 11-hour capacity shortfall. In this scenario, the shortfall event never occurs because the grid can use APR-1400 plants as a steady baseload energy source while SMR plants act as a ramping resource.

In the LCD Scenario, SMRs increase and decrease their output to perfectly match changes in electricity demand. APR-1400 nuclear plants and the state's remaining hydroelectric facilities act as baseload power plants, providing steady, reliable power around the clock. The limited battery storage capacity built under the LCD Scenario is not needed to support the reliable output of the state's dispatchable plants in this case.

Those same reliability attributes of the LCD Scenario would save Colorado ratepayers $230 billion compared to the Polis Plan and deliver far superior results for grid reliability. Still, the average residential ratepayer would see their electricity expenses increase by more than $60 per month in 2040 to finance the construction of new nuclear power plants and battery storage to make that happen.

CARBON EMISSIONS REDUCTIONS AND GLOBAL TEMPERATURE IMPACTS

Considering that the entire impetus for the remaking of Colorado's electric grid is centered around eliminating carbon emissions to combat climate change, it is worth evaluating how each proposal would fare in accomplishing decarbonization and what costs and benefits each plan offer.

Considering that the entire impetus for the remaking of Colorado's electric grid is centered around eliminating carbon emissions to combat climate change, it is worth evaluating how each proposal would fare in accomplishing decarbonization and what costs and benefits each plan offer.

Both the Polis Plan and the LCD Scenario would reduce carbon emissions in the state's electricity sector 100 percent by 2040 compared to 2021 levels of 31.1 million metric tons.[38]

Because climate change is a global problem (emissions don't respect geographical boundaries), it is important to put the potential temperature impact of reducing CO2 emissions by 31 million metric tons in a global context using past government estimates as a guide.

In 2015, the Obama administration unveiled its Clean Power Plan (CPP), a series of Environmental Protection Agency (EPA) guidelines and regulations designed to wring carbon emissions out of the U.S. electricity sector.[39] The Obama administration claimed the CPP would have reduced annual CO2 emissions nationally by 730 million metric tons by 2030.

The Obama administration's EPA used a climate model called the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC) to determine the CPP's impact on future atmospheric warming. It estimated the CPP would have reduced future warming by 0.019° C by 2100.

The 31.1 million metric tons of CO2 no longer emitted from power plants serving Colorado under either of the modeled scenarios would account for 4.2 percent of the 730 million metric tons averted by the CPP. From this figure, we can extrapolate that the Polis Plan and LCD Scenario would avert 4.2 percent of the 0.019° C by 2100, for a potential future temperature reduction of 0.0008° C by 2100—an infinitesimal fraction of global temperature reductions required to avert the worst impacts of climate change. When evaluating policies aimed at reducing greenhouse gas emissions, it is important to weigh the cost of reducing emissions against the expected benefits of doing so. If the costs associated with a strategy for reducing emissions exceed the expected benefits, the policy is economically inefficient, and vice versa.

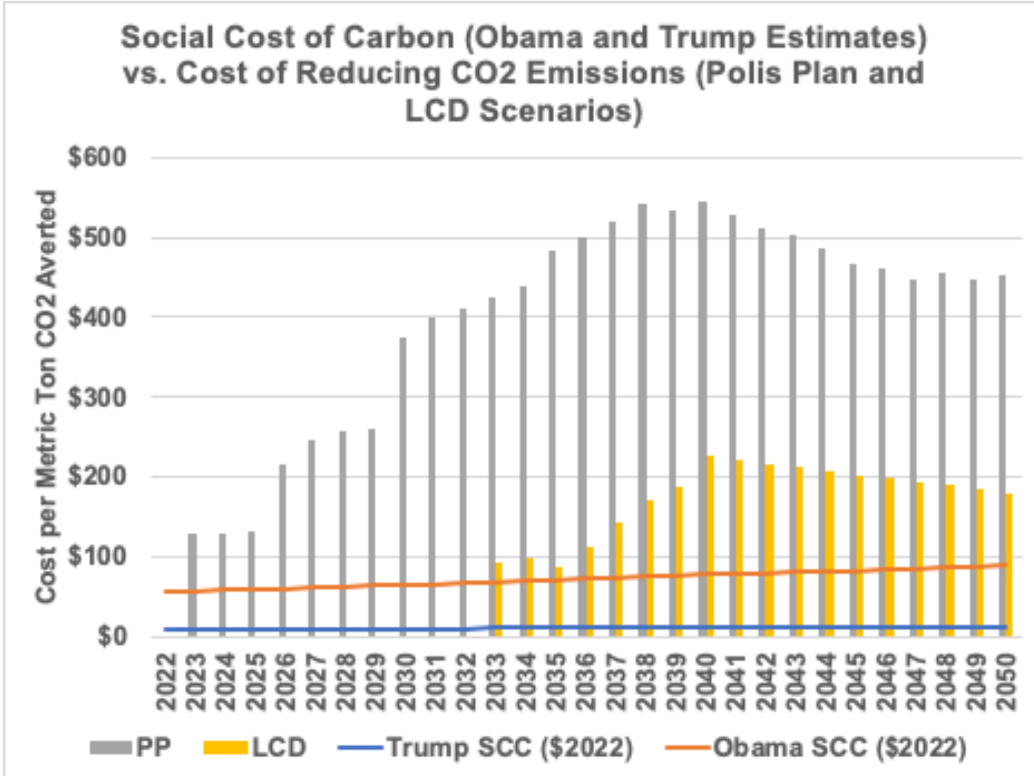
When evaluating policies aimed at reducing greenhouse gas emissions, it is important to weigh the cost of reducing emissions against the expected benefits of doing so.

To conduct this cost-benefit analysis, lawmakers, regulators, and private organizations often rely on a metric known as the Social Cost of Carbon (SCC) when weighing their options. The SCC is an attempt to estimate the marginal economic cost (in dollars) of emitting one additional ton of carbon dioxide into the atmosphere based on the damage done by a warming climate. In the reverse, it can also be thought of as the marginal economic benefit of reducing each additional ton of emissions.[40]

Like the LCOE estimates discussed earlier in this report, SCC estimates can have serious shortcomings based on what assumptions are included when arriving at a particular number. [41] Nevertheless, it can be useful metric for evaluating the economic rationality of pursuing a given climate policy.

Figure 20 shows the shows the cost of reducing each ton of carbon dioxide through the year 2050 under the Polis Plan and the LCD Scenario and compares it to the different social cost of carbon estimates used by the Obama and Trump administrations.

Figure 20.



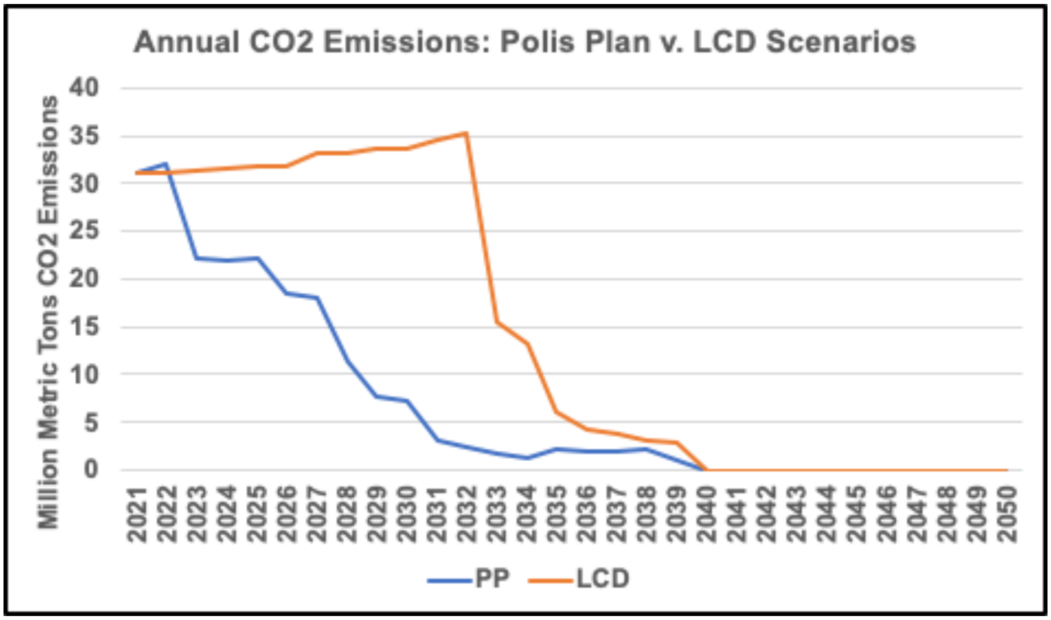
The cost of reducing CO2 emissions under both the Polis Plan and LCD Scenario exceed the high and low SCC estimates used by the Obama and Trump administrations, respectively.

Considering that the entire impetus for the remaking of Colorado's electric grid is centered around eliminating carbon emissions to combat climate change, it is worth evaluating how each proposal would fare in accomplishing decarbonization and what costs and benefits each plan offer.

Under the Polis Plan, the average cost of reducing carbon-dioxide emissions would be $441 per metric ton reduced through 2050. Under the LCD Scenario, the average cost of reducing carbon-dioxide emissions would be $182 per metric ton reduced through 2050. While the LCD Scenario would reduce emissions at far less expense, the average cost of reducing carbon emissions under both scenarios is higher than the different social cost of carbon values relied on by the Obama and Trump administrations. This means that the costs of implementing either scenario to reduce emissions would outweigh any pecuniary benefit of doing so.

Figure 21 shows the annual CO2 emissions reductions that would occur under both the Polis Plan and LCD Scenario.

Figure 21.



Colorado would avert a total of 411.7 million metric tons of CO2 emissions by 2040 compared to 2021 levels under the Polis Plan, at an average of 21.7 million metric tons per year. Under the LCD scenario, Colorado would avert 175 million metric tons by 2040 compared to 2021 levels, or 9.2 million metric tons per year.

Given the high cost of reducing carbon dioxide emissions under both the Polis Plan and the LCD Scenario, it would be rational to reevaluate the assumptions of either proposal. While there are undoubtedly non-pecuniary benefits to reducing power plant emissions, the economic costs of implementing each strategy, under the timeline envisioned, far outweighs the environmental benefit.

Given the high cost of reducing carbon dioxide emissions under both the Polis Plan and the LCD Scenario, it would be rational to reevaluate the assumptions of either proposal.

This suggests a strategy with more flexibility for different resources, on a less aggressive timeline, would be economically beneficial for Colorado's electricity sector.

CONCLUSION

Compliance with the all-renewable mandate envisioned by the Polis Plan would cost the state $318.8 billion through 2050. This would result in an average cost of $243 per month for the typical Colorado household over the same timeframe. By contrast, the nuclear-focused LCD Scenario would cost the state $88.4 billion through 2050 and would only increase the average residential electricity bill to $122 per month for the typical household.

Polis Plan costs are driven primarily by the need to massively overbuild new wind and solar facilities in a rapid time span. That rapid capacity increase drives additional costs associated with the need for new transmission lines to move power and large amounts of battery storage to ensure reliability when the wind does not blow, and the sun does not shine. All of this capacity expansion would also result in added expense to cover electric utility profits and the property taxes for massive increase of new physical assets.

LCD Scenario costs are driven mainly by the high upfront costs of building new nuclear power capacity and some limited battery storage to quickly replace retiring fossil fuel plants. Those new nuclear plants would also drive increased costs for transmission lines, utility profits, and property taxes, but to a far lesser extent than under the Polis Plan.

Ultimately, the idea behind attempting to power a grid at scale with just wind, solar, existing hydropower, and current battery technology is a profoundly unserious one. It is primarily a reflection of ideological preferences more than any consideration of real-world economic costs and physical constraints.[42],[43]

> Ultimately, the idea behind attempting to power a grid at scale with just wind, solar, existing hydropower, and current battery technology is a profoundly unserious one. It is primarily a reflection of ideological preferences more than any consideration of real-world economic costs and physical constraints.

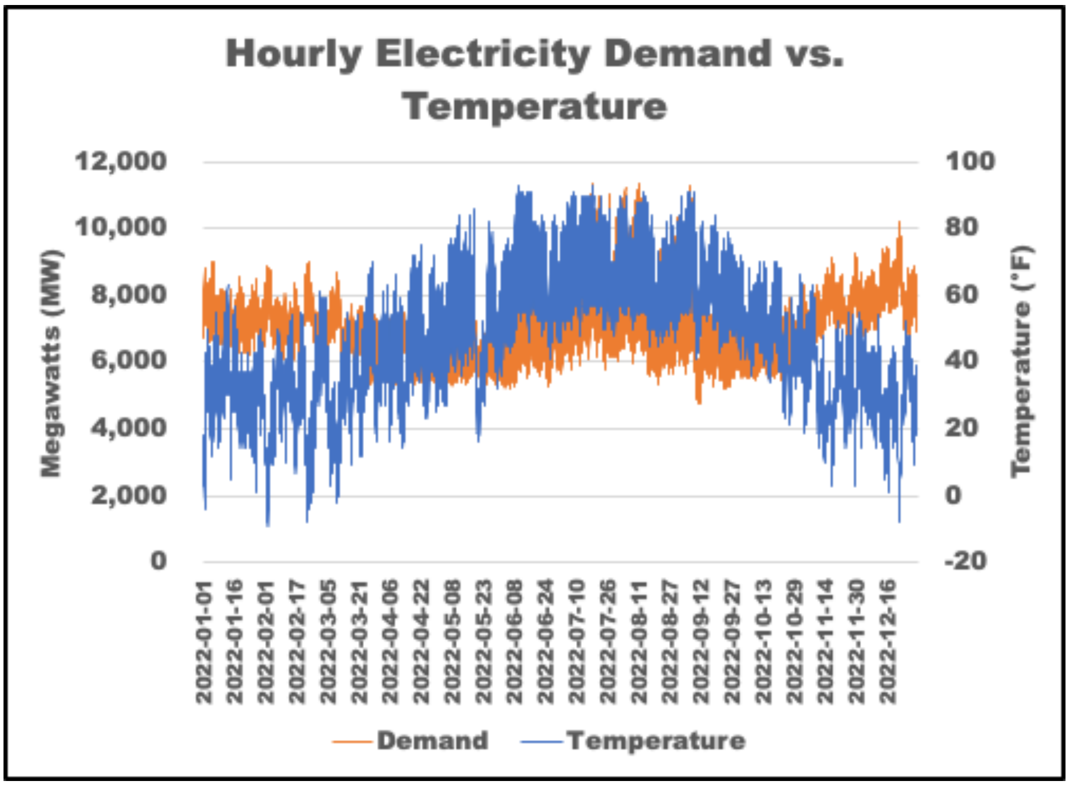
An all-nuclear scenario, while also somewhat unrealistic given political constraints, at least presents a compelling counterfactual for a clean, 100 percent reliable grid at lower cost. If climate change is truly the existential threat most committed activists believe it to be, they would do well to begin incorporating clean, firm power in their policy goals before the stability of the electric grid and the pocketbooks of Colorado residents are sacrificed on ideological vanity projects.

APPENDIX

STUDY ASSUMPTIONS:

- Hourly model utilizes 2022 EIA electricity demand and wind/solar capacity factors to determine peak load and wind, solar, and battery storage capacity needs.
- Existing Levelized Cost of Energy (LCOE) values are based on the most recent FERC Form 1 files from 2020.
- New LCOE values are based on EIA's 2022 assumptions to the annual energy outlook.
- Uses Xcel Energy's capital structure and cost of capital assumptions.

Colorado's 2022 Hourly Electricity Demand and Temperature



ANNUAL CAPACITY ADDITIONS AND RETIREMENTS UNDER EACH PLAN

Polis Plan

	2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal	0	(383)	0	0	(842)	0	(828)	(636)	(1,035)
Natural Gas (CC)	0	(84)	0	0	0	0	0	0	(288)
Natural Gas (CT)	0	0	0	0	0	(185)	0	0	(235)
Natural Gas (ST)	0	(208)	0	0	0	0	(310)	0	0
Petroleum	0	0	0	0	0	0	0	0	0
Wind	0	2,230	0	0	2,785	611	3,761	2,104	5,153
Solar	0	3,337	0	0	4,168	914	5,629	3,149	7,713
Storage	0	1,414	0	0	1,766	387	2,386	1,334	3,269

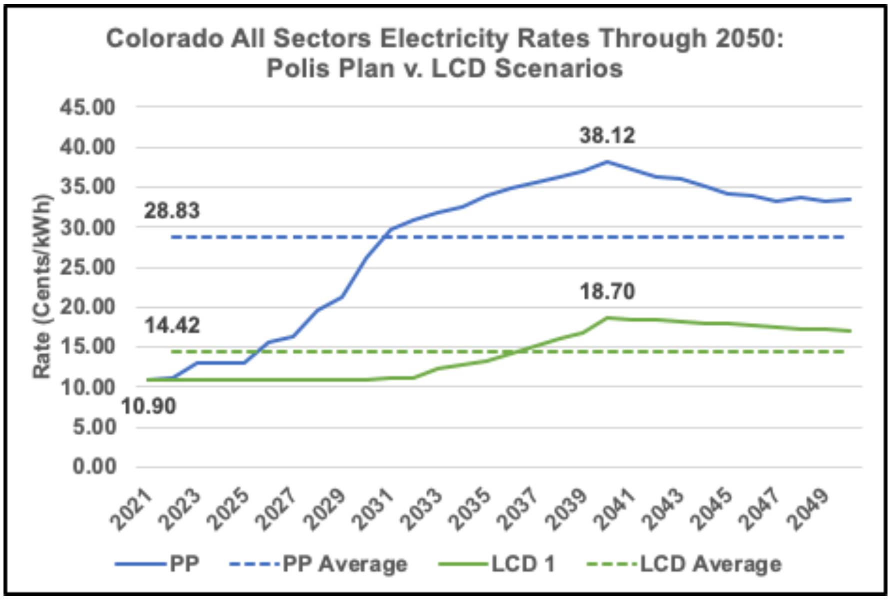
	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Coal	(857)	0	0	0	0	0	0	0	0	0	(4,581)
Natural Gas (CC)	(288)	(288)	(288)	(288)	(288)	(288)	(288)	(288)	(288)	(288)	(3,255)
Natural Gas (CT)	(235)	(235)	(235)	(235)	(235)	(235)	(235)	(235)	(235)	(235)	(2,772)
Natural Gas (ST)	0	0	0	0	0	0	0	0	0	(98)	(616)
Petroleum	0	0	0	0	0	0	0	0	0	(151)	(151)
Wind	4,563	1,730	1,730	1,730	1,730	1,730	1,730	1,730	1,730	2,552	37,603
Solar	6,829	2,590	2,590	2,590	2,590	2,590	2,590	2,590	2,590	3,819	56,276
Storage	2,894	1,098	1,098	1,098	1,098	1,098	1,098	1,098	1,098	1,619	23,850

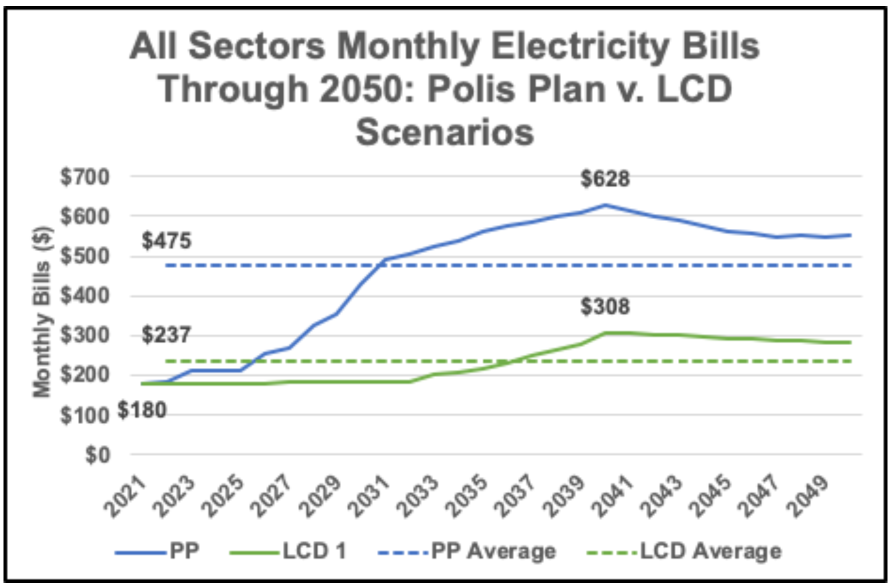
LCD Scenario

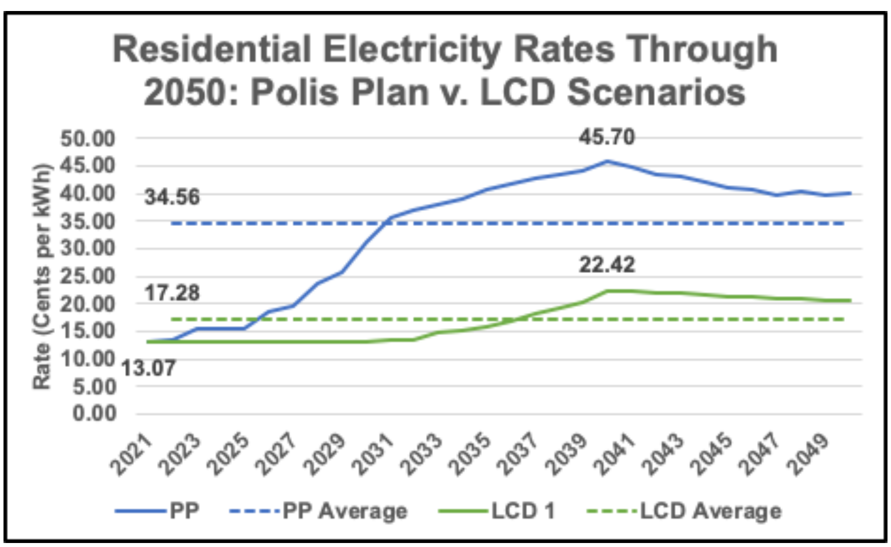
	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036
Coal	0	0	0	0	0	0	0	0	0	0	0	(383)	0	(396)	(465)
Natural Gas (CC)	0	0	0	0	0	0	0	0	0	0	0	(480)	(396)	(396)	(396)
Natural Gas (CT)	0	0	0	0	0	0	0	0	0	0	0	(508)	(323)	(323)	(323)
Natural Gas (ST)	0	0	0	0	0	0	0	0	0	0	0	(518)	0	0	0
Petroleum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wind	0	0	(190)	(1)	(61)	(774)	(0)	(174)	(57)	(499)	(478)	(32)	(241)	(418)	(64)
Solar	0	0	0	0	0	0	0	0	0	0	(8)	(3)	(3)	(27)	(45)
Nuclear SMR	0	0	0	0	0	0	0	0	0	0	0	500	500	0	1,200
Nuclear APR-1400	0	0	0	0	0	0	0	0	0	0	0	2,800	0	1,400	0
Storage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

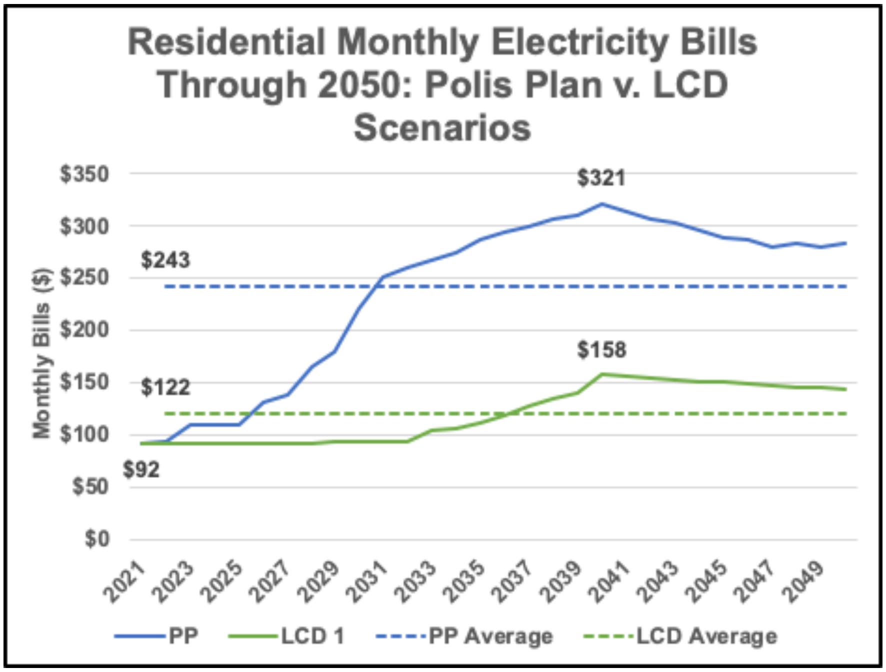
	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	Total
Coal	(446)	(446)	0	(2,445)	0	0	0	0	0	0	0	0	0	0	(4,582)
Natural Gas (CC)	(396)	(396)	(396)	(396)	0	0	0	0	0	0	0	0	0	0	(3,255)
Natural Gas (CT)	(323)	(323)	(323)	(323)	0	0	0	0	0	0	0	0	0	0	(2,772)
Natural Gas (ST)	0	0	0	(98)	0	0	0	0	0	0	0	0	0	0	(616)
Petroleum	0	0	0	(151)	0	0	0	0	0	0	0	0	0	0	(151)
Wind	(80)	(598)	(54)	(953)	(96)	0	0	0	0	0	0	0	0	0	(4,770)
Solar	(30)	(5)	(7)	(65)	(225)	(43)	(70)	(75)	(74)	(87)	0	0	0	0	(768)
Nuclear SMR	1,200	1,200	800	1,600	0	0	0	0	0	0	0	0	0	0	7,000
Nuclear APR-1400	0	0	0	1,400	0	0	0	0	0	0	0	0	0	0	5,600
Storage	0	0	0	500	0	0	0	0	0	0	0	0	0	0	500

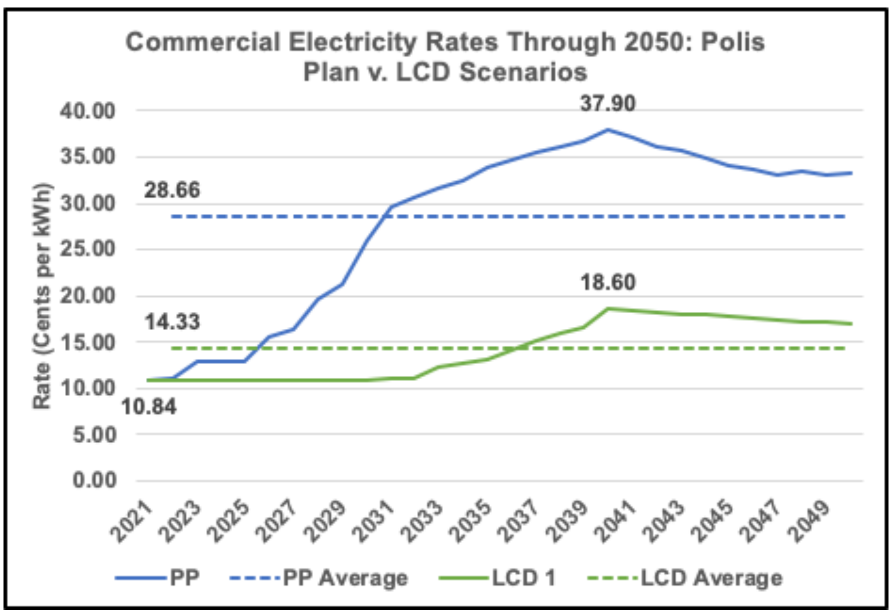
COMPARING AVERAGE RATE AND BILL IMPACTS BY CUSTOMER CLASS

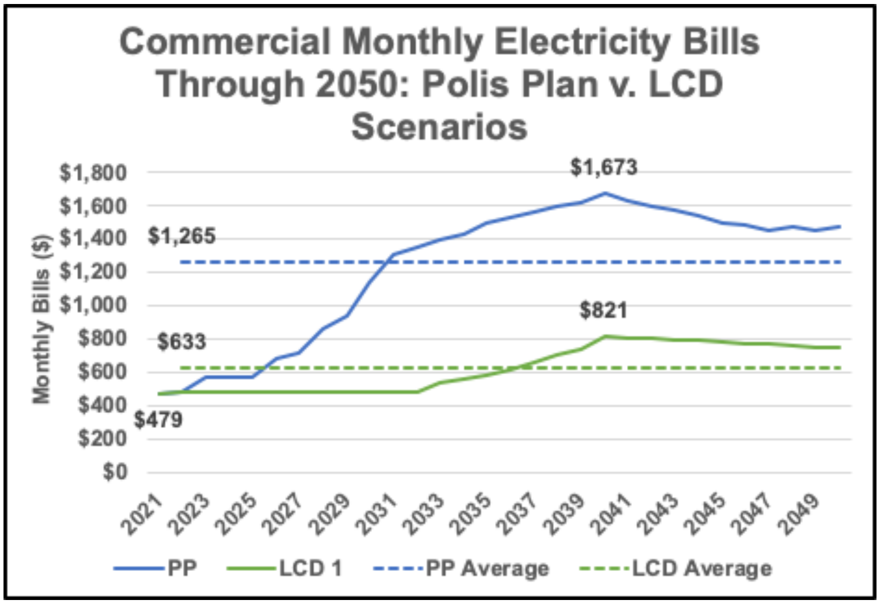




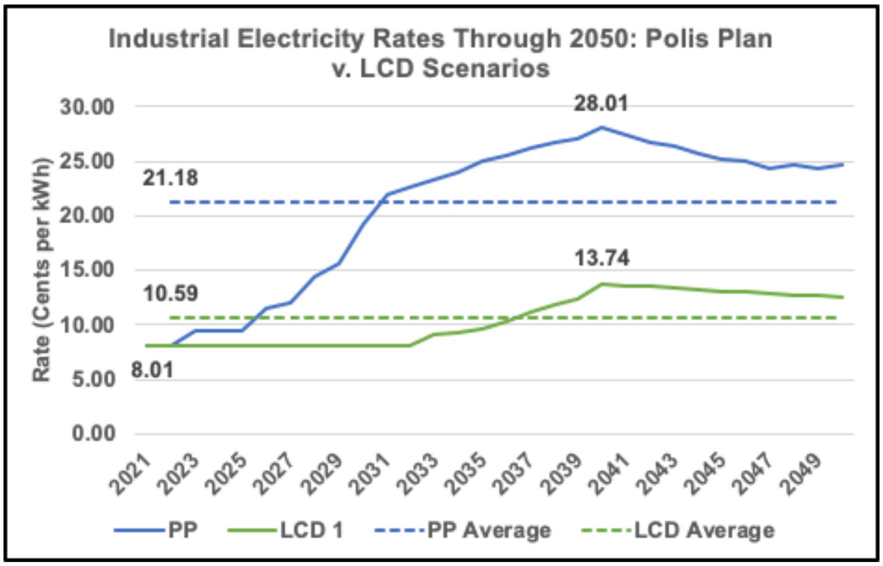



Residential Monthly Electricity Bills Through 2050: Polis Plan v. LCD Scenarios
Monthly Bills ($)
$350
$300
$250
$200
$150
$100
$50
$0
$321
$243
$158
$122
$92
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
2049
PP
LCD 1
PP Average
LCD Average

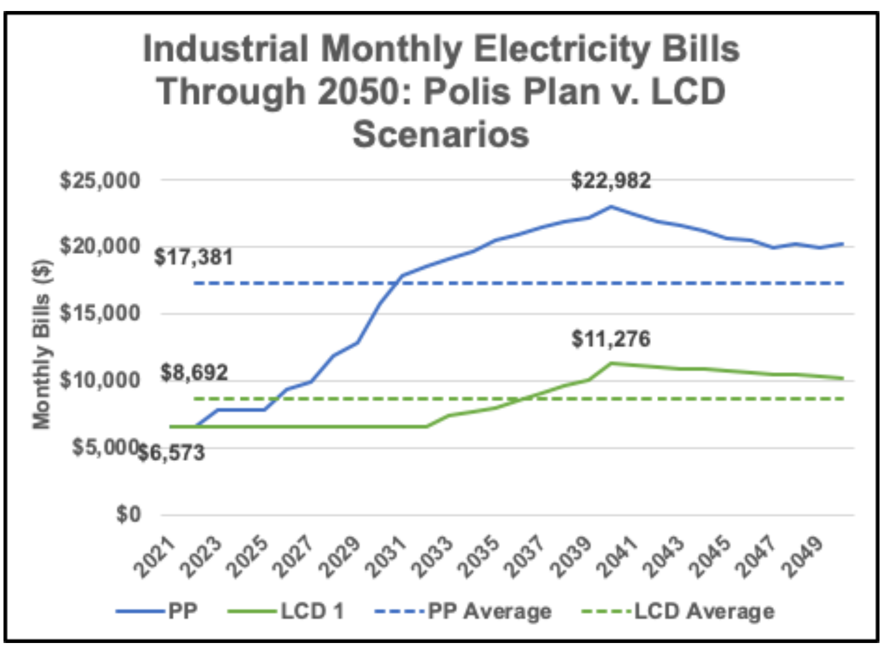

Commercial Electricity Rates Through 2050: Polis Plan v. LCD Scenarios
Rate (Cents per kWh)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
37.90
28.66
18.60
14.33
10.84
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
2049
PP
PP Average
LCD 1
LCD Average



Commercial Monthly Electricity Bills Through 2050: Polis Plan v. LCD Scenarios
Monthly Bills ($)
$1,800
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
$1,673
$1,265
$821
$633
$479
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
2049
PP
LCD 1
PP Average
LCD Average



Industrial Electricity Rates Through 2050: Polis Plan v. LCD Scenarios
Rate (Cents per kWh)
30.00
25.00
20.00
15.00
10.00
5.00
0.00
28.01
21.18
13.74
10.59
8.01
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
2049
PP
LCD 1
PP Average
LCD Average



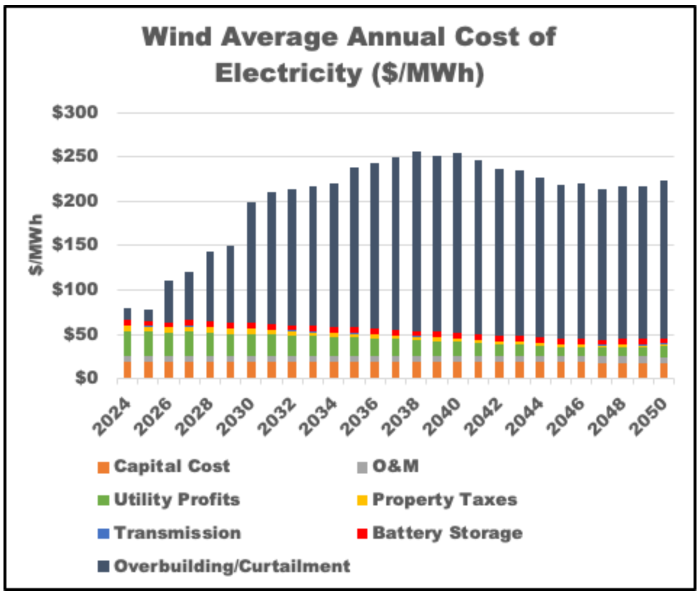
Industrial Monthly Electricity Bills Through 2050: Polis Plan v. LCD Scenarios
Monthly Bills ($)
$25,000
$20,000
$15,000
$10,000
$5,000
$0
$22,982
$17,381
$11,276
$8,692
$6,573
2021
2023
2025
2027
2029
2031
2033
2035
2037
2039
2041
2043
2045
2047
2049
PP
LCD 1
PP Average
LCD Average

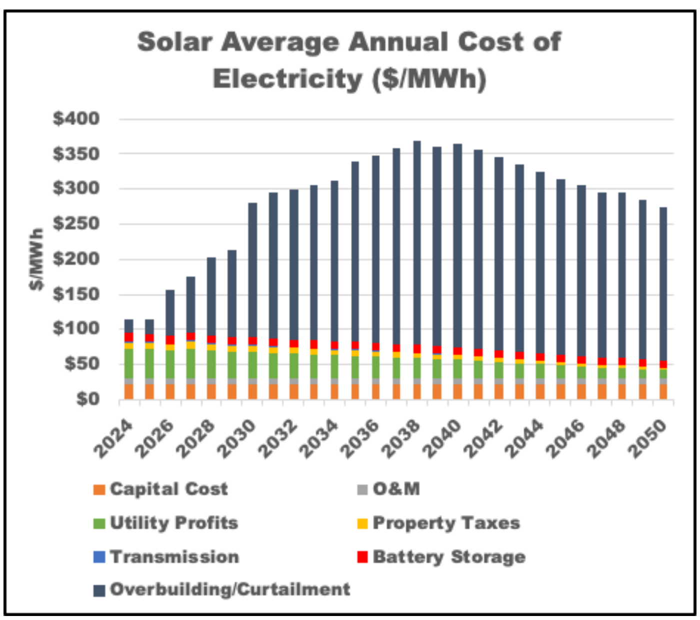
AVERAGE COST OF ANNUAL CAPACITY ADDITIONS

Under the Polis Plan, average annual costs for new build wind and solar projects begin rising over time due to increased curtailment needs as renewables are overbuilt. This forces individual wind and solar projects to recover costs over fewer hours of actual generation.

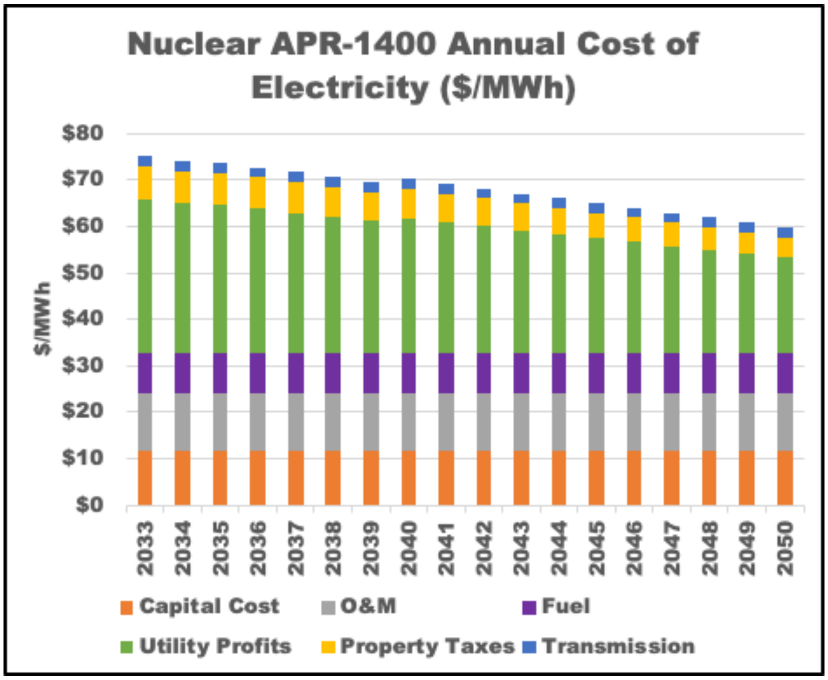
Under the LCD Scenario, average annual costs for new build APR-1400 nuclear reactors start high due to the high upfront capital costs necessary to build out large scale reactors. Average costs begin decreasing over the model run as the plant begins to depreciate over a steady state of generation. The opposite is the case for the SMR build out. The average annual cost per MWh of new SMRs begins to increase in 2036 and peaks in 2040 due to SMRs becoming the primary load following resource after all of the state's carbon-emitting dispatchable resources are retired. This forces the SMR projects to generate less electricity overall and thus recover costs over fewer MWhs. This added expense is labeled "ramping" in the chart below.

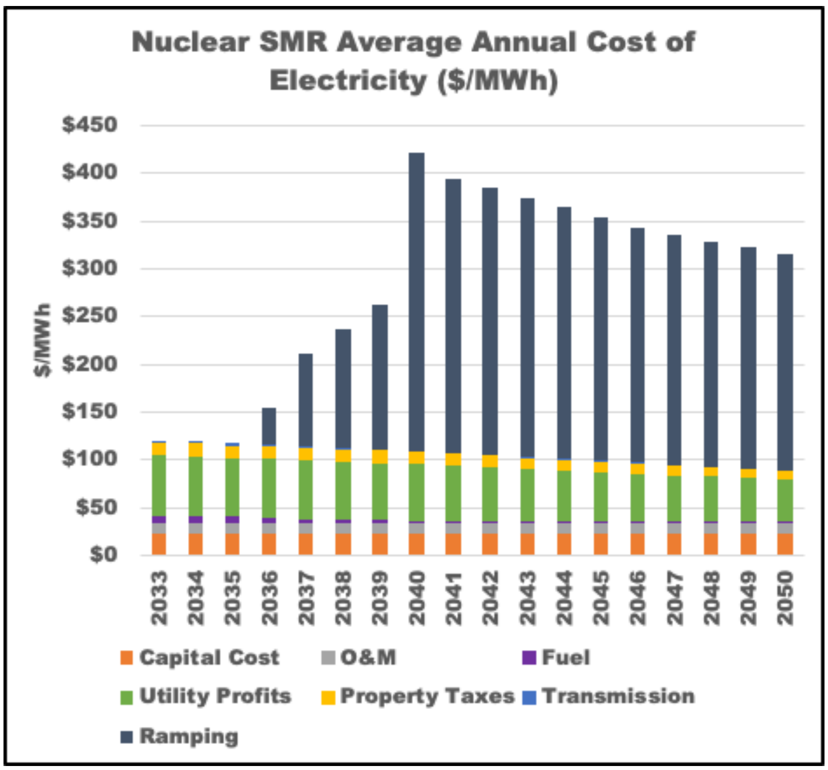
Polis Plan Average Annual Costs





LCD Scenario Average Annual Costs





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JON CALDARA is President of the Independence Institute.

DAVID KOPEL is Research Director of the Independence Institute.

JAKE FOGLEMAN is a Policy Analyst with the Independence Institute's Energy and Environmental Policy Center.

CONTRIBUTORS:

ISAAC ORR is a Policy Fellow at Center of the American Experiment, where he writes about energy and environmental issues.

MITCH ROLLING is a Policy Fellow at the Center of the American Experiment, where he analyzes the energy industry and electricity policy.

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