THE HIGH COST OF THE VIRGINIA CLEAN ECONOMY ACT

The Virginia Clean Economy Act Will Cost Virginia an Additional $203 Billion through 2050

ISAAC ORR & MITCH ROLLING

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

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

Mitch Rolling is a Policy Analyst at Center of the American Experiment, where he conducts research and writes about energy issues. Prior to his current role, he interned at the Center for several months and wrote extensively on renewable energy and electricity policy. Several of Mitch's writings have since appeared in numerous national and Minnesota publications, and his research has been cited by publications such as *The Wall Street Journal*.

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Executive Summary

- The Virginia Clean Economy Act (VCEA) will cost Virginia families and businesses an additional $203 billion through 2050 compared to the current grid.
- Virginia households will see their electricity expenses increase by an average of $1,160 per year, every year, through 2050.
- In contrast, an energy portfolio focused on providing reliable electricity would cost just $15.5 billion during this period, saving $188 billion compared to current Virginia law. It would also reduce the risk of blackouts on the Virginia electric grid.
- Offshore wind dramatically increases the cost of providing the electricity Virginians rely upon. This energy source will cost $154 per megawatt-hour (MWh) when the often-hidden transmission costs, property taxes, utility returns, and battery storage costs are accounted for.
- The VCEA will reduce the reliability of the grid by making the state more reliant upon weather-dependent energy sources like wind and solar, and energy imports from other states. This is the same strategy California has pursued, with unenviable results.
- Virginians would benefit most from modest investments in reliable electricity generation technologies, which provide superior reliability value at a fraction of the cost of the VCEA.

AUTHORS' NOTE: This report is a continuation of the work performed by Center of the American Experiment modeling the cost of renewable energy mandates in states throughout the country. Portions of this report have been repurposed and modified to reflect the circumstances of the Commonwealth of Virginia as a result of the passage of the Virginia Clean Economy Act.

Introduction

Laws mandating the use of wind and solar power have been a popular measure used by state policymakers to increase the amount of electricity generated by these energy sources in the United States for nearly two decades. These laws, commonly known as Renewable Portfolio Standards (RPSs) or Renewable Energy Mandates (REMs), have been passed in 30 states and Washington D.C. The mandates have also become increasingly stringent over time.[1]

Unfortunately, the lawmakers enacting these mandates failed to grasp the consequences that these policies would have on the reliability and affordability of the American electric grid. As a result, prices have increased, and reliability has faltered.

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

"Many people believe replacing coal and natural gas-fired power plants with wind turbines, solar panels, and battery storage technologies will be easy to accomplish and reduce electricity prices."

Wind turbines and solar power can only produce electricity when the wind is blowing or the sun is shining. Furthermore, many people seem to think of the grid as a device that stores electricity for later use, like a giant bathtub that fills with power that can be accessed when needed at a later time. This misconception leads people to believe that wind and solar can increase the availability of electricity on the grid and improve reliability.[2] They cannot.

Texas and California are poster children for states with heavy reliance on wind and solar generation that experienced blackouts when the weather did not cooperate, but the Southwest Power Pool, a consortium including 17 states that relies heavily on wind generation, also experienced rolling blackouts during winter storm Uri in February of 2021 because the wind wasn't blowing.[3]

In her best-selling book ***Shorting the Grid***, Meredith Angwin describes a fatal trifecta afflicting electric grids throughout the nation. The fatal trifecta occurs when grids are overly reliant upon generation from weather-dependent renewable resources, such as wind and solar, electricity imports from neighboring regions, and just-in-time delivery and power generation from natural gas.[4]

Angwin is a strong proponent of nuclear energy, which she sees as the most reliable, affordable way to reduce carbon dioxide emissions from the power generation sector, but she also acknowledges the vital role that coal plants play in keeping the lights on due to their large, on-site fuel supplies.

This study assesses how the Virginia Clean Economy Act (VCEA) would increase costs for families and businesses in the Commonwealth and make the grid more fragile. It also assesses an alternative scenario, the Reliable Resource Scenario (RRS), where reliability and affordability are given the prioritization they deserve. ■

Section I: What Is the Virginia Clean Economy Act?

On April 12, 2020, then-Governor Ralph Northam signed the Virginia Clean Economy Act, establishing sweeping new requirements for renewable energy, energy storage, and energy efficiency in the Commonwealth.[5]

Prior to the passage of the VCEA, Virginia had only voluntary renewable energy goals. Now, it has one of the most aggressive renewable energy mandates in the nation. The law requires that 100 percent of the electricity generated in Virginia come from sources of electricity that do not emit carbon dioxide by 2050.

The law also established yearly renewable energy benchmarks for Virginia's investor-owned utilities (IOUs), Dominion Energy and Appalachian Power. It also sets specific timelines by which these electric companies must install thousands of megawatts of offshore wind, solar panels, onshore wind turbines, and energy storage systems.[6]

The law also requires nearly all the existing coal-fired power plants in the state—which generated 3.8 gigawatt-hours (GWh) of Virginia's electricity in 2019— to retire by December 31, 2024.

"Prior to the passage of the VCEA, Virginia had only voluntary renewable energy goals. Now, it has one of the most aggressive renewable energy mandates in the nation."

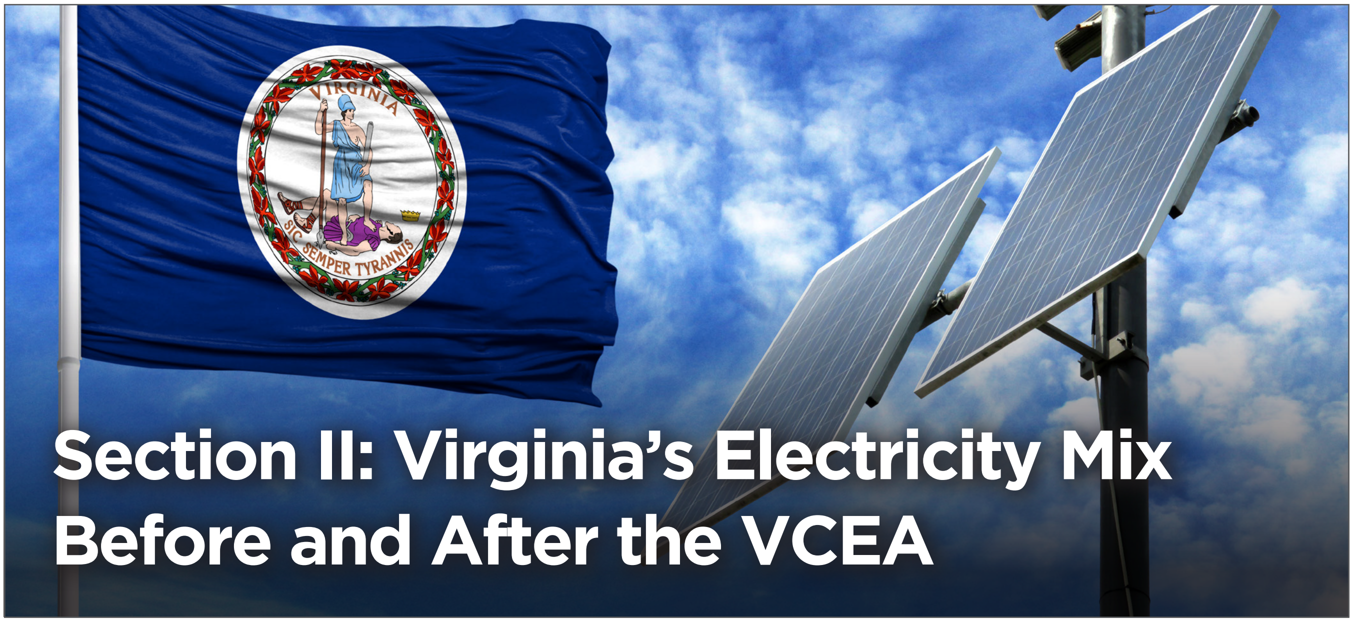
This analysis examines the cost and reliability implications of complying with the VCEA and compares it to the RRS, which emphasizes providing the most reliable electricity at the lowest possible cost for Virginia families and businesses. We conclude that complying with VCEA mandates will make maintaining a reliable electricity grid exponentially more expensive and more difficult, while the RRS will cost far less and bolster the reliability of Virginia's electric system.

Importantly, this analysis does not account for federal subsidies paid to wind and solar facilities. We believe this methodology is appropriate because federal subsidies would not reduce the cost of complying with the VCEA; they would simply shift who pays for it.

It also assumes that electricity consumption in Virginia will remain constant at approximately 122 million MWhs from 2019 through 2050.[7,8] This assumption is conservative because proponents of renewable energy mandates also often promote the widespread adoption of electric vehicles and the broader electrification of the energy sector for purposes such as home heating.

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

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



Section II: Virginia's Electricity Mix Before and After the VCEA

In 2019, Virginia derived 45 percent of its electricity generation from natural gas, 23 percent from nuclear plants, 24 percent from imports of electricity from other states (mostly imports of coal-generated electricity in West Virginia), 3 percent from coal, 2 percent from wood, one percent from hydroelectric, and one percent from solar (See Figure 1).[9]

"In 2019, Virginia derived 45 percent of its electricity generation from natural gas, 23 percent from nuclear plants, 24 percent from imports of electricity from other states..."

Under the VCEA, this electricity mix would be required to shift dramatically, but minimal changes to the existing electric grid would be required under the RRS.

Readers should note that 2019 data are used for this analysis because 2020 data are likely distorted due to the COVID-19 pandemic and full 2021 data were not available at the time of this writing.

Under the VCEA, electric companies will be allowed to retain and relicense their existing nuclear power plants. However, these companies will be required to replace the electricity currently generated with natural gas, coal, and biomass with qualifying renewable energy sources such as offshore wind, onshore wind, solar panels, and battery storage by 2050, unless it would impair the reliability of the electric grid.[10]

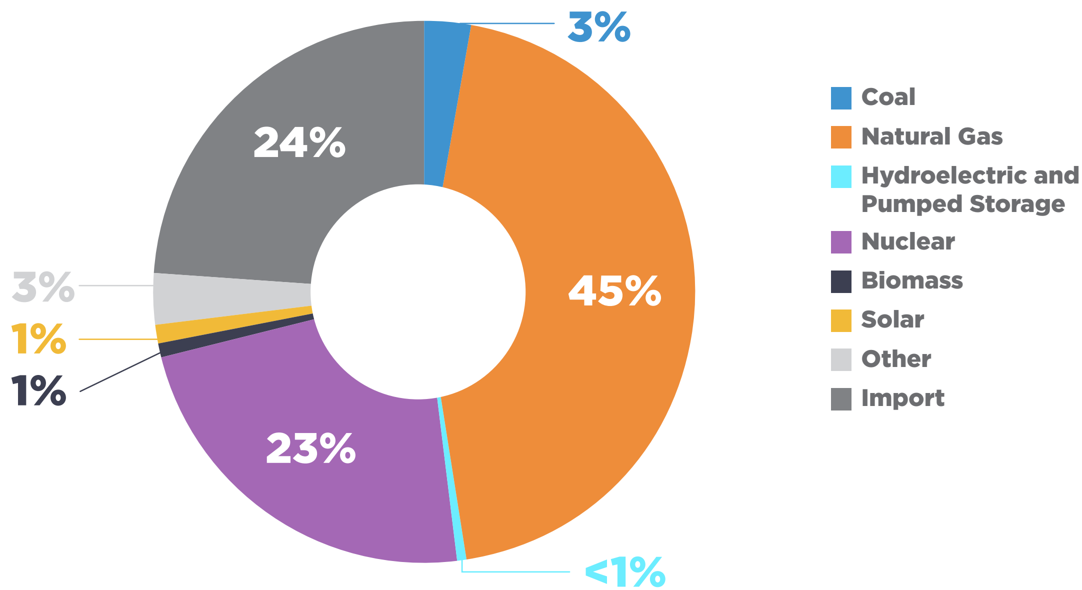
While natural gas would be a much more affordable option than battery storage for maintaining grid reliability, our analysis calculates the cost of using batteries to provide electricity to the grid when the wind is not blowing or the sun is not shining. We do this because quality analyses conducted by the Virginia State Corporation Commission and Dominion Energy have already evaluated the role of natural gas.[11] Therefore, duplicating these studies would not add new value to the discussion surrounding the VCEA.

Generation Mix Under the VCEA

Our model calculates the generation mix for VCEA compliance in Virginia using offshore wind, onshore wind, solar generation, and battery storage. Figure 2 shows Virginia's electricity mix in

FIGURE 1

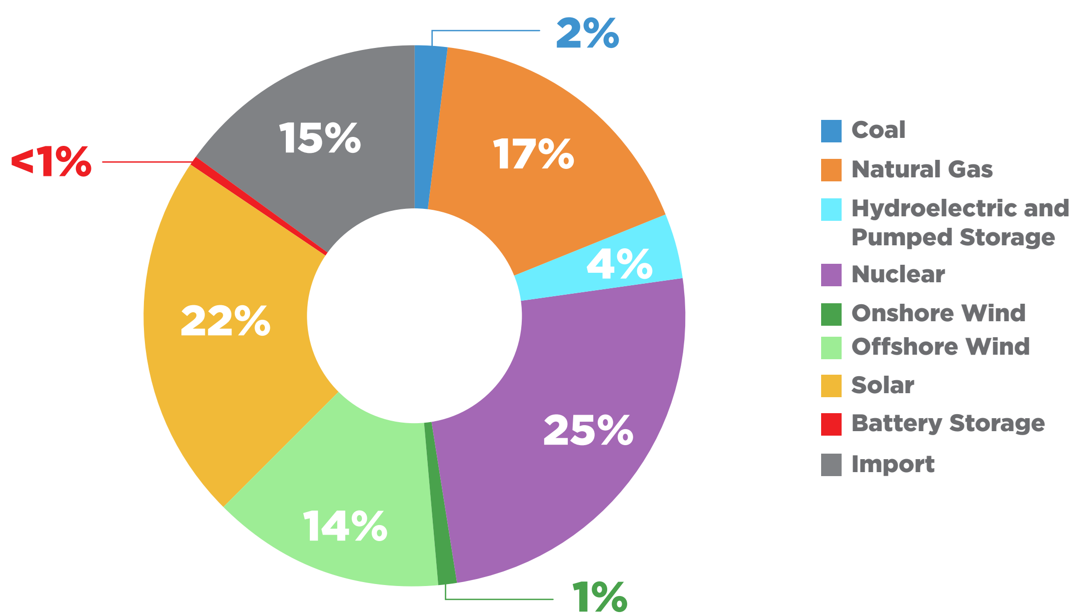
Virginia Electricity Generation by Source in 2019



Natural gas, electricity imports, nuclear energy, and coal provided 92 percent of the electricity consumed in Virginia in 2019. Hydroelectric accounted for 1 percent of generation, but pumped storage consumed one percent of generation; the net generation is thus less than one percent in Figure 1.

FIGURE 2

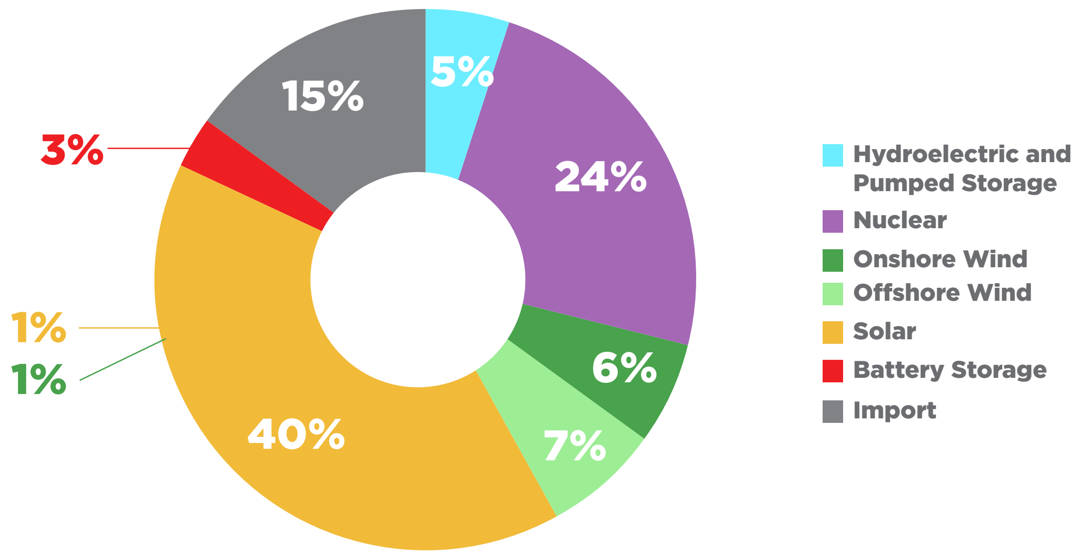
VCEA Production by Energy Source in 2035



Natural gas generation declines by 2035 as solar grows to 22 percent of generation.

FIGURE 3

VCEA Production by Energy Source in 2050



Solar power will become the largest source of electricity in Virginia by 2050, with nuclear power providing the second-largest source of energy.

2035, and Figure 3 shows the electricity generation mix in 2050.

Under the law, utilities are required to build large quantities of offshore wind, onshore wind, and solar panels by the dates specified in the legislation. As a result, by 2035, 2 percent of the electricity generation in the state would come from coal, 17 percent would come from natural gas, 4 percent from hydroelectric and pumped storage, 25 percent from nuclear, 1 percent from onshore wind, 14 percent from offshore wind, 22 percent from solar, effectively zero from battery storage, and 15 percent from imports.

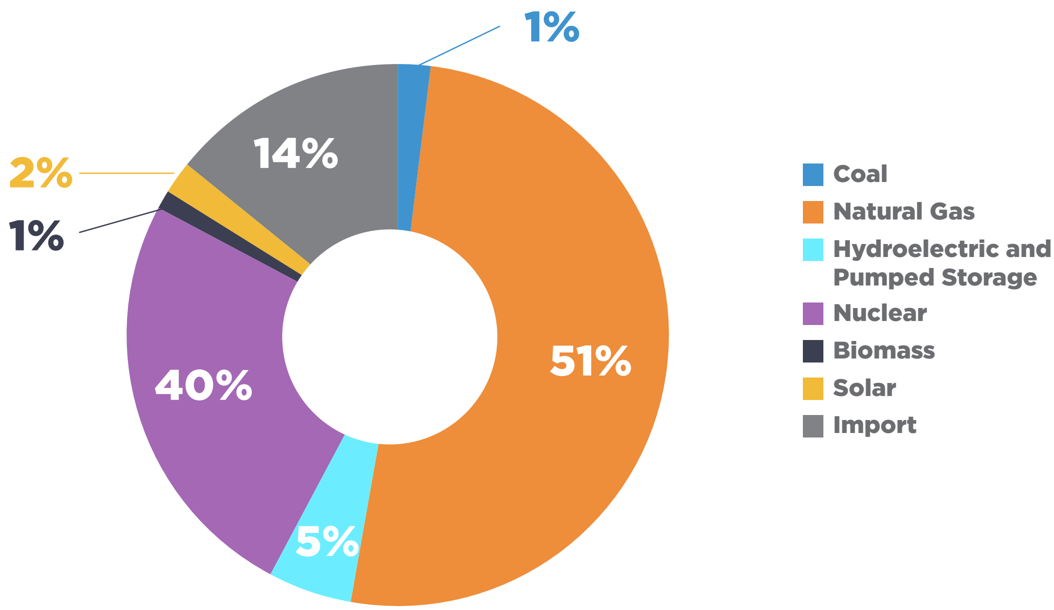
By 2050 utilities are required to remove all carbon-dioxide emitting power plants from their systems, resulting in a generation mix that relies on nuclear for 24 percent of total generation, onshore wind for 6 percent, offshore wind for 7 percent, solar for 40 percent, battery storage for 3 percent, imports for 15 percent, and hydroelectric and pumped storage for 5 percent.

Generation Mix Under the RRS

Under the RRS, Virginia would continue to utilize the existing nuclear, coal, and natural gas power plants on its electric system, and Dominion

FIGURE 4

RRS Electricity Production by Energy Source in 2050



Under this scenario, natural gas increases its share of generation to reduce Virginia's reliance upon imports. Nuclear power remains relatively constant, and coal generation increases slightly.

Energy and Appalachian Power would continue to generate electricity at their West Virginia coal facilities for use in Virginia.

However, additional natural gas capacity would be built in Virginia to limit the state's exposure to potential electricity shortages in other states if they become overly reliant upon intermittent wind and solar resources.

As a result, in 2050, Virginia would derive 51 percent of its electricity generation from natural gas plants, 25 percent from nuclear plants, 14 percent from imports of electricity from other states (mostly imports of coal-generated electricity in West Virginia), 2.5 percent from coal, 5 percent from hydroelectric and pumped storage, 1.4 percent from biomass, and 1.5 percent from solar (See Figure 4).[12]

The changing electricity generation mix under the VCEA will have profound impacts on the cost of electricity for Virginia families and businesses and on the reliability of the electric grid in the Commonwealth. In contrast, the RRS would enhance reliability at low cost. ■

Section III: Comparing the Cost of the VCEA and RRS

Both the VCEA and RRS will increase the cost of electricity for Virginia families and businesses, but consumers would save $188 billion under the RRS compared to complying with the VCEA through 2050.

VCEA Costs

Our modeling indicates that complying with the VCEA will cost an additional $203 billion (in constant 2022 dollars) to implement in the Commonwealth, compared to operating the current electric grid, which equates to an average annual cost of $1,770 for each Virginia utility customer, the equivalent of paying an additional $147 per month.

In contrast, the costs associated with the RRS would total $15.5 billion, which translates to an average additional cost of $136 per year for each utility customer in Virginia. Therefore, the RRS represents a savings of $1,634 per customer per year relative to the cost of the VCEA.

Figure 5 shows the average cost of complying with the VCEA and RRS from 2021 through 2050 by dividing the annual cost of the programs between all Virginia utility customers, including residential, commercial, and industrial electricity users. VCEA costs are lowest during the initial years but increase as the renewable energy requirements in the law become more stringent over time.

VCEA costs are highest by 2045 when complying with the law costs more than $3,500 per customer, which is the equivalent of $290 per month. RRS costs are highest in 2035 when costs are as high as $207 per customer—$17 per month.

Residential customers

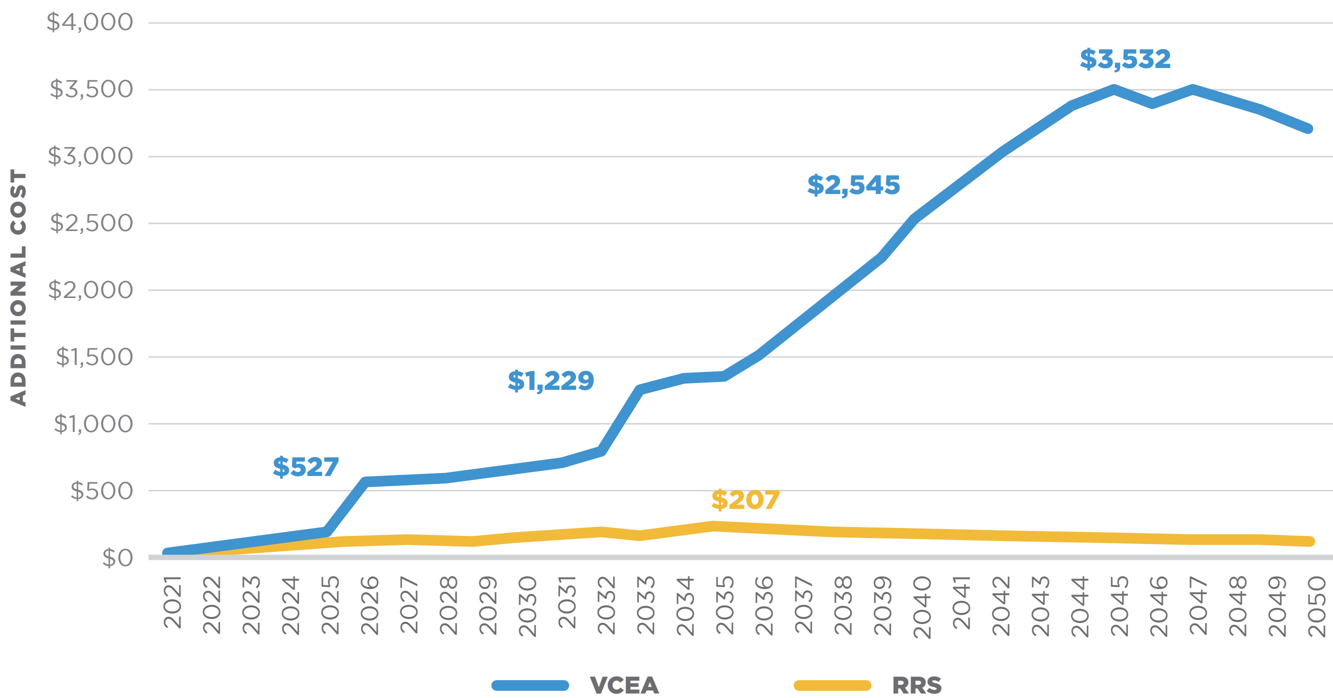
Under the VCEA, residential customers would see their annual electricity costs increase by an average of $1,160 per year through 2050, with costs peaking at $2,325 for residential customers in 2045. Residential customers would see annual average electricity costs increase by $88 under the RRS, with costs peaking at $135 in 2035 (See Figure 6).

Commercial customers

Under the VCEA, commercial customers would see their annual electricity costs increase by an average of $6,800 per year through 2050, with costs peaking at $13,700 in 2045. These customers would see their yearly electricity costs increase by $520 on average under the RRS, with costs peaking at $800 in 2035 (See Figure 7).

FIGURE 5

Average Annual Additional Cost Per Customer



Annual costs for Virginians increase by an average of $1,770 under the VCEA. Costs peak at $3,532 in 2045. The RRS would cost an average of $136 per year, with costs peaking at $207 in 2035.

Industrial customers

Industrial companies in Virginia, as significant users of electricity, would be hit hard under the VCEA. Electricity bills would increase by $218,000 per year on average through 2050, with costs peaking at $437,000 in 2045. These customers would see their costs increase by $16,600 under the RRS, with expenses peaking at more than $25,000 in 2035 (See Figure 8).

VCEA compliance costs are driven by the need to build enough offshore wind turbines, solar panels, onshore wind turbines, and transmission lines to meet the law's stipulation that the Virginia electric grid be carbon-free by 2050.

Other factors that increase costs include increasing property taxes, utility returns, and the need to build and maintain battery storage facilities to provide electricity when the sun is not shining and the wind is not blowing.

RRS costs are driven by relicensing Virginia's existing nuclear power plants and building a new natural gas plant to ensure Virginia has enough capacity to meet peak electricity demand without relying upon imports outside of the coal plants operated by Dominion Energy and Appalachian Power in West Virginia.

Rising Prices from Increasing Electricity Generation Capacity

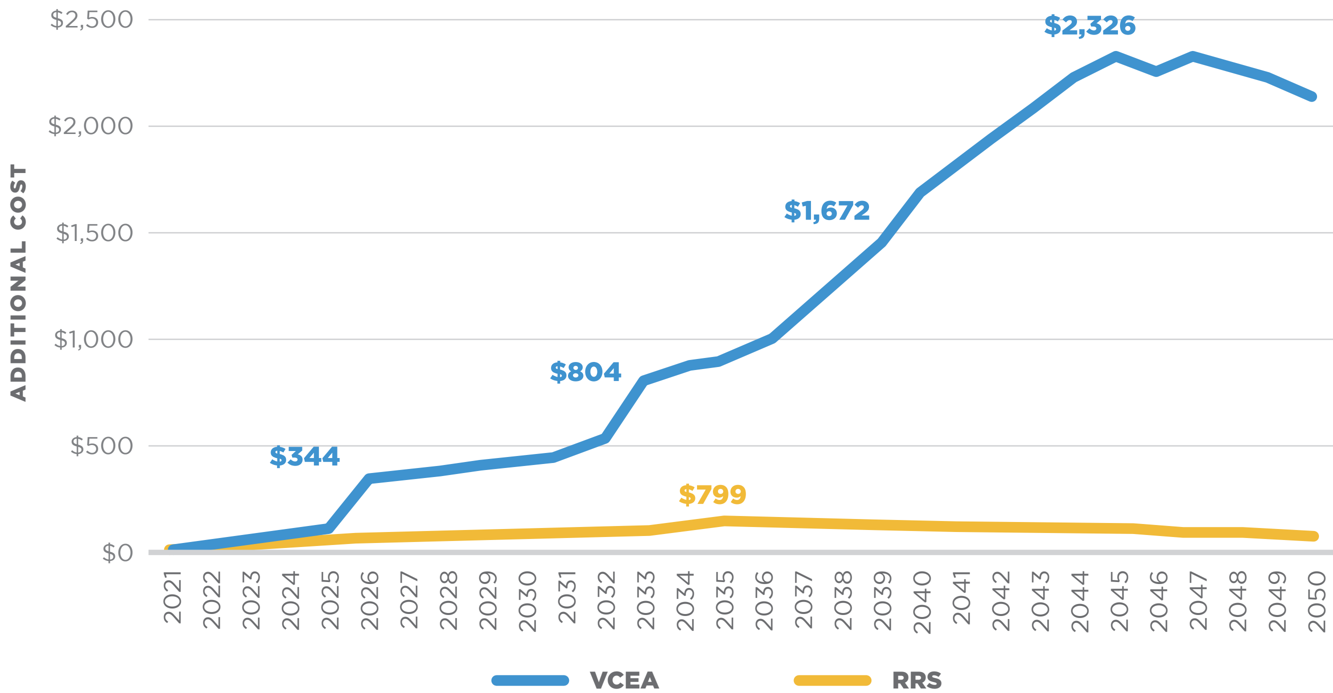
In 2021, Virginia had just 26,300 MW of installed power plant capacity on the grid. Both the VCEA and RRS would increase the amount of installed capacity on the Commonwealth's electric grid, but the VCEA would do so to a much greater extent.

VCEA

Under the VCEA, the amount of installed capacity on Virginia's electric grid would increase from

FIGURE 6

Annual Additional Cost for Residential Ratepayers



Under the VCEA, residential electricity consumers in Virginia would see their electricity costs increase by an average of $1,160 per year, with costs reaching $2,300 per residential customer in 2045. Costs would increase by an average of $88 per year under the RRS.

26,300 MW in 2021 to 54,200 MW by 2035 and increase to 105,000 MW by 2050, representing a quadrupling of the amount of installed capacity on the Virginia electric system (See Figure 9).

While adding additional capacity to the grid may sound like a good thing, increasing capacity merely to meet renewable energy mandates rather than meeting electricity demand is an unnecessary cost that will harm Virginia families and the state's economy. Solar, onshore wind, offshore wind, and battery storage capacity increase most, nuclear power plant capacity remains constant, and coal and natural gas are phased out by 2050 to comply with the law.

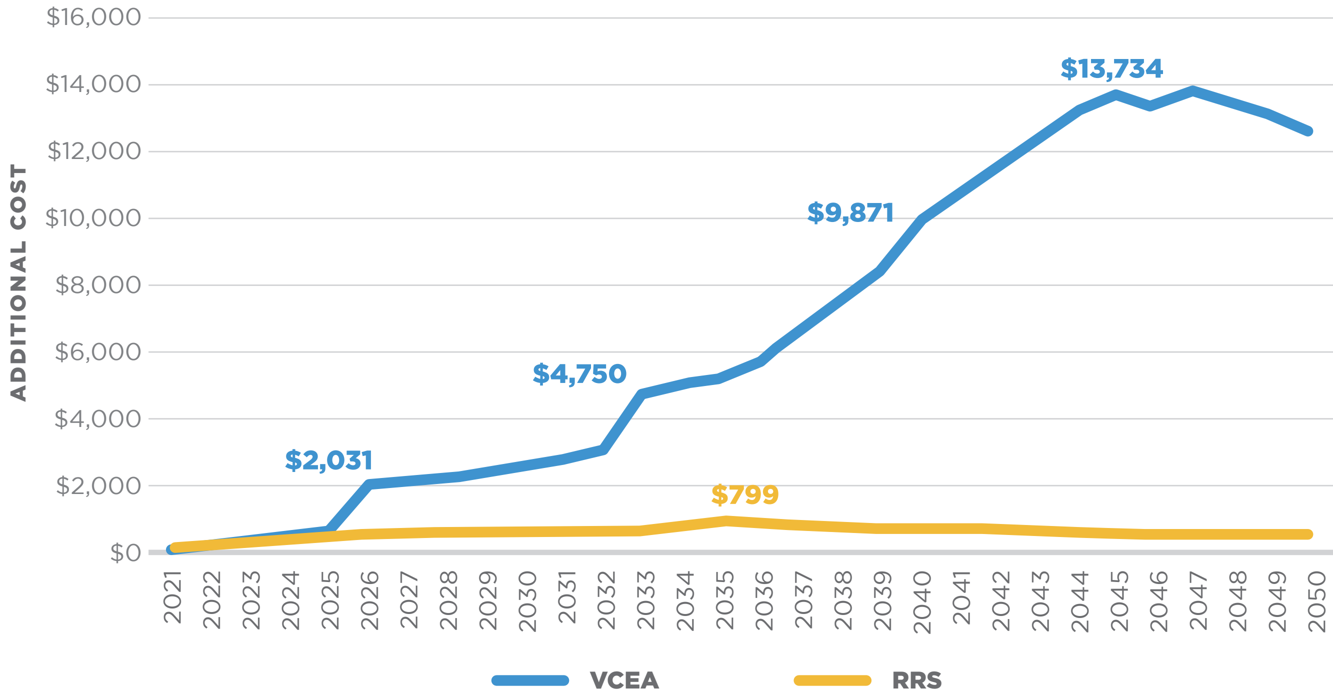
Solar installations would grow the most under the VCEA, increasing from 956 MW of installed capacity in 2020 to 51,100 MW of capacity in 2050. Onshore wind capacity would grow from zero MW in 2020 to 7,500 MW in 2050, offshore wind would grow from 12 MW in 2020 to 5,200 MW in 2050, and battery storage would increase from zero MW in 2020 to 33,500 MW in 2050.[13]

It is important to note that our model selected these solar, onshore wind, and battery storage resources because they were the most cost-effective portfolio for meeting the renewable energy mandates enacted by the VCEA and maintaining grid reliability.

Building these solar panels, onshore and offshore wind turbines, and battery facilities would cost $39 billion, $13 billion, $20 billion, and $39 billion, respectively. Battery facilities are needed to comply with the VCEA because these facilities allow Virginia to meet the statutory requirement of the law, and to store excess electricity generated by solar, onshore wind, and offshore wind for later use.

FIGURE 7

Annual Additional Cost for Commercial Ratepayers



Virginia businesses would pay far more for electricity under the VCEA than the RRS.

Figure 10 shows electricity generation from each resource during a hypothetical scenario when electricity demand peaks during the week of January 30, 2050, through February 5, 2050. Electricity demand is highest during this week due to the high rate of homes in Virginia that use electricity for home heating.[14]

The black line shows the demand for electricity during every hour of this week. Demand for electricity is highest during the evening and early morning hours when temperatures are lowest, prompting the use of more electricity for heating.

Battery storage, shown in red, provides electricity during the peak electricity demand before solar power ramps up production during the day. Solar generation, shown in yellow, exceeds the demand shown with the black line because solar capacity must be "overbuilt" to comply with the VCEA.

A portion of the extra solar power and wind must be used to charge the batteries. Once the batteries are fully charged, any additional solar or wind power that is generated is curtailed, or turned off. Curtailment is expected to become increasingly common as more wind and solar are placed into service on the grid.[15]

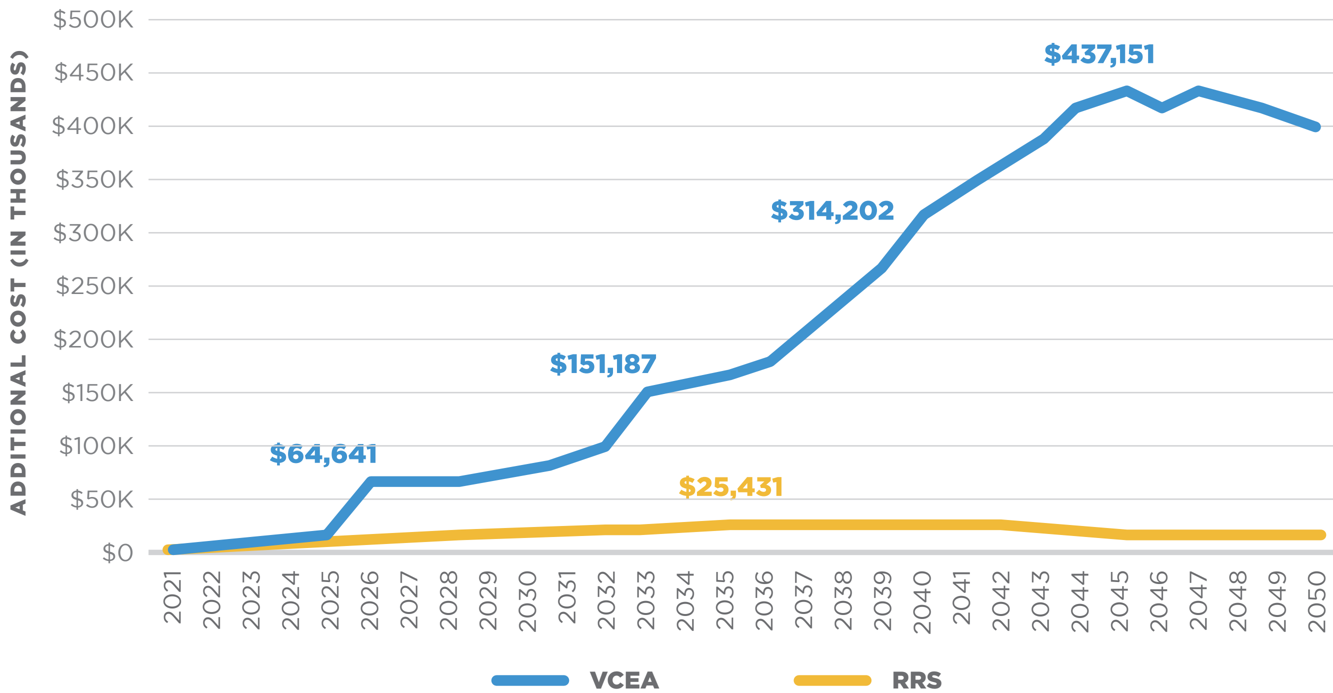
RRS

The amount of additional capacity needed under the RRS would be minimal. This is because the RRS prioritizes the continued operation of reliable power plants in Virginia and the construction of new natural gas plants that can be turned on and off, or dispatched, as needed to meet the demand for electricity at any hour of the day, regardless of weather conditions.

Figure 11 below shows the amount of installed

FIGURE 8

Annual Additional Cost for Industrial Ratepayers



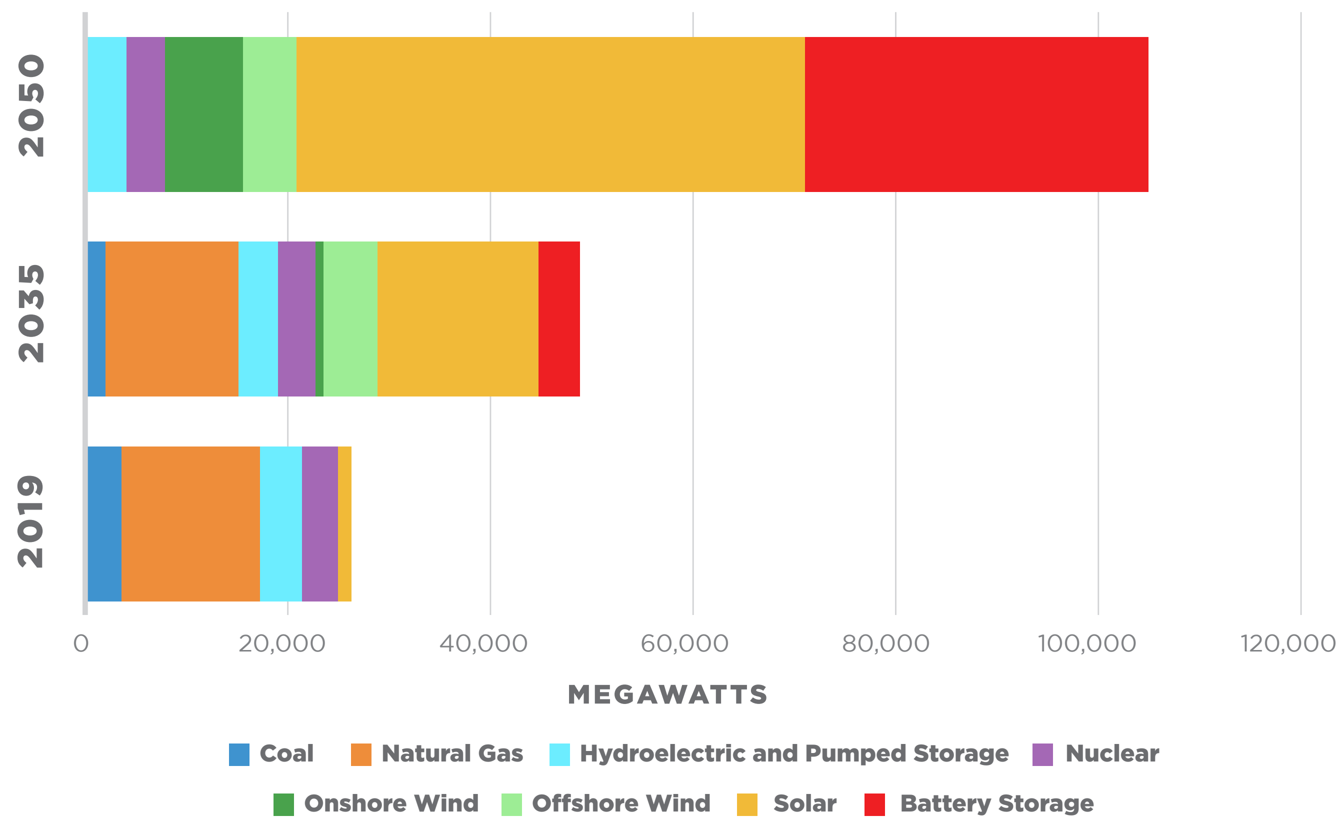
Industrial electricity users would see large increases in costs under the VCEA, while costs would be more manageable under the RRS.

Constructing additional offshore wind installations beyond the 5,200 MW of capacity that was determined to be in the public interest under the VCEA would have increased the cost of compliance. For example, doubling installed offshore wind capacity to 10,400 MW while modestly reducing solar capacity, would have increased the total cost of VCEA compliance to $224 billion, a difference of $21 billion. Therefore, only 5,200 MW of offshore wind was built during our model run for the cost of the VCEA.

Rather than build more offshore wind, this model includes an extensive, 7,500 MW buildout of onshore wind, which is beyond the scope of the 650 MW of onshore wind currently planned by Appalachian Power. Our model selects onshore wind because it is lower cost than adding more offshore wind. For example, keeping the onshore wind buildout to 650 MW and building more offshore wind capacity would increase costs by $60 billion to $263 billion through 2050.

FIGURE 9

Virginia Installed Capacity Mix for VCEA Compliance



Complying with the VCEA would require a quadrupling of the amount of installed capacity on Virginia's electric grid to maintain a reliable system. This massive buildout of capacity would drive significant cost increases for families and businesses.

capacity on the Virginia electric grid growing from 26,300 MW in 2021 to 31,200 MW by 2050.

The modest capacity additions in the RRS are the main reason why the price tag of this scenario is much lower than the costs incurred under the VCEA.

Transmission Costs

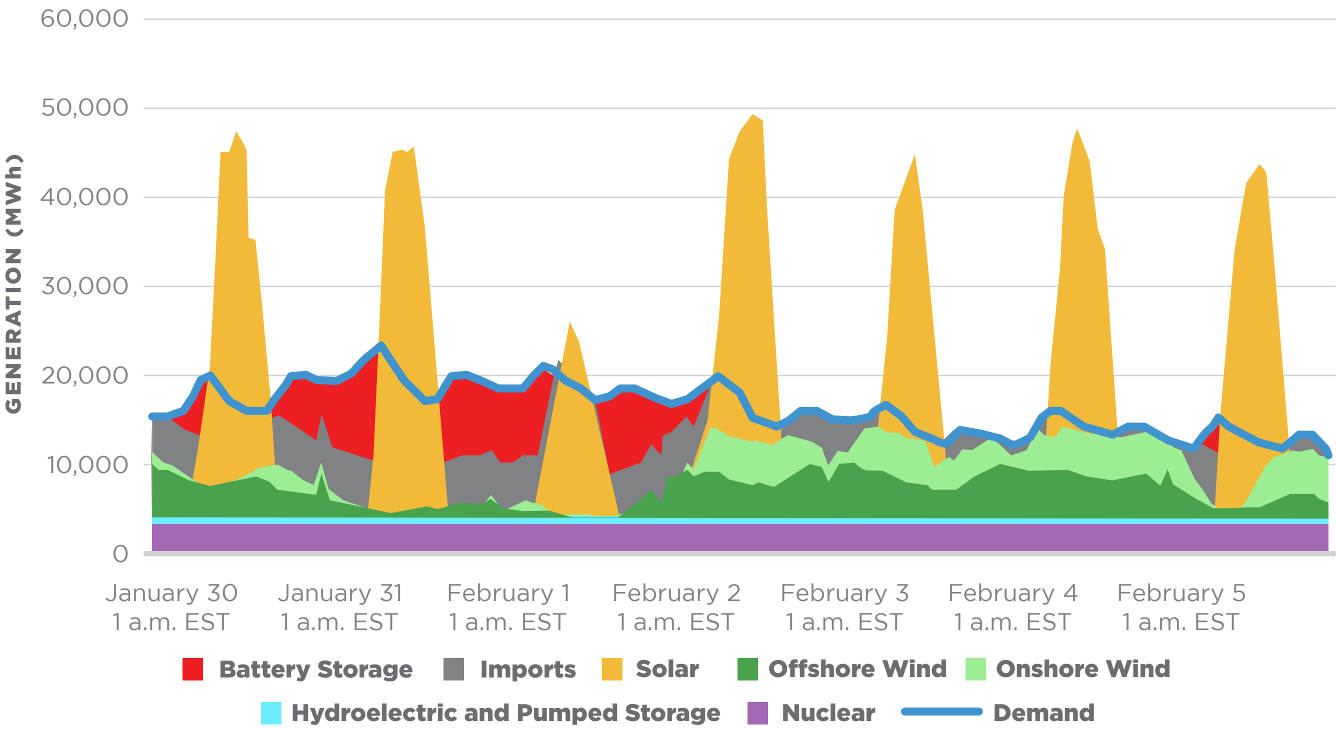
Transmission lines are important: It is pointless to generate electricity if it cannot be transported to the homes and businesses that rely upon it. Implementing the VCEA in Virginia would require $13.2 billion in additional transmission and distribution spending compared to the current system, which already meets the electricity demands of Virginians.

Transmission costs are driven by the need to build new infrastructure to connect offshore wind turbines into the grid. Additional transmission lines will also be needed to connect solar and onshore wind facilities located in rural areas to the populous areas of Virginia, where the electricity will be consumed.

Dominion Energy estimates it will require $1.4 billion to upgrade onshore transmission lines and build offshore transmission cables for phase one of the Coastal Virginia Offshore Wind project, which is comprised of approximately 2,600 MW.[16] This

FIGURE 10

2050 Virginia Generation Mix After VCEA Compliance



Battery storage is needed to help meet demand during the evening and during periods of insufficient wind generation. The batteries are charged by the solar panels and wind turbines on the grid and discharged when wind and solar are unavailable.

equates to transmission costs of $538,000 per MW for offshore wind developments.

Furthermore, the National Renewable Energy Laboratory (NREL) estimates that achieving a grid powered by 70 percent solar and wind in the United States would require the construction of approximately 75 million MW miles of transmission lines. For context, NREL estimates there are currently between 150 and 200 million MW miles of transmission lines, meaning a grid powered by 70 percent renewable energy would require, at a minimum, a 37.5 percent to 50 percent increase in transmission infrastructure.[17]

Assuming similar increases in transmission lines would be needed for each state, Virginia's grid—which would be powered by 52.8 percent solar and wind under the VCEA—would require the amount of existing transmission lines to increase by 50 percent to accommodate higher penetrations of intermittent renewable energy.

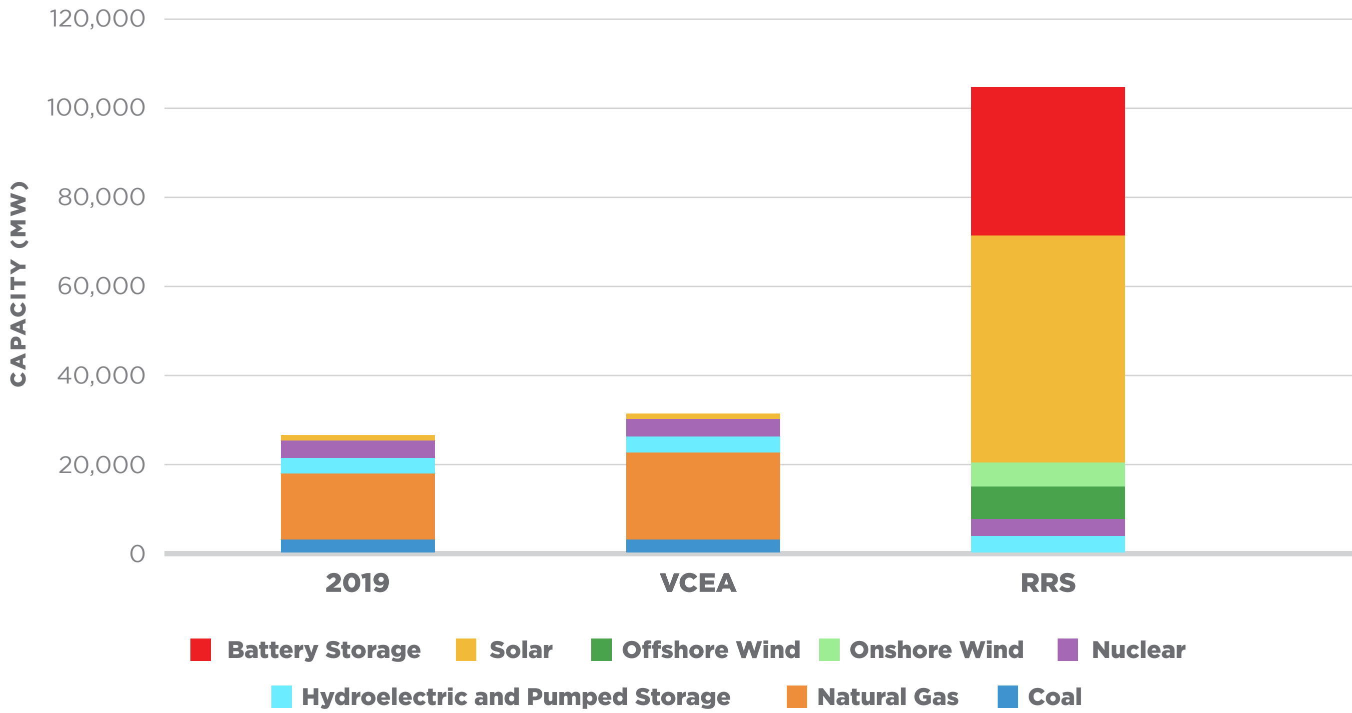
According to the U.S. Department of Energy, Virginia has 1,249 MW miles of transmission lines that are 230 kilovolts (kV) or larger and 374 miles of transmission lines smaller than 230 kV.[18] According to our assumptions based on NREL estimates, these values would double under the VCEA.

Transmission lines routinely cost $2.5 million per mile for 115 kV lines and $3.2 million per mile for 230 kV lines. As a result, building enough transmission lines to comply with the VCEA would cost $2.5 billion.[19] Lastly, the Virginia SCC identified $8 billion in additional grid upgrades in a Dominion Energy investor presentation that will aid in VCEA compliance.[20]

The RRS, in contrast, would require minimal transmission buildout, increasing transmission

FIGURE 11

Total Capacity VCEA vs. RRS



This graph shows the amount of capacity on Virginia's electric grid each year from 2021 through 2050. Only 4,900 MW of additional capacity is built in this scenario.

costs by an additional $720 million by 2050 to accommodate new natural gas plants built in the Commonwealth.[21]

Utility Returns

Because investor-owned utilities (IOUs) such as Dominion Energy and Appalachian Power Company are regulated monopolies in Virginia, they are not allowed to make a profit on the electricity they sell.

Instead, they are guaranteed a 9.35 percent profit, or rate-of-return on equity, when they spend money on capital assets such as power plants, transmission lines, and even new corporate offices, if the State Corporation Commission deems these expenses to be in the public interest.[22]

The VCEA will require utilities to spend billions of dollars on new infrastructure. As a result, additional utility returns would be roughly $109 billion in the VCEA Compliance scenario. Under the RRS, additional utility profits would be $11.3 billion.

Property Taxes

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

Additional property tax payments under the VCEA were calculated to be $11 billion, compared to operating the existing power grid.[23] Under the RRS, additional property taxes would be $1.2 billion, relative to current expenditures.

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

Almost all studies that examine the cost of renewable energy use a methodology called the Levelized Cost of Energy, or LCOE, to assess the cost of wind and solar compared to different technologies.[24] LCOE estimates reflect the cost of generating electricity from different types of power plants, on a per-unit of electricity basis (generally megawatt hours), over an assumed lifetime and quantity of electricity generated by the plant.

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

However, the introduction of intermittent renewable resources has made LCOE calculation less informative over time because this metric was developed to compare resources that were able to provide the same reliability ***value*** to the grid. However, wind and solar are not able to supply reliable power on demand like dispatchable energy sources such as coal, natural gas, or nuclear power.

As a result, the U.S. Energy Information Administration cautions readers against comparing the LCOE of dispatchable and non-dispatchable resources because they are not an apples-to-apples comparison.[25] Unfortunately, this word of caution is seldom heeded.

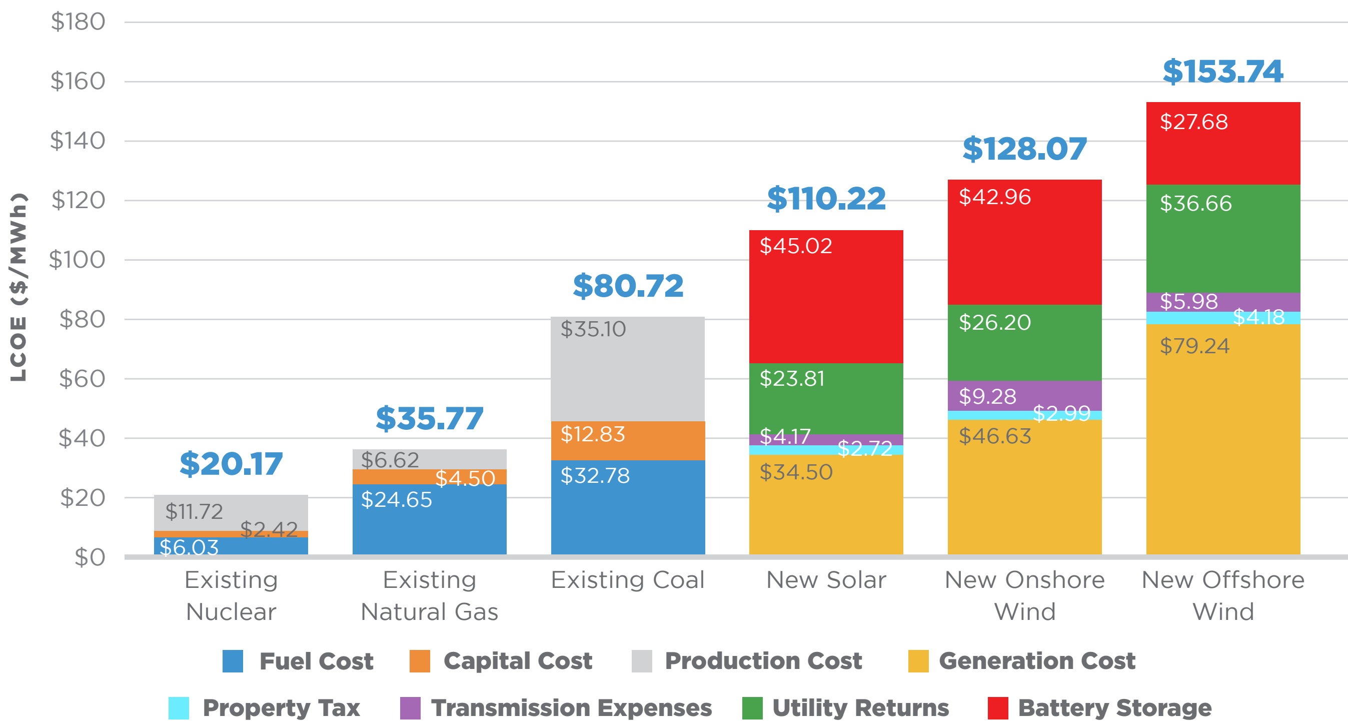
To compensate for the different reliability attributes for dispatchable and non-dispatchable resources, this analysis includes the additional costs that are incurred from building intermittent renewable resources, including costs for transmission, utility profits, property taxes, and battery storage used for providing electricity during periods of low wind and solar output. These costs are then compared to the LCOE of existing nuclear, natural gas, and coal plants operating in Virginia (See Figure 12).

Data from the Federal Energy Regulatory Commission (FERC) show Virginia's nuclear plants are some of the lowest-cost sources of electricity in the state, generating electricity at a cost of \$20 per MWh. Virginia's natural gas plants generated electricity for \$36 per MWh, and coal plants in the Commonwealth generated electricity for \$81 per MWh, on average.

Costs are higher for wind and solar facilities because unlike traditional fossil fuel plants and nuclear plants, grids powered with large concentrations of intermittent wind and solar projects require much more transmission than systems consisting largely of dispatchable power systems.

FIGURE 12

LCOE: Existing Thermal Power Plants vs. New Renewable Facilities for VCEA Compliance



New offshore wind is the most expensive form of new energy built under the VCEA. Once costs such as property taxes, transmission, utility returns, and battery storage costs are accounted for, new offshore wind costs $154 per MWh, new onshore wind costs $128 per MWh, and new solar costs $110 per MWh.

Wind and solar advocates often cite Lazard's LCOE analysis to argue that wind and solar are the lowest cost forms of energy. However, Lazard does not incorporate costs of providing backup electricity with natural gas, coal, or battery storage when the wind is not blowing or the sun is not shining; transmission costs, property taxes, or utility profits. Therefore, Lazard's cost estimates are not an estimate of the total cost of electricity that will be paid by consumers but rather a small piece of a much larger puzzle.[26]

These grids also require massive amounts of battery storage to provide reliable "backup" electricity when the wind is not blowing or the sun is not shining. *The cost of battery storage in the graph above can be thought of a levelized cost of intermittency, or unreliability*. Furthermore, large quantities of batteries also require electric companies to build additional wind and solar installations to charge the batteries during windy and sunny periods for use later.

It is important for the reader to understand that the cost of "backup" power increases dramatically as the amount of reliable power plants, such as nuclear, natural gas, or coal on the electric grid is reduced because the amount of wind, solar, and battery storage must be "overbuilt" to account for the intermittency of wind and solar, which is why the VCEA scenario has an installed capacity of 105,000 MW, and the RRS has a capacity of 31,200 MW. ■

Section V: Implications for Reliability

In addition to making electricity more expensive for Virginia families and businesses, the VCEA will also undermine the reliability of the Commonwealth's electric grid by making it more reliant on weather-dependent energy sources and imports of electricity from neighboring states. In contrast, the RRS makes the Virginia electric grid more resilient over time.

Unfortunately, the VCEA is the exact same energy strategy that California has employed for the last two decades, and the results have been electricity shortages.

California: An Example to Avoid

In August of 2020, the state of California experienced blackouts during a regional heatwave. Electricity demand surged in the evening hours as Californians sought to keep cool by turning up their air conditioning. [27] However, electric companies were unable to supply the desired power because of low wind speeds, and the sun was setting, reducing the output of solar panels in the Golden State.[28]

Several factors contributed to the rolling blackouts that occurred in California, but chief among them is the fact that California shuttered thousands of megawatts of reliable nuclear and natural gas plants from 2012 through 2020. During this time, California also became overly reliant upon weather-dependent renewable energy resources and on imports from neighboring states when electricity was needed most.

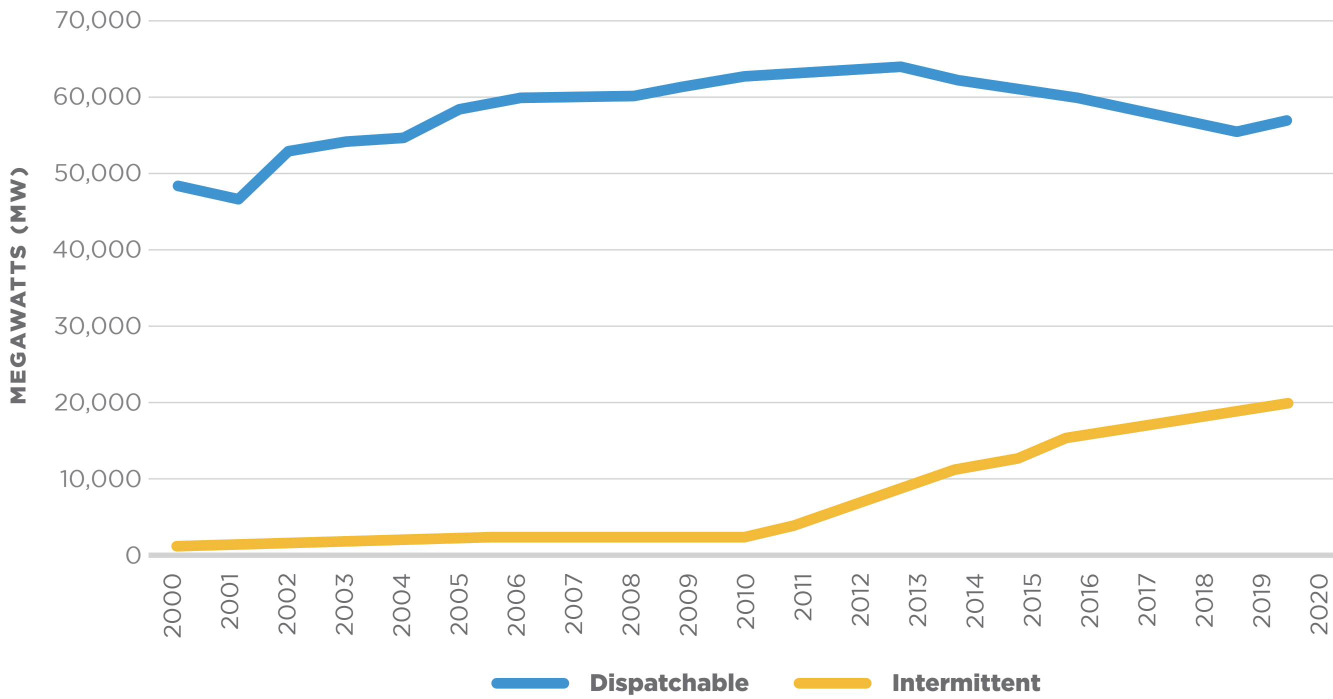
Figure 13 shows that the amount of dispatchable power plant capacity compared to intermittent power plant capacity in California from 2000 to 2020. Dispatchable power plants consist of power plants that can be turned on when needed and include coal, nuclear, natural gas, geothermal, hydroelectric, pumped storage, and wood-burning power plants. Intermittent power plants consist of wind turbines and solar panels.

U.S. Energy Information Administration data show California had more installed power plant capacity in 2020 than in any previous year.[29] However, the growth in capacity since 2012 was almost entirely due to a 13,166 MW increase in solar capacity. During this time, California reduced the amount of natural gas capacity on the grid by 4,595 MW, and nuclear capacity by 2,150 MW.[30]

California has attempted to keep the lights on despite shutting down reliable natural gas plants by increasing the quantity of electricity imported from other states. In fact, despite having more electricity generating capacity online in 2020 than in any previous year, 28.7 percent of all the electricity

FIGURE 13

Dispatchable Power Plant Capacity in California



California increased the amount of intermittent power plant capacity on its grid and decreased dispatchable capacity. From 2012 through 2020, the amount of intermittent capacity increased by 13,600 MW while dispatchable capacity fell by 6,600 MW.

consumed in California was imported that year.[31]

The problem with California-styled energy policy is that eventually, you run out of other people's electricity. During the regional heatwave, Nevada and Arizona did not have enough power to spare for California, resulting in rolling blackouts. Virginia policymakers would be wise to learn from California's mistakes, rather than replicate them.

How the VCEA "California's" Virginia's Electric Grid

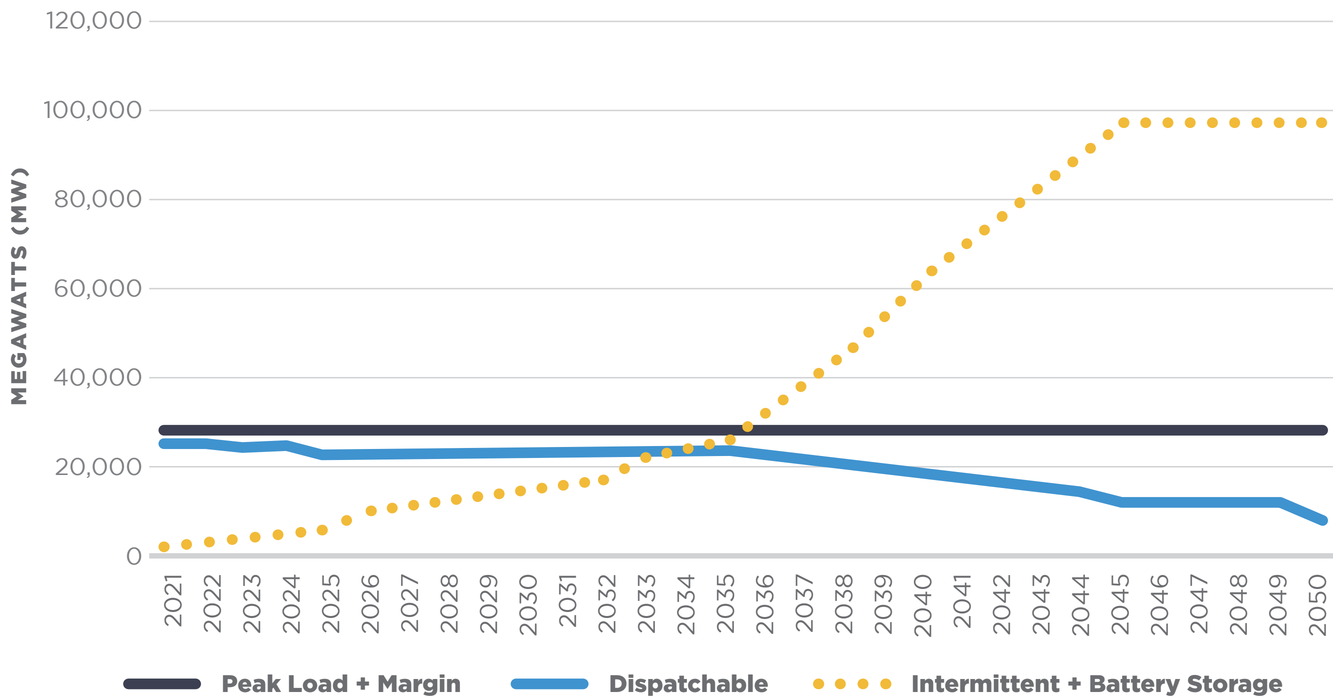
Electric companies will need to build 80,000 MW of new capacity under the VCEA, but California has demonstrated that adding more solar, wind, and battery storage while closing down natural gas facilities does not necessarily translate into a reliable electric grid.

The black line in Figure 14 shows the peak electricity demand in Virginia and the amount of dispatchable and intermittent power plant capacity online in the Commonwealth from 2021 through 2050 under the VCEA. In this case, dispatchable power plants consist of coal, nuclear, natural gas, hydroelectric, pumped storage, and biomass-burning power plants. Intermittent power plants consist of onshore wind turbines, offshore wind turbines, solar panels, and battery storage facilities.

In 2021, Virginia is able to meet 93 percent of its peak load using dispatchable, in-state sources of electricity. This falls to 84 percent by 2035, and 28

FIGURE 14

Dispatchable Capacity in Virginia for VCEA Compliance



The amount of dispatchable power plant capacity in Virginia decreases under the VCEA while intermittent capacity increases substantially.

percent by 2050 as the Commonwealth's biomass, coal, and natural gas facilities are shuttered.

Although battery storage is a dispatchable technology, it is treated as an intermittent resource in this analysis because the battery storage devices would be charged by weather-dependent wind and solar resources. This is potentially problematic because based on our hourly load forecast models, there were multiple 15+ hour time frames where the combined capacity of wind and solar – totaling nearly 64,000 MW of installed capacity in Virginia in 2050 – produced less than 10 percent of its potential output. At times, they produced no electricity at all.

In one of these instances, wind and solar produced less than 10 percent of their potential for an 18-hour stretch, which came within a 64-hour period where the production of combined wind and solar facilities was 11.6 percent of their potential output and the highest it reached was 29 percent.

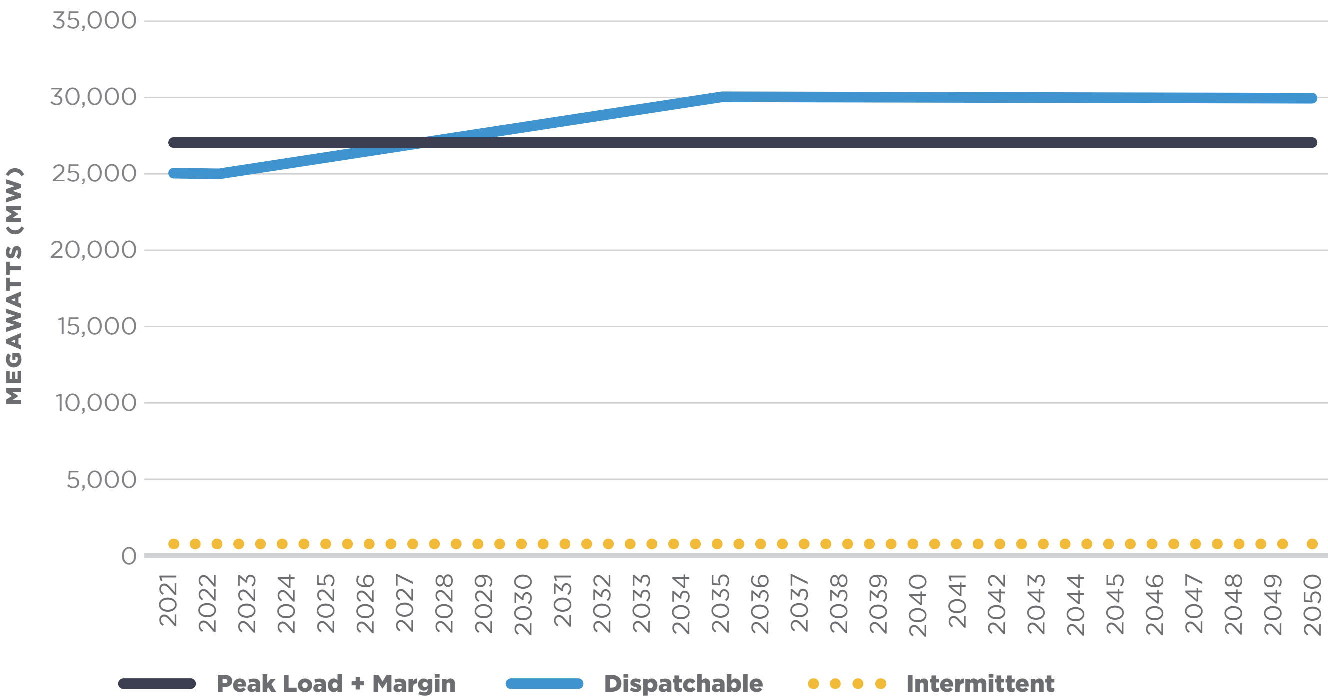
Our hourly load forecast models were based on wind and solar generation for 2019.[32] If generation from these sources is lower in the future, it would potentially result in rolling blackouts or brownouts if electricity imports are not available to meet demand.

RRS

While the VCEA will make Virginia's electric grid more reliant upon unreliable sources of electricity generation, the RRS will increase the amount of dispatchable capacity in the state. Figure 15 shows there is enough dispatchable capacity on the Virginia electric grid to meet peak electricity demand, with a 15 percent margin of safety. ■

FIGURE 15

RRS Dispatchable vs. Intermittent Capacity



The RRS would bolster the reliability of Virginia's electric grid by reducing the need for imported electricity to meet peak demand.

Section VI: High Energy Costs Harm Virginia Families and the Economy

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

Spending hundreds of billions of dollars on new solar panels, onshore wind turbines, offshore wind turbines, transmission lines, and battery storage facilities will cause significant increases in electricity costs for each Virginia electricity customer.

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

As discussed earlier in this report, the VCEA will result in additional costs of $1,770 per customer per year through 2050, whereas the RRS would increase costs by $136 per customer per year.[33] Rising electricity costs mean Virginians will have less money for rent or mortgage payments, nutritious food for their families, healthcare for their children, or savings for rainy day funds.

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

Data from the U.S. Department of Energy's Low-Income Energy Assistance Data (LEAD) program show a significant number of Virginia residents already spend between 6 and 8 percent of their income on energy (See Figure 16).[34]

By increasing energy costs on Virginia consumers, the VCEA will increase the cost of essential services like refrigerating food and medicine, home heating, and air conditioning. As a result, the policy is incredibly regressive because those with the least will lose the most.

Broader Economic Impacts

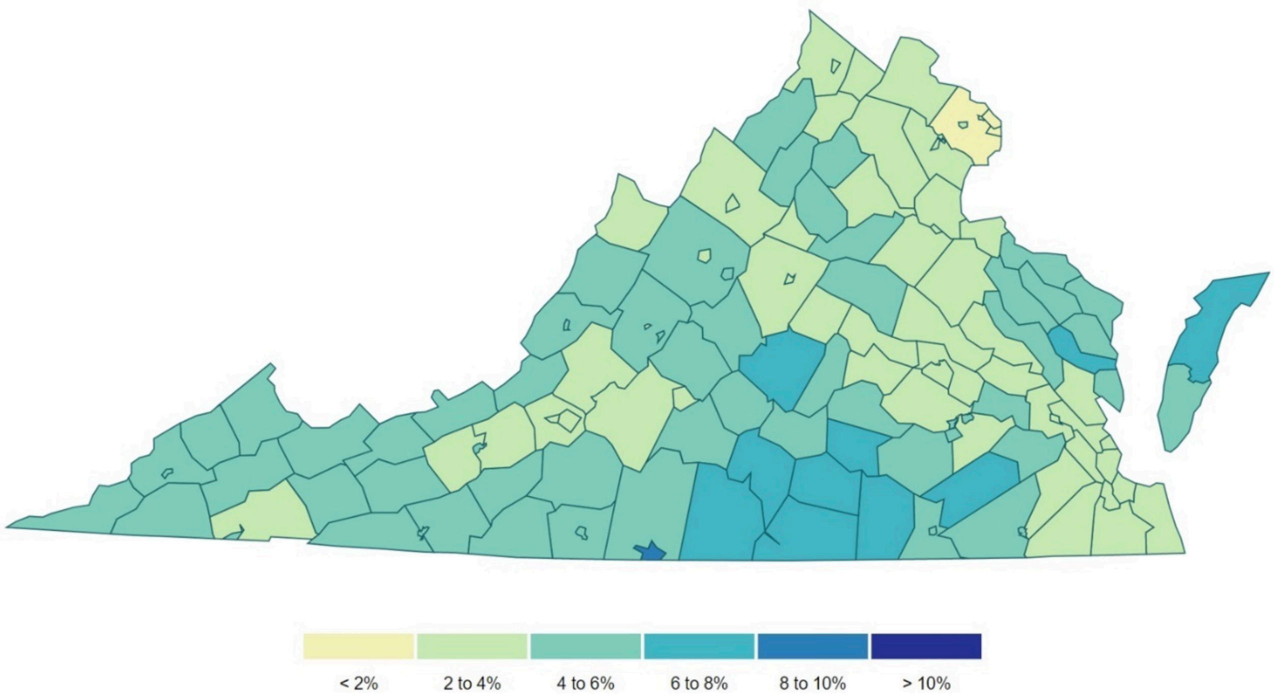
Increasing the cost of electricity in Virginia will harm the state's economy in two primary ways.

One, it will reduce the amount of household income available to families to spend on goods and services, therefore reducing demand in other sectors of the economy. For example, the extra money a family spends on electricity may mean fewer

FIGURE 16

Average Energy Burden (% Income) in Virginia

Federal data show Virginia households living in several counties already pay between 6 and 8 percent of their income for energy bills.



meals at local restaurants or delayed repairs to a home or automobile.

Two, it will increase the costs of healthcare, education, food, and durable goods, because electricity is the invisible ingredient in everything. Rising electricity costs force businesses to raise the prices of the goods and services they offer.

High electricity costs also jeopardize jobs in energy-intensive industries like manufacturing which compete in a global marketplace. Rising prices also threaten the future of high-tech jobs in the Commonwealth, such as those at data centers, which require enormous quantities of reliable electricity to power and cool computers. ■

Conclusion

Compliance with the VCEA in Virginia will cost at least $203 billion through 2050. This is the equivalent of $1,770 per electricity customer per year through this timeframe. In comparison, the RRS will increase costs for consumers by $15.5 billion through 2050 and represents a savings of $188 billion compared to implementing the VCEA while bolstering grid reliability.

VCEA costs are driven by a massive buildout of solar panels, onshore wind turbines, offshore wind turbines, and transmission lines, in addition to the costs associated with higher property taxes, utility profits, and the cost of building battery storage facilities to provide power when the sun is not shining, or the wind is not blowing. RRS costs are driven by nuclear plant refurbishing and building new natural gas plants in the Commonwealth to reduce the need for imported electricity.

Acknowledgements

We thank Brent Bennett, Ph.D. of the Texas Public Policy Foundation for his assistance on this report, particularly with respect to determining the capacity of battery storage capacity necessary to meet VCEA requirements. We also thank Steve Haner of the Thomas Jefferson Institute for his help contacting the Virginia State Corporation Commission (SCC) and Dominion Energy for hourly generation data for the Coastal Virginia Offshore Wind project. Unfortunately, the SCC did not have this data, and Dominion Energy declined to provide the requested information. ■

Appendix

Annual Average Additional Cost Per Customer

The annual average additional cost per customer was calculated by dividing the average yearly expense of VCEA and RRS compliance by the number of electricity customers in Virginia.[35]

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

Annual Average Cost Per Rate Class Customer

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

For example, electricity prices for residential, commercial, and industrial rate classes in Virginia were 12.03, 7.63, and 6.28 cents per kwh in 2019, respectively. Based on general electricity prices 9.16 cents per kwh, residential, commercial, and industrial rates had rate factors of 1.31, .83, and .69, respectively. This means that, for example, residential customers have historically seen electricity price 31 percent above general rates. This model continues these rate factors to asses rate impacts for each rate class.

Time Horizon Studied

This analysis studies the impact of the VCEA and RRS on electricity prices from 2021 to 2050 to determine the cost of compliance during the implementation of the renewable energy mandates.

However, it should be noted that this time horizon will necessarily exclude many of the costs associated with complying with the VCEA because power plants are large investments, like houses.

Like a mortgage, electricity customers pay off the cost of the plant each year, meaning decisions made today will affect the cost of electricity for decades to come. As such, the total cost highlighted by this study is not the "all-in" cost of compliance, but rather the total cost that ratepayers would pay off through 2050.

Electricity Generation Assumptions

Electricity generation is kept constant at 122 million MWh throughout the course of this model run based on electricity generation data for Dominion Energy from the Energy Information Administration's (EIA) electricity monitor. This data was then extrapolated for the rest of Virginia by increasing electricity load by 19 percent – which is the remainder of Virginia that Dominion Energy does not serve.

This assumption is made for two reasons. One, load-growth projections are subject to a wide variety of assumptions, such as energy efficiency measures that reduce electricity demand. Furthermore, electric vehicle adoption and the electrification of other sectors of the economy are difficult to predict accurately.

Two, this analysis is intended to show the difference in cost between operating the electric system in Virginia today compared to what it would cost to generate the same number of MWhs of electricity under the VCEA and RRS. Doing this is especially insightful when new capacity is not being built to meet expected growth in electricity demand but rather to comply with government mandates like the VCEA.

Plant Construction by Type

Our model uses the Dominion Energy Integrated Resource Plan and Appalachian Power Company's Renewable Portfolio Standard (RPS) plan as templates for our analysis, specifically as it pertains to dates for coal plant retirements and for capacity additions of offshore wind, onshore wind, solar, and battery storage.[36][37]

This methodology is employed through 2045, and the resource additions made by Dominion after 2035 are prorated for the rest of Virginian electricity suppliers to account for electricity consumption throughout the rest of the Commonwealth.

However, plans submitted by Dominion Energy and Appalachian Power Company do not satisfy the carbon-free requirements of the VCEA extending out to 2050. In order to meet full compliance, this analysis makes capacity additions for offshore and onshore wind, solar, and battery storage beyond the scope of the IRP and RPS plans submitted by the two utilities from 2035 to 2045.

Load Modifying Resources

Our model does not allow for load modification. Instead, battery capacity is built to provide enough firm, dispatchable capacity to supply Virginia's electricity needs under the VCEA at all times based on historical generation.[38] However, our analysis is based on one year's worth of solar, onshore wind, and solar data. Yearly fluctuations in these generating resources could lead to electricity shortfalls.

Transmission

Offshore wind transmission costs were assumed to be $1.4 billion per 2,600 MW of installed capacity, or $538,461 per MW, consistent with reports of the cost of the Dominion Coastal Virginia Offshore Wind project.[39]

These numbers are generally consistent with a recent PJM study that found it could cost $6.4 billion to incorporate 15,600 MW of offshore wind capacity or $410,000 per MW of installed capacity.[40] It should be noted that Dominion upwardly revised the estimated project cost of its offshore wind facility after this study was published due to increases in costs that have affected many sectors of the American economy.

For onshore transmission costs, distance per mile costs were estimated from the 2021 Midcontinent Independent Systems Operator Transmission Cost Estimation Guide.[41] This analysis uses the MISO-wide average cost estimates of double circuit 115kv lines for any lines less than 230kv, and the MISO-wide average cost estimates for double circuit 230kv for any lines above 230kv.

Utility Returns

The amount of profit a utility makes on capital assets is called the Rate of Return (RoR) on the Rate Base.

For the purposes of our study, the capital structure used is that of Dominion Energy: 47.9 percent debt and 52.1 percent equity, a return on debt of 4.38 percent, and return on equity of 9.35 percent.[42]

Property Taxes

Additional property tax payments for utilities were calculated to be 0.795 percent of the undepreciated cost of generation assets installed to comply with the VCEA, based on Virginia property tax rate classes established Virginia Code 58.1 Chapter 26. Subsection C:

"Notwithstanding any of the foregoing provisions, generating equipment that is reported to the Commission by electric suppliers shall be taxed at a rate determined by the locality but shall not exceed the real estate rate applicable in the respective localities. However, generating equipment that is reported to the Commission by electric suppliers utilizing wind turbines, for which an initial interconnection request form has been filed with an electric utility or a regional transmission organization on or before July 1, 2020, may be taxed by the locality at a rate that exceeds the real estate rate by up to $0.20 per $100 of assessed value. All other generating equipment that is reported to the Commission by electric suppliers utilizing wind turbines may be taxed by the locality at a rate that exceeds the real estate rate but that does not exceed the general class of personal property tax rate applicable in the respective localities."[43]

For this analysis, American Experiment averaged the real estate tax rates of each Virginia county and applied them to all new electricity assets in the state.

Unit Lifespans

Different power plant types have different useful lifespans. According to the National Renewable Energy Laboratory (NREL), wind turbines have a useful life of 20 years, and solar panels have a useful life of 25 to 40 years.[44] Our analysis uses a 25-year lifespan for solar because this is the typical warranty period for solar panels. Wind, solar, and battery storage facilities are rebuilt, or "repowered," in our model after reaching the end of their useful lifespans.

Dominion Energy estimates their offshore wind facilities will last for 30 years.[45] However, observed lifespans of offshore wind facilities in Europe have been 14 to 24 years, with significant capacity factor reductions as they age.[46] Our study attributes a 20-year lifespan to acknowledge the range of lifespans observed in Europe and to address the need to maintain capacity factors above 40 percent to ensure reliability.

Levelized Cost of Energy

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

LCOE values for existing energy sources were derived from FERC Form 1 data submitted by Appalachian Power Company, Dominion Energy, and Old Dominion Energy. Data utilized in FERC Form 1 filings include capacity factors, capital costs, and production expenses. These LCOE values are inserted into the model and adjusted annually based on annual capacity factors for existing resources for the rest of Virginia. This method is used because while FERC Form 1 data is the best available source for LCOE cost assumptions for existing resources, it does not account for all power sources in Virginia. In this way, this report adjusts LCOE values for the three largest utility companies in Virginia for the rest of the power plants within the Commonwealth.

For new LCOE values, this report calculated levelized transmission, property tax, and utility profit expenses resulting from each new power source over the course of the facility's useful life and according to the additional capacity in MWs installed and generation in MWhs of that given source. Capacity installed is used to determine capital costs and additional expenses (transmission, property taxes, and utility profits) of each electricity source over the course of its useful lifespan.[47]

For example, a 200 MW combustion turbine natural gas facility would cost roughly $145 million based on our capital cost assumptions. This plant would also accumulate an expense of $156 million in utility profits and $18 million in property taxes over the course of the natural gas plant's 30-year lifespan, which are both paid for through electricity rates.[48]

We then calculated the levelized cost of these expenses over the number of MWhs that each technology would produce in this lifespan by dividing the costs by the MWhs of electricity generated.

For example, the same 200 MW combustion turbine natural gas facility would generate roughly 5.3 million megawatt-hours of electricity if it ran at a constant 10 percent capacity factor over its 30-year lifespan. Therefore, the levelized cost of utility profit expenses over 30 years would be an extra $29.72 per MWh, and property taxes would be an extra $3.39 per MWh.[49]

Levelized Cost of Intermittency (i.e. Battery Storage Costs On LCOE Values)

This report also calculated the levelized cost of intermittency for offshore wind and solar energy resulting from having to build backup generation facilities to cover for windless or sunny days. This report assumed backup generation assets to be battery storage facilities in order to comply with the VCEAs requirement of a zero-carbon future, which naturally excludes natural gas peaker plants.

Similar to levelized transmission, property tax, and utility profit expenses, this calculation was based on battery storage capacity installations under the VCEA, which are guided by resource plans filed by Dominion Energy and Appalachian Power.

We calculated the cost of intermittency by determining the total cost of operating battery storage resources during the time horizon of the model. These costs are then attributed to the LCOE values of wind and solar by dividing the cost of battery storage by the generation of new wind and solar facilities (capacity-weighted). In this way, the levelized cost of intermittency allows for a more equal comparison between non-dispatchable energy sources like wind and solar facilities, which require backup generation to maintain reliability, and dispatchable energy sources like coal, natural gas, and nuclear facilities that do not require backup generation.

To understand why intermittency costs are required, Figure 10 shows the generation mix by source during the hypothetical week of January 30, 2050, through February 5, 2050. Low generation from wind and solar resources necessitate the use of battery storage to meet electricity demand. Because wind and solar cannot offer stand-alone reliability, the cost of battery storage must be attributed to these resources in order to accurately convey the true cost of using them.

Hourly Load, Capacity Factors, and Peak Demand Assumptions

Hourly load shapes were determined using EIA electricity monitor data for Dominion Energy in 2019 and extrapolating it for the rest of Virginia.[50] This is the best available data for hourly load shape profiles for the state of Virginia.

Capacity factors used for onshore wind and solar facilities were determined by using EIA electricity monitor data for PJM (the regional electric grid operator for Virginia) in 2019.[51] This was the best available data for wind and solar hourly capacity factors in the area. For offshore wind, this analysis used available hourly data for offshore wind facilities in the United Kingdom (U.K.) in 2019 that are in areas with similar wind speed and with similar capacity factors as those expected at Dominion's offshore wind facilities.[52] UK data are used because the Virginia State Corporation Commission does not have hourly-generation data for the 12 MW of operational offshore wind at the Coastal Virginia Offshore Wind facility, and Dominion Energy did not respond to requests made by Steve Haner of the Thomas Jefferson Institute for the hourly data.

In the absence of publicly available hourly load shapes for offshore wind facilities in the United States, this was the best available data for hourly load profiles for offshore wind.

The peak demand for Virginia is estimated to be 23,500 MW based on 2019 Energy Information Administration (EIA) electricity monitor data for Dominion Energy and extrapolated for the rest of Virginia.[53] These are the best available data for peak demand in the state of Virginia.

These inputs were entered into a model provided by the Texas Public Policy Foundation to assess hourly load shapes, capacity shortfalls, and calculate storage capacity needs.

Solar Panel Degradation

Recent research has found that solar panels are degrading faster than previously anticipated.[54] This research found the degradation rate for utility-scale solar is 0.8 percent per year. Our study does not take this degradation into account.

Wind Turbine Degradation

Academic research from Lawrence Berkeley National Labs has found wind turbine performance declines smoothly with age until there is a large step-down in production after ten years.[55] This analysis does not incorporate declines in wind turbine performance.

Curtailment

Future curtailment values in the VCEA scenario will depend largely on transmission buildout and battery storage technologies. Annual curtailment levels for this model were estimated based on hourly load forecasts and were found to reach up to 24 percent of total wind and solar generation by the end of the model.

Annual Capacity Factors

Initial capacity factors for existing power facilities in 2021 are derived from the Energy Information Administration (EIA) state electricity profile of Virginia. These capacity factors were used because it is the best available data for capacity factors for each energy source in Virginia and change annually as resource portfolios change according to the given energy proposals.

Annual LCOE values for existing energy sources are based on annual capacity factors. For example, combined cycle natural gas power facilities in Virginia produced electricity for $35.77 per MWh at a 56 percent capacity factor according to the most recent FERC Form 1 data in 2019. This information is then inserted into the model and the model adjusts these LCOE values annually by dividing the fixed costs of each energy source by the annual capacity factors projected by the model. For example, in 2026, combined cycle natural gas plants produce electricity at 50 percent capacity factors in the VCEA scenario. Accordingly, LCOE values for combined cycle natural gas increase to $36.30 per MWh as the fixed costs of the plant are spread over fewer megawatt-hours sold.

Capacity factors for new energy sources were derived from projections by Dominion Energy. Solar capacity factors are assumed to be 21 percent based on estimates from Dominion Energy. Offshore wind capacity factors are assumed to be 43.3 percent, which is the capacity factor estimated by Dominion Energy for its offshore wind turbines in documents filed with the State Corporation Commission.[56]

Battery Storage Capacity Assumptions

Battery storage capacity was estimated based on the annual hourly load shape for the state of Virginia. The load shape was based on demand and generation data for 2019 through EIA's Hourly Electricity Grid Monitor for Dominion Energy, as explained in the "Hourly Load, Capacity Factors, and Peak Demand Assumptions" section.

Capital Costs

Total Overnight Capital cost estimates for new capacity for each generation technology are taken from Region 11 PJMW of the EIA's Electricity Market Module, Assumptions for the Annual Energy Outlook 2021.[57] National estimates are used for Variable Operations & Maintenance (O&M), Fixed O&M, and heat rates. These capital and operating costs are held constant throughout the model run.

Fuel Cost Assumptions

Fuel costs for existing natural gas and coal facilities were estimated using FERC Form 1 data for existing facilities. Fuel costs for new natural gas facilities were estimated using historical data provided by EIA's Electric Power Monthly.[58] All fuel costs were held constant throughout the model run.

Generation Costs

Generation costs are based on LCOE values for new and existing energy sources in the state of Virginia during the duration of the model (2021-2050). Generation costs represent the additional generation costs incurred above present-day costs of operating the grid.

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