Electricity Sales Forecast for Virginia: 2020-2050

William Shobe

ENERGY TRANSITION INITIATIVE
University of Virginia

UNIVERSITY of VIRGINIA | Weldon Cooper Center for Public Service

How will Virginia's electricity demand change through 2050?

This report begins with a discussion of recent trends in Virginia's electricity demand, including the effect of the coronavirus pandemic. Shobe then forecasts how Virginia's electricity demand will change through 2050, and discusses what will drive these changes. By far, the biggest contributor to these changes will be Virginia's increased data center use, which will drive a 38% increase in electricity sales by 2035. Even before considering the likely shift to electric vehicles, by 2050, electricity sales will increase by at least 56%. With electric vehicles included, electricity demand is likely to grow by more than 78% by 2050. Efforts to decarbonize the state's economy could result in even greater growth in electricity demand by 2050.

ABOUT THE AUTHOR

William Shobe is director of the Energy Transition Initiative at the Weldon Cooper Center for Public Service and a professor in the University of Virginia Batten School of Leadership and Public Policy.

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The Energy Transition Initiative (ETI) at the University of Virginia is dedicated to helping policy makers and other stakeholders navigate the challenges that come with shifting Virginia's energy systems away from fossil fuels and towards renewables and other zero-carbon sources. The ETI brings together experts from the Weldon Cooper Center, Virginia Solar Initiative, Virginia Clean Energy Project, and other units at the University of Virginia to research clean energy and sustainability practices; develop and maintain tools to help localities understand the process, costs, and benefits of adopting cleaner energy technologies; and engage directly with policymakers, energy providers, entrepreneurs, consumers, and other interested stakeholders to smooth the transition to a sustainable energy economy.

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EXECUTIVE SUMMARY

Electricity demand in Virginia can be expected to grow fairly rapidly between now and 2035. It will likely continue to grow even more quickly between 2035 and 2050 as the state accelerates its efforts to eliminate carbon emissions from the economy. Most of the shorter-term growth comes from increased sales to data centers in Virginia. In the longer-run, electric vehicles will become an increasingly important contributor to growth in electricity sales.

Electricity demand could rise even faster, depending on how quickly the state moves to decarbonize its energy economy. A more rapid decarbonization pathway would imply increased electricity use beyond what is included in the forecast presented here. That increased use will occur in transportation, industry and buildings.

The Covid-19 pandemic reduced Virginia electricity use in 2020 by a little over 2%. Large reductions in commercial and industrial demand were partially offset by increases in residential and data center sales. But total electricity sales have returned to the levels that were forecasted pre-Covid-19 by the end of the year.

Forecast summary

Most electricity use sectors in Virginia are not growing. Commercial and industrial demand for electricity in Virginia have both been falling for several years, and we can expect this to continue for some time. Residential sales are growing very slowly due to slower population growth and improved energy efficiency. The one growing sector of electricity demand in Virginia is sales to data centers. Data center use is growing nationally, and Virginia is a particularly attractive location for data center services. So data center electricity use is growing faster here than in most other states.

- Electricity use will increase substantially by 2035 and beyond.
- Growth in data centers will add substantially to electricity demand.
- Electric vehicles will soon become an important source of growth in electricity demand.
- Electricity use in 2020 fell 2.1% due to Covid-19 but will quickly return to its pre-pandemic trend.

In 2020, electricity sales amounted to 115,585 GWh. Given a continuation of recent experience, we estimate that annual electricity sales will grow between 17% (20,000 GWh) and 38% (44,000 GWh) from 2020 to 2035. Our mid-range estimate is for a 30% (32,800

GWh) increase in electricity sales by 2035. This increase does not include increased electric vehicle sales but rather is nearly all due to increased data center use. The lower growth figure of 17% assumes a rapid reduction in the rate of growth of data center sales, well-below what the state has experienced in the last several years.

To put this increased demand in context, in 2020, Virginia's four nuclear reactors generated approximately 30,000 GWh of electricity, about a quarter of all electricity generated in the state.

Data Centers Continued data center sales growth on their recent trajectory would imply *an increase in electricity use* of around 44,000 GWh/year between 2020 and 2035 which would imply a nearly 40% increase between 2020 and 2035. Recent experience notwithstanding, it seems unlikely that this rapid growth is sustainable over the next 30 years. We develop three alternative scenarios for data center sales growth. These imply a 71%, 56% and 22% growth respectively in electricity sales by 2050, all primarily due to growth in data center sales alone.

The actual sales data through 2020 do not show any "saturation" in the Virginia data center market. Some growth is likely to continue through the forecast period. Given this, we expect non-transportation electricity sales to be between 137,000 GWh/year and 162,000 GWh/year by 2035 and between 144,000 GWh/year and 198,000 GWh/year by 2050.
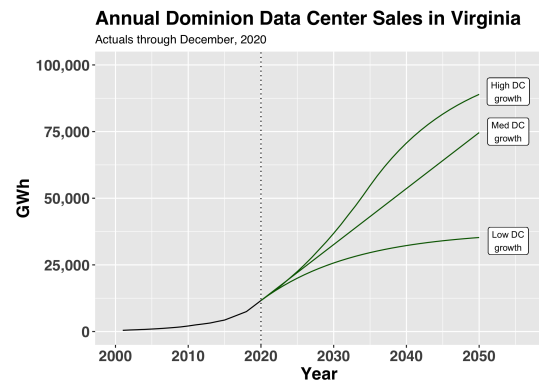

Figure 1

Electric Vehicles The increased use of EVs (light-duty cars and trucks) will add to these totals. Assuming that Virginia's new Zero Emission Vehicle standard is in place, we can expect to add about 5,000 GWh per year to these totals in 2035. Light-duty EVs will likely add between 25,000 and 32,000 GWh to demand by 2050, assuming that these vehicles are battery electric vehicles.[1]

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[1]Note: This forecast does not include some potentially important future considerations. Strong energy conservation policies, if effectively implemented, can reduce energy use substantially. Old buildings can be retrofitted for efficiency, and new buildings can be more efficient still. Much faster improvements in data center energy efficiency would lower the future growth path to some extent, although we should note that recent rapid growth in data center electricity use has occurred as the energy efficiency of data centers has improved. But some energy conservation measures, such as the use of heat pumps to replace natural gas in building heating and cooling, will increase electricity consumption, even as they reduce total energy use.

Covid-19 and Electricity Sales in 2020 The Covid-19 pandemic reduced total electricity sales in Virginia by 2.1% during 2020. An increase in sales to residences and to data centers compensated partially for significant and persistent drops in industrial and commercial sales.

After correcting for the effect of weather on residential electricity sales, it appears that the pandemic resulted in a 5.5% *increase* in residential electricity sales during the months of the pandemic. An 8% drop in April was followed by a 6.8% increase in residential electricity use in the last 8 months of 2020 compared to what was expected.

Weather Adjusted Forecast and Actuals
Actuals (circle), weather normed forecast (triangle)

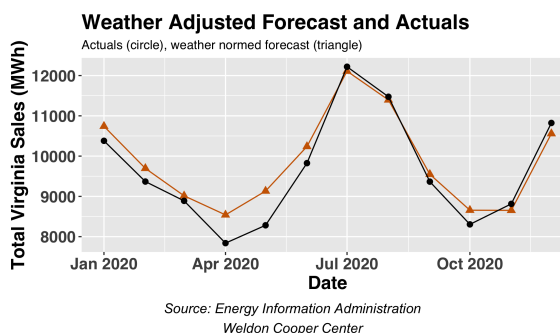*Source: Energy Information Administration*
Weldon Cooper Center

Figure 2

Commercial and industrial sales fell 20% during the heart of the pandemic compared to the weather adjusted forecast. Industrial sales had not recovered appreciably by the end of the year. Commercial sales ended the year with a 13% reduction for the April through December period. Data center sales increased 4% during the months of May through December, compared to what was otherwise expected.

Because its overall effect on electricity sales was small, the pandemic did not have a significant effect on the 2035 and 2050 demand forecasts. These remained remarkably stable after adding observations for 2020 to prior data.
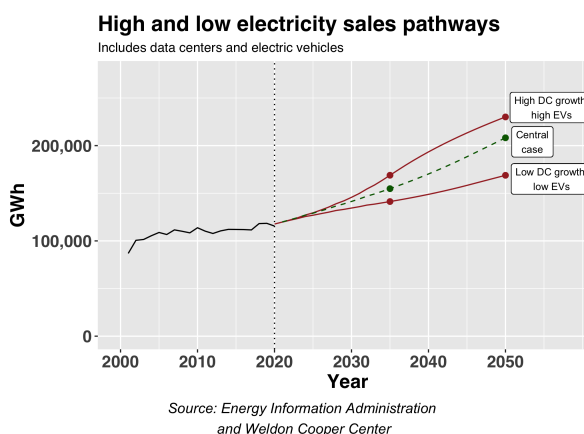
Overall Electricity Demand Forecast Figure 3 shows three key scenarios illustrating the mid-range forecast and the range in which sales are likely to fall between now and 2050. The mid-range forecast assumes continued, constant growth

High and low electricity sales pathways
Includes data centers and electric vehicles

Source: Energy Information Administration
and Weldon Cooper Center

Figure 3

in data center sales along with lower EV sales (resulting in a 75% share for battery electric vehicles). The high-range forecast combines high data center growth with high EV growth (achieving a 98% share for EVs). The low-range scenario combines low data center growth with low EV growth.

1 Introduction

Given the long investment lead-times for new generation and transmission infrastructure, there is great value in having forecasts of future electricity demand that are unbiased and have the lowest feasible prediction error. A forecast is unbiased if the errors in forecasting the future are not consistently too high or too low. Forecast error is just the inevitable difference between what we predict and what actually occurs. In planning for future, large-scale capital investments, both unbiasedness and low error are important for keeping the costs of electricity as low as possible.

Today, we have the added challenge that Virginia's energy system is entering a dramatic transition away from generation based on CO_2-emitting fossil fuels. And indeed, we expect that this transition away from fossil fuels will affect the transportation, building and industrial sectors as well as the electricity sector. The energy transition has important consequences for future electricity demand, since electrification of services now provided by oil and natural gas is an essential component of decarbonizing an economy.

It is our goal with this report to provide an independent and open forecast of future electricity sales in Virginia. We have worked to ensure that our forecast will prove to be unbiased and will keep the size of our forecast errors as low as possible. The data, statistical models and results are publicly available to facilitate a robust public discussion of future pathways of electricity demand in Virginia.

Forecasting future electricity demand is particularly challenging this year for four reasons. First, the covid pandemic has had a very significant effect on the makeup of electricity sales, although somewhat less so on total sales. We do not yet know which of these effects will last and which will not. In this report, we will make some effort to describe the likely effects of the pandemic on 2020 electricity sales. That said, it will take some time before we understand the full, long-term effects of the difficult year.

A second challenge in producing an accurate forecast is the rapid expansion of data center sales. Data center sales are rising at an increasing rate. We do not yet have a strong basis for predicting future data center electricity use. Data center electricity use has been accelerating and is on a trajectory to rival all other commercial electricity sales in the state by 2030. There is not a good reason to believe that this acceleration will stop in the near future, but there is great uncertainty about the years past 2030. Our forecast simply follows the historical pattern of data center sales growth, which results in a dramatic increase by the end of the forecast horizon. This is the single greatest source of uncertainty

in the later periods of the forecast horizon.

The third current challenge in estimating future demand is the coming transition to electric vehicles (EVs). While there is no doubt that EVs will represent a rapidly rising share of total vehicle sales in Virginia and elsewhere over the next 20 years, the pace of this transition is highly uncertain, as is the actual electricity use for powering the electric fleet. The current fleet of EVs is currently too small to have any measurable effect on electricity sales. So we cannot use the history of past sales as a helpful guide to future sales. We have not "forecasted" EV electricity use but rather have provided two scenarios that illustrate the likely magnitude of EV electricity sales, a slower and more rapid transition. The slower transition has about 75% EV light-duty cars and trucks by 2050. The more rapid transition reaches almost 100% EVs by 2050. Because of the great uncertainty about the technology pathway for long-haul freight transport, we have not included this sector in our analysis.

The fourth factor contributing to forecast uncertainty is the constantly changing policy environment. The Virginia Clean Economy Act included a number of provisions specifically designed to change the growth of energy use in Virginia. There are requirements for public utilities to engage in energy conservation activities, and considerable funds for energy conservation in low income housing are made available from the proceeds of selling emission allowances under the Regional Greenhouse Gas Initiative (RGGI). Half of the proceeds from the auctioning of emission allowances are to be used for weatherization of low-income housing. The proceeds from the RGGI auctions will add tens of millions of dollars to Virginia weatherization programs. It is far too early to tell what effect these efforts will have on actual energy use. The actual outcome from given energy conservation activities are notoriously hard to estimate accurately. We have not included any change in sales due to expanded energy conservation efforts in our forecast. We do not believe that this omission is large enough to cause a dramatic shift in our forecast. When reliable data becomes available on actual outcomes from conservation efforts, we will add this to future forecasts.

We will proceed as follows. We will review the historical data, including an assessment of the effects of the 2020 pandemic. Then we will discuss the methodology used in our forecast. Finally, we will present our actual forecast of electricity sales and some scenarios that illustrate the reasonable range of uncertainty.

2 Historical Data

2.1 Changes in Electricity Use and Sales Over Time

The level of electricity demand (or sales) at any point in time is a complicated function of population, consumer behavior, the weather, the stock of existing structures and equipment and the general level of economic activity. These determinants of present and future sales change at different rates and are subject to great uncertainty concerning their future evolution. Further complicating matters, the sensitivity of electricity sales to changes in the key demand drivers is itself subject to change.

Historical sales: Electricity demand grew quite rapidly throughout the 1980s and 1990s as Virginia experienced growth in its population and its economy. At the same time, increased use of lighting and electric appliances, along with electric space heating and air conditioning, resulted in rising sales per household.
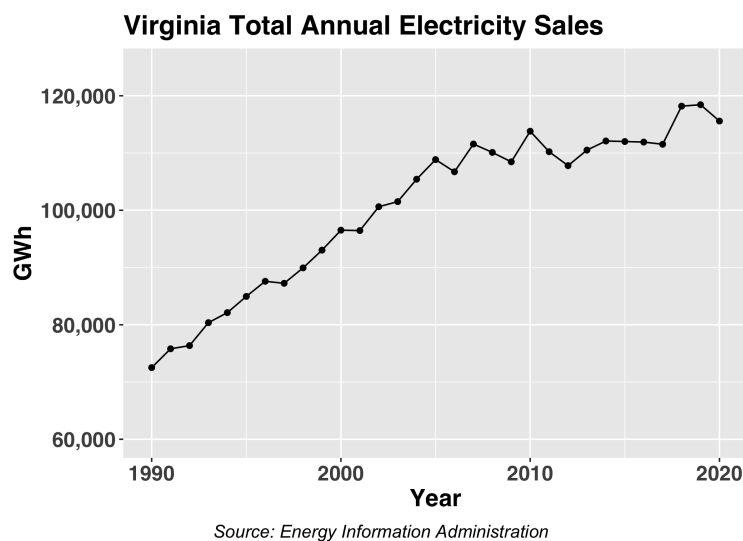

Source: Energy Information Administration

Figure 4

As shown in Figure 4, the earlier, rapid growth in electricity sales began to level off between 2005 and 2008. Until 2008, electricity sales growth was tightly linked to economic growth, and the rate of economic growth was a reliable predictor of electricity demand growth. This link was greatly attenuated following 2008. While this break in the growth trend occurred contemporaneously with the Great Recession, the reasons for the break go far beyond the recession; as we will show shortly, even as the economy recovered from the recession, electricity demand growth in the key demand sectors did not resume until quite

recently, and the reasons for the recent growth are quite different than for earlier periods of growth in sales.

Population growth: A number of factors appear to be responsible for this apparent break in the relationship between economic growth and demand growth. First, the population growth rate slowed, bringing with it a slowing in household formation (Figure 5). Population growth had been slowing before, but fell below one percent in 2013 reaching about 0.5% in 2018. The resulting decline in household formation greatly reduced potential growth in residential sales.

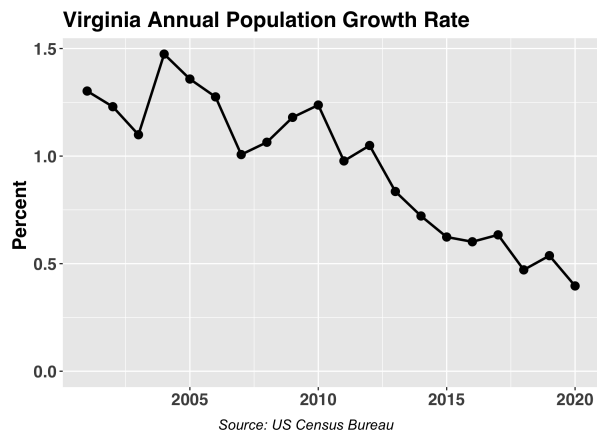**Virginia Annual Population Growth Rate**

Source: US Census Bureau

Figure 5

Efficiency improvements: Following the Great Recession, residential and commercial electricity sales remained flat even as economic activity began growing again. Increasing energy efficiency in lighting and space heating contributed to declining electricity use per household and per commercial establishment. More efficient lighting also contributed to reduced growth peak cooling demand. It will take years for the new lighting and space conditioning technologies to replace the large stock of equipment in existing buildings. Newer, more efficient technologies also reduce the increment to demand from each new household and each new commercial establishment. The combination of these factors makes it extremely unlikely that electricity sales to residences and commercial establishments will increase much in the forecast period.

Industrial demand peaked in the early 2000s, declining by about 30 percent since then.

Data center sales: The one sector where Virginia is experiencing robust demand growth is in data center services. Data center services are an increasingly important input to practically all other economic activity. [2] Starting around 2010, data center sales began to emerge as a significant factor in Virginia electricity sales growth. The annual increase in data center sales has increased markedly in recent years and is growing at an increasing rate. *Data center sales is the only significant current source of growth in electricity demand*

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[2] Virginia is an especially attractive location for server farms due to a quirk in the architecture of the Internet. A very significant fraction of all Internet traffic passes through Northern Virginia.

and will continue to be so until such time as electric vehicle sales increase substantially.

Figure 6 shows annual sales by end-use category for Virginia. Dominion Energy data center sales are shown as a separate category and the commercial sales category excludes Dominion's sales to data centers.[3] Residential and commercial sales have been remarkably close throughout the period covered by our data. The growth and subsequent flattening of these two largest components of sales is quite apparent, with the flattening occurring between 2005 and 2008, just prior to the Great Recession.

Annual Electricity Sales By Category

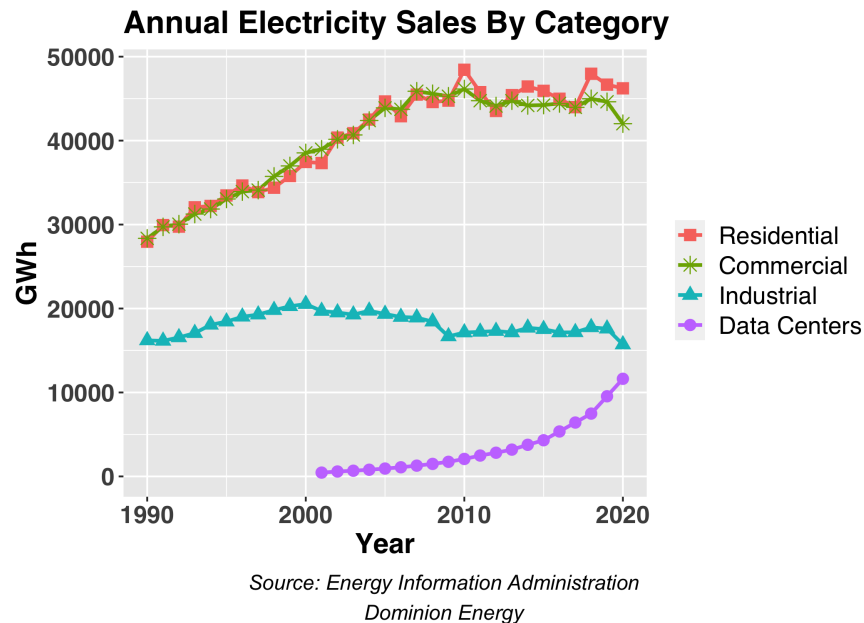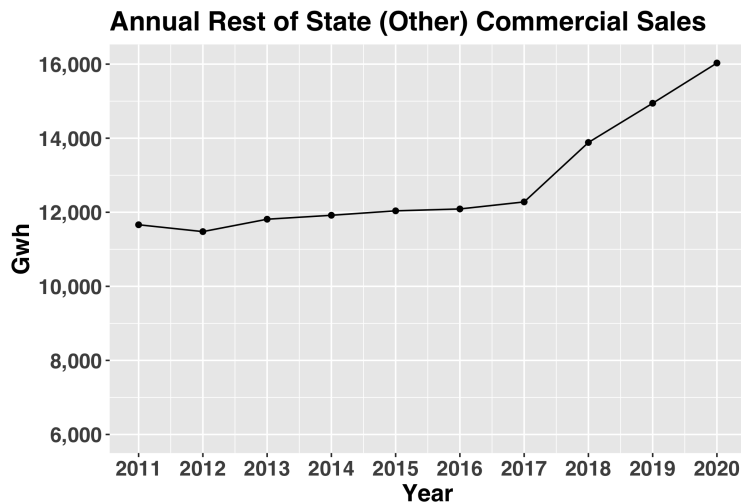Source: Energy Information Administration
Dominion Energy

Figure 6

Data center sales have been growing outside of Dominion's service territory as well. In particular, the Northern Virginia Electric Co-op (NOVEC) has experienced a strong recent up-tick in commercial electricity sales, which can largely be attributed to increased data center sales. Figure 7 shows historical commercial sales in a small group of Virginia electricity coops, the largest of which is NOVEC. Monthly commercial electricity sales have roughly doubled between 2018 and 2020 due primarily to growth in data center sales.

We expect that data centers will remain an important source of growth in electricity sales through our forecast horizon. Data center services are an input to the production for virtually all other goods produced by the economy. With the rapidly increasing use of data

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[3]Dominion Energy data center sales prior to 2010 were estimated by fitting data from 2010 to 2018 to a log-linear function and back-casting to 2001. The values from 2010 forward are courtesy of Dominion Energy. Since not all data center sales are in Dominion Energy's service territory, these figures actually underestimates statewide sales of electricity for data centers.

Annual Rest of State (Other) Commercial Sales

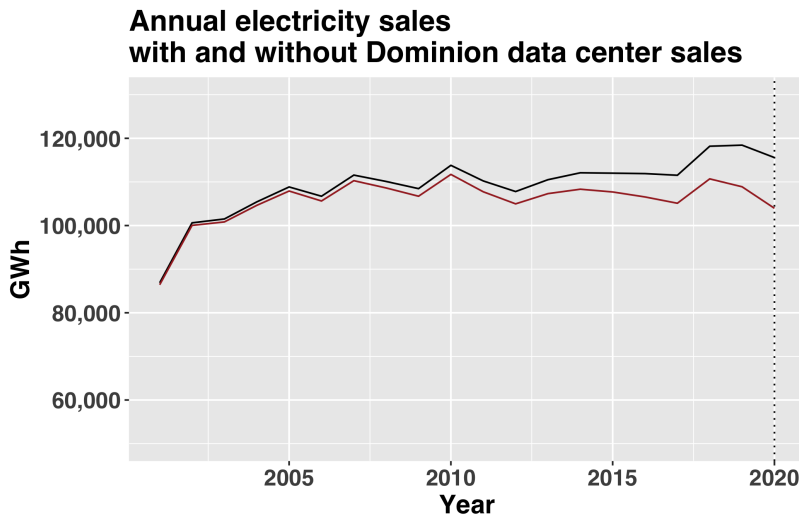

Source: Energy Information Administration

Figure 7

center services across the economy, there is no reason (*a priori* to believe that sales will 'saturate'). But there is a tension between two opposing factors that make future growth in data center sales highly uncertain.

First, data center technology has become much more energy-efficient in the past decade with prospects for continued improvement in the future. According to a 2016 study from Lawrence Berkeley National Laboratory, the rate of growth in data center energy use has fallen dramatically, even as the level of services have continued to rise (Shehabi et al., 2016).

On the other hand, Virginia's rapidly increasing data services sector reflects the continued attractiveness of the state as a location for data centers.

There is currently no way to predict with any accuracy what the net effect of these two trends will be over the forecast horizon. The currently available data continue to show an annual acceleration in the rate of growth of data center electricity sales. But we do not expect that this rapid acceleration can continue indefinitely. We will instead use two scenarios, high data center growth and moderate data center growth, to show the importance of this sector in determining the future path of electricity sales.

Electric vehicles: Electric vehicles are just beginning to play a role in Virginia electricity sales. In 2020, EVs were approaching 2 percent of car sales in the state. As of 2020, only 1/3 of 1 percent of vehicles in Virginia were fully electric with a combined monthly electricity use of under 6 GWh per month. Given recent announcements by major

**Annual electricity sales
with and without Dominion data center sales**

*Source: Energy Information Administration
and Dominion Energy*

Figure 8

auto manufacturers and given Virginia's recent adoption of the California zero emission vehicle standards, we can expect a rapid increase in electric vehicle adoption in Virginia. In order to incorporate this anticipated addition to future electricity sales, we will provide some illustrative scenarios of EV penetration in cars and light-duty trucks for incorporation in our forecast. [4]

2.1.1 Changes in patterns of energy use

The relationship between electricity sales and the drivers of those sales changes over time. Residential customers are using less electricity per household. So, even as we add households, sales will not rise by the same amount as before. Figure 9 shows how residential sales per customer have a clear downward trend for Dominion, APCO and the rest of the state. Electric appliances are becoming more efficient. Lighting is a telling case in point. The incandescent bulb is on the way out. LED fixtures use a fraction of the electricity and have the added benefit of reducing waste heat that adds to air conditioning loads in the summer.

2.1.2 Electricity intensity of the economy

Since almost all economic activity depends on electricity, then we would expect that an increase in economic activity would, other things equal, increase electricity sales. This is almost certainly the case, but other things are not equal. Improvements in efficiency cause a downward pressure on the

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[4]We discuss how these scenarios are constructed in our methodology appendix.

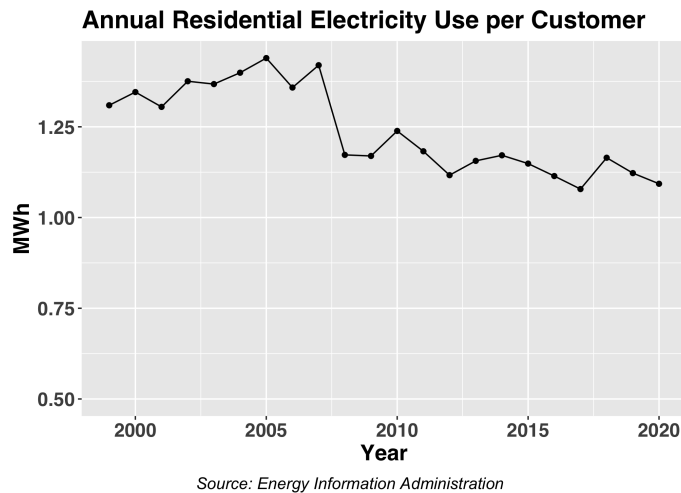**Annual Residential Electricity Use per Customer**

Figure 9

electricity intensity of the economy—defined as electricity use per dollar of gross state product (GSP). Whether total electricity sales rise or fall with economic activity depends on the balance between the rate of economic growth and the rate of efficiency improvement. In Virginia, since the year 2000, efficiency has been winning this race, at least until recently. Electricity use per unit of economic activity has been falling steadily, resulting in flat or declining sales in residences, commercial establishments and industry. The only exception has been data centers.

Figure 10 shows the long decline in electricity use relative to a widely used monthly index of economic activity that is closely correlated with state GSP. The energy intensity of Virginia's economy has fallen by around 20 percent since 2000 even with the rapid growth in data center services. This decline is important because GSP is often used by utilities in their models for forecasting future electricity sales. Since sales per dollar of GSP are falling, then linear forecasting models with fixed trend

Electricity Sales per Unit of Economic Activity

Activity measured by coincident index of economic activity

Figure 10

coefficients will be unstable and will provide very poor forecast performance because those models depend critically on there being a stable relationship between sales and GSP. We will discuss this point further when we discuss our forecasting methodology.
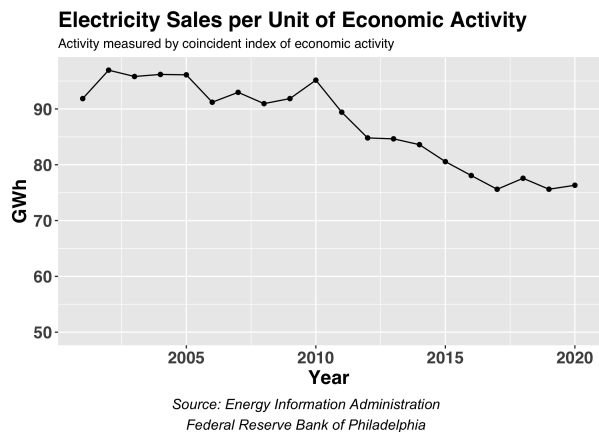
2.2 The effect of the corona virus pandemic

Of particular interest this past year is what effect the Covid-19 pandemic had on electricity demand in 2020 and what effect the pandemic might have on future electricity demand. To estimate the effect of the pandemic, we forecast electricity sales based only on data through the end of 2019. We then adjusted (or normalized) the forecast for the actual weather that occurred in 2020. This weather normalized forecast removes most of the effect of temperatures being higher or lower than normal for the given month.

Weather Adjusted Forecast and Actuals
Actuals (circle), weather normed forecast (triangle)

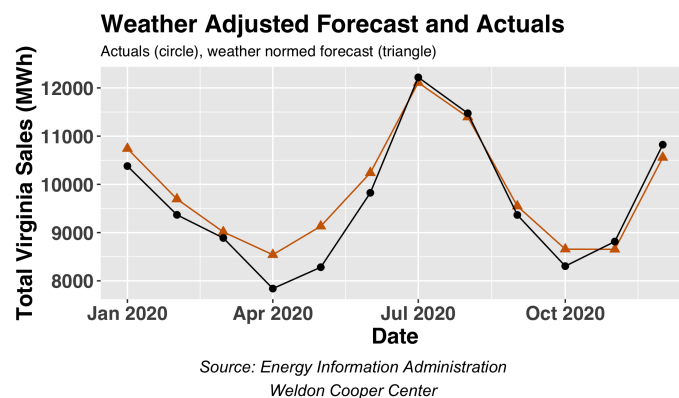*Source: Energy Information Administration*
Weldon Cooper Center

Figure 11

Overall, Virginia electricity sales were only 2.1% lower than what we would have expected to occur based on data only through December of 2019. This is in rather dramatic contrast to the nearly 7% drop in all energy sales across the U.S. in 2020 estimated by the Energy Information Administration. The largest part of the difference was the nearly 15% drop in transportation energy use nationally, which is generally direct use of gasoline rather than electricity.

One factor that complicates our ability to assign forecast errors to Covid-19 is the unexpectedly fast growth in data centers during the second half of 2020. Weather normalized data center sales were 4% higher than forecasted for the last six months of 2020. We do not yet know what fraction of this can be attributed to covid. What we do know is that data center sales by Dominion were well above what we forecasted using data through December of 2019. We also know that there was a significant increase in data center sales by NOVEC due to expected additions to data center capacity in 2020. Had data center sales not grown faster than expected, electricity sales in Virginia surely would have fallen considerably more in 2020.

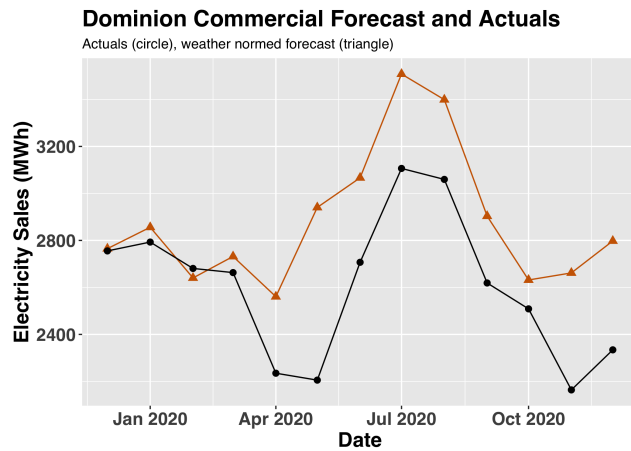The largest drops in electricity sales were in the industrial and commercial sectors.

Dominion Commercial Forecast and Actuals
Actuals (circle), weather normed forecast (triangle)

Figure 12

Dominion Industrial Forecast and Actuals
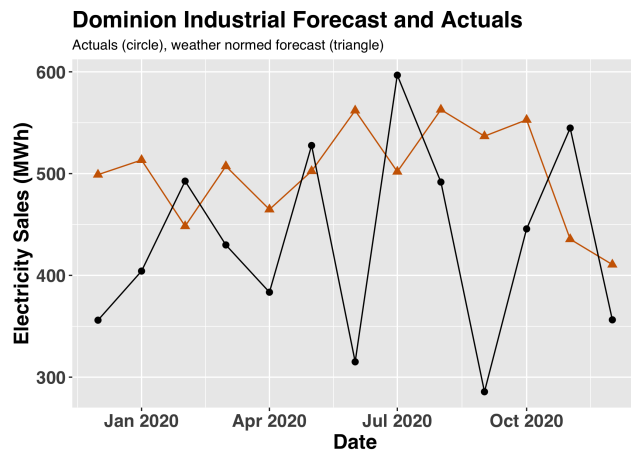Actuals (circle), weather normed forecast (triangle)

Figure 13

Both of these sectors had sales drops of about 20% during April, May and June compared to the normalized forecast error of the prior three-months. We use the prior three months as our benchmark to account for any pre-existing macroeconomic conditions that may have affected activity in those months. Industrial sales did not recover much in the second half of the year. Commercial sales were down by about 12% compared to what was forecasted for the April through December period. These sectors can be expected to recover somewhat in 2021, although the speed of this recovery is still highly speculative.

Residential sales fell slightly in April, but were higher than expected for the rest of the year except for October. The nearly 4.8% increase in residential sales almost certainly reflects a shift in work effort from offices (commercial) to home (residential).

Data center sales had a minor drop in April but rose substantially during the
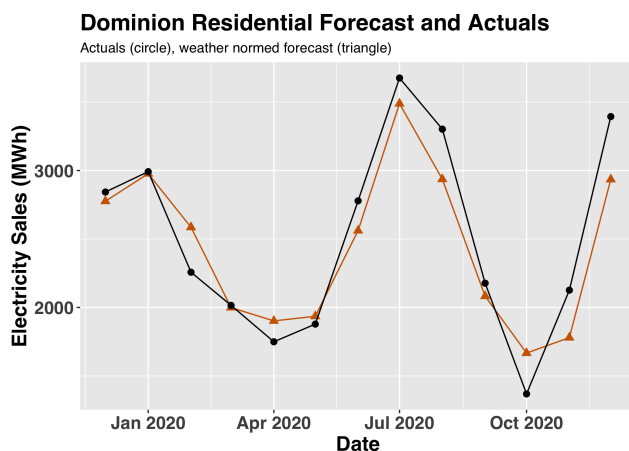
Dominion Residential Forecast and Actuals

Actuals (circle), weather normed forecast (triangle)

Figure 14

Dominion Data Center Forecast and Actuals

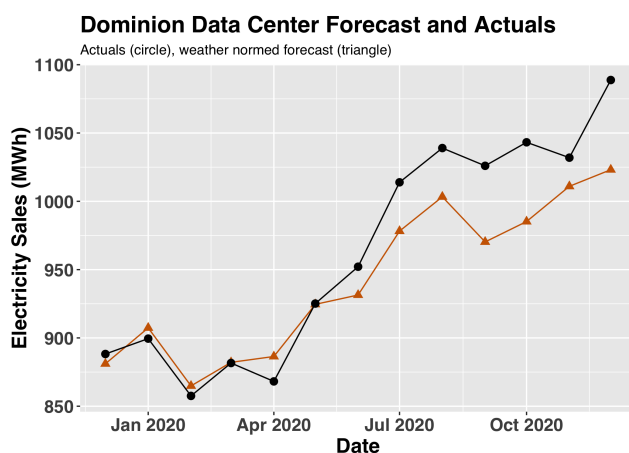Actuals (circle), weather normed forecast (triangle)

Figure 15

remainder of the year, rising by 4% above the normalized forecast. December data center sales were 6% above the normalized forecast. We cannot conclude that all of the growth in data center sales was due to covid. Data center sales have been rising rapidly over the last several years. Some of the unexpected increase in sales could be due to an acceleration in the expansion of data centers in Virginia above the trend forecast based on data through 2019. Likely, the increase in data center sales is due to some combination of covid effects and acceleration in the secular expansion of data center capacity.

In the end, because the increase in data center sales offset the reduced sales due to covid, the covid pandemic did not result in appreciable change in the forecast of electricity sales in Virginia. The forecast path using data through 2020 is nearly identical to the forecast using data only through 2019. There is a small reduction in sales between 2020 and 2030, but by 2030, the forecasts are identical. Electricity sales (not accounting for

the increased penetration of electric vehicles) reaches 165,000 MWh in 2035.

3   Forecast Results

We will divide our forecast of state energy sales into three main parts, Appalachian Power Company (APCO), Dominion Energy (Dominion) and Rest of State (ROS). In 2019, APCO sold about 13 percent of electricity sold to final consumers in Virginia. ROS sold just over 18 percent. Dominion Energy sold 69 percent of electricity to final consumers in Virginia (although it generates a larger share and sells some power to other distributors). Because of Dominion Energy's large share of electricity sales, we will pay additional attention on the determinants of potential changes in sales. We disaggregate Dominion's demand into four parts—residential, commercial, industrial and data centers—to understand in more detail the reasons for the recent trends in sales. Throughout this report, Dominion's commercial sales exclude data center sales, which are evaluated separately. For APCO and ROS, we will not break down sales into the component parts but will focus on total sales.
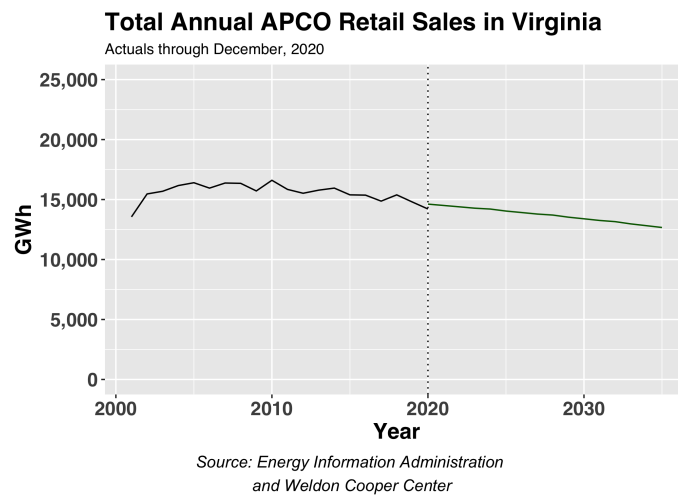

Total Annual APCO Retail Sales in Virginia
Actuals through December, 2020

*Source: Energy Information Administration
and Weldon Cooper Center*

Figure 16

3.1   APCO

APCO sales have, in recent years, settled into a slow decline due to efficiency improvements as well as declining population and industrial activity in its service region in Southwest Virginia. There is no compelling reason to expect a sharp turnaround in this trend.

3.2　Dominion Power

Total Annual Dominion Retail Sales in Virginia
Actuals through December, 2020

Source: Energy Information Administration
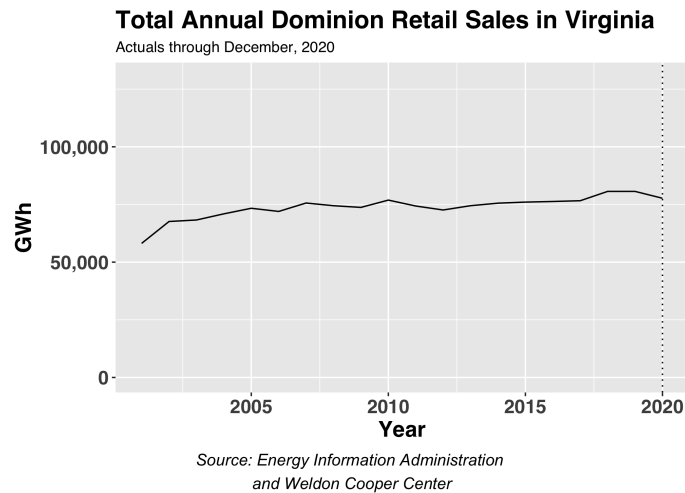and Weldon Cooper Center

Figure 17

A visual inspection of Dominion sales (Figure 22) clearly demonstrates that sales growth shifted down around 2008 and sales were flat even as the economy has resumed its growth after the Great Recession. Statistical tests confirm the clear break in trend around 2008. Sales growth clearly becomes less directly tied to the rate of economic growth for all sectors except data centers. Growth in data centers starts to have a significant effect only from 2018 on.[5]

We estimate four separate components of sales: residential, commercial (excluding data centers), industrial and data centers.

3.2.1　Residential
As we have already discussed, an important reason for flat residential sales is increased efficiency of appliances even as the number of electric devices in the home continues to increase. LED lighting, more efficient heat pumps and more efficient hot water heaters, washers and dryers all contribute to lower demand. Figure 9 shows how residential demand per customer has fallen in recent years. Since the stock of appliances takes many years to fully turn over, we can expect this existing downward pressure on residential demand to continue over the entire forecast horizon. We have not included any estimated effects of the energy conservation provisions of the Virginia Clean Economy Act, in excess of the historical trend of increased residential energy efficiency. The effectiveness

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[5]This means that giving equal weight to data before 2008 in the forecast estimation will lead to biased forecast errors. Our model adjusts for the changing relationship between economic activity and electricity sales. (See the technical appendix for more detail.)

Annual Dominion Residential Sales in Virginia

Actuals through December, 2020

Source: Energy Information Administration
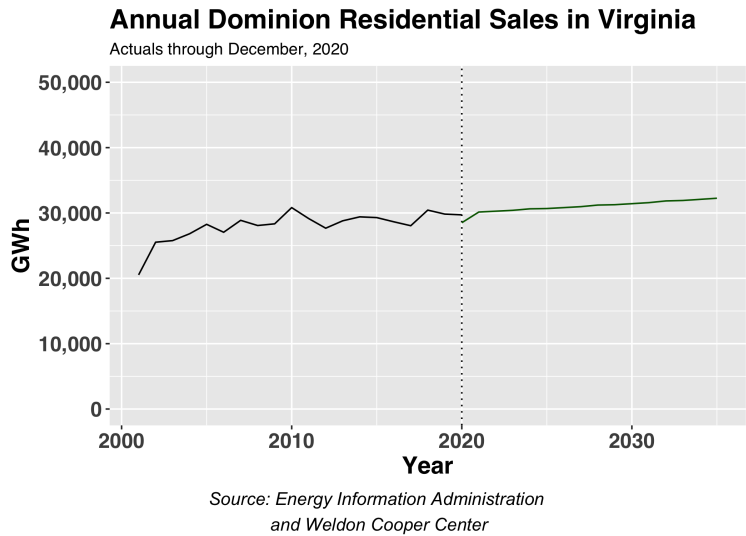and Weldon Cooper Center

Figure 18

of the VCEA provisions in increasing the rate of energy efficiency improvement, depend on how they are implemented. If the VCEA provisions are effective, they will tend to place additional downward pressure on residential sales for Dominion and elsewhere, but the size of this effect is purely speculative at this time.
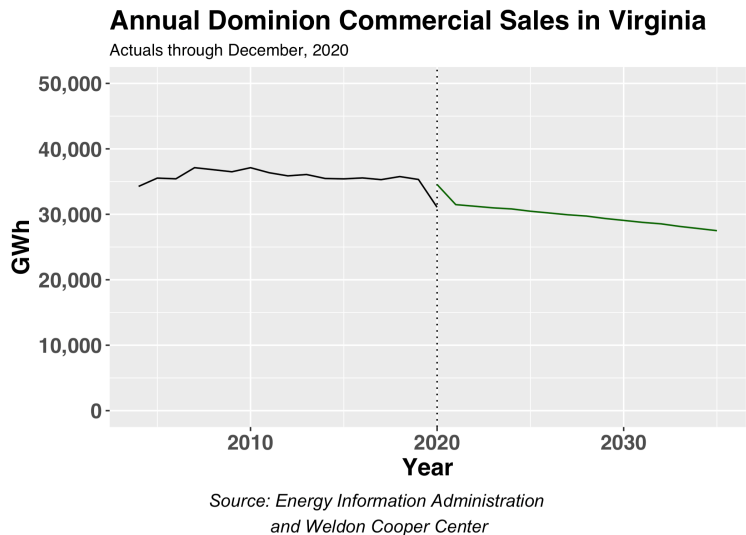
Annual Dominion Commercial Sales in Virginia

Actuals through December, 2020

Source: Energy Information Administration
and Weldon Cooper Center

Figure 19

3.2.2 Commercial (without data centers) We separate data center sales from commercial sales. As shown in Figure 19, commercial sales are flat or declining since around 2008. This is true even as Virginia's economic activity index has grown by 33%

since 2008. The commercial category includes public authority and street lighting sales. These are small and not showing any signs of growth. Increased efficiency of street lighting has resulted in declines in sales for this purpose as older lighting fixtures have been replaced with much more efficient LED fixtures. Overall commercial sales show no sign of trending upwards even in 2018 and 2019.
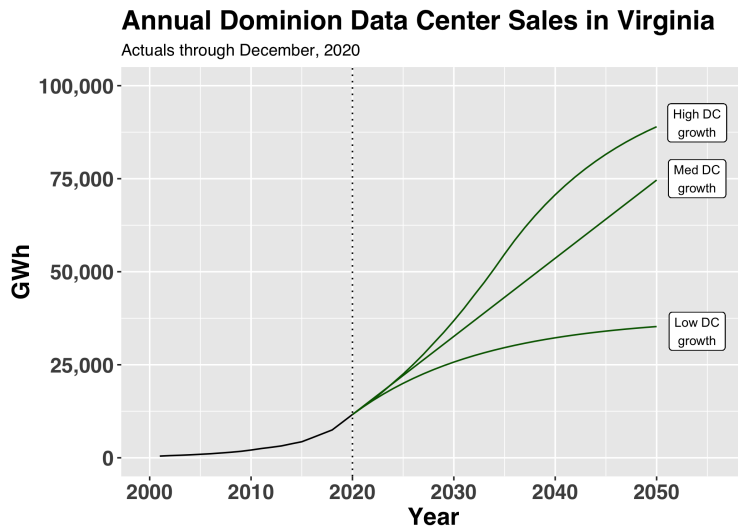
Annual Dominion Data Center Sales in Virginia
Actuals through December, 2020

Figure 20

3.2.3 Data centers
The one exception to flat sales in the state is in electricity sales to data centers. Dominion Energy's 2020 data center sales were 11,627 GWh. The growth in electricity demand for data centers in Virginia is accelerating throughout the period from 2010 (our earliest sales data) to the end of 2020, the last period used in this forecast. Northern Virginia is a preferred location for siting data centers; this technical advantage does not appear to be diminishing, at least through the end of the available data. If we are to hypothesize a substantial slowdown in data center growth, the reasons for expecting a slowdown must come from some other source than the historical data.

Virginia data centers are an input to the production of nearly all goods and services, and serve global markets, not just those in Virginia. The range of applications of data services will probably continue to increase with the expansion of mobile communications and data services, industrial controls, crypto-currency mining, gaming, internet-aware appliances and many other applications.

The two important unknowns are the rate of energy efficiency improvements in data centers and the continued concentration of data center expansion in Virginia. As yet, there

is no sign in the actual sales data that efficiency improvements are happening fast enough to counter the rapid increase in demand for locating data center services in Virginia. To incorporate this uncertainty in our forecast, we provide three scenarios for future data center growth: (1) a statistical "best fit" model, which builds continued acceleration of future data center sales at least through 2035 followed by a gradual reduction in the growth rate, (2) a forecast that assumes an end to the acceleration in data center sales, which increase by a constant increment each year starting in 2021 and (3) a forecast that assumes a rapid, 8% per year, slowing of growth in data center sales.

Our "best-fit" trend model for Dominion data center sales is different from the models for the other sectors. We use a simple quadratic trend specification along with the seasonal factors (temperature and months) used in the other models. This model *assumes* accelerating future growth. This model has a superior fit to the historical data compared to models that do not assume accelerating growth. This high growth scenario leads to an increase in data center electricity sales of 43,000 GWh per year by 2035 and a further 36,000 GWh by 2050. In extending this forecast to the 2050 horizon, we had to make a judgement about whether to continue along a path of rapidly accelerating growth. Such a path would take Virginia well-outside of any historical experience. We have chosen to assume a deceleration of growth starting in 2035 for the purposes of our out-year demand scenarios. Starting in 2035, we take the rate of increase forecast for that year and discount it by 8% in each subsequent year. This forces a slowing of data center sales growth starting in 2035.[6]

Our mid-range estimate of data center sales uses a simple linear extrapolation from the rate of increase in sales experienced in 2020 (2,100 GWh/year increase). This linear growth path adds the same amount of growth in each year. This growth scenario leads to an increase in data center sales by 2035 of approximately 31,500 GWh.

The third scenario posits a slowing from the 2020 increment, with the growth increment falling by 8% per year. This low-growth scenario results in an increase in Dominion data center sales of 25,500 GWh per year by 2035. We emphasize that there is no evidence for such a slowdown in the currently available data. Such a slowing in the rate of increase would be a sharp break from recent experience.

We do not have any firm statistical basis for choosing a most likely path, but we can say that, unless data center sales stop growing within the next few years, they will

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[6]The assumed 8% annual drop in the growth in sales is illustrative. There is no current information on which we can base a statistical estimate for this rate.

contribute to substantial growth in electricity sales by 2035. A saturation of the Virginia data center market in the near future would lower our forecast, but no such saturation is evident in the available data or in discussions available to us in the trade press. At least through 2020, increased growth in data centers locating in Virginia has more than offset any increases in technical efficiency.

It is striking that, even with a dramatic slowing of growth in data center sales, by 2030, Dominion data center sales will surpass all other Dominion commercial sales combined. The increased data center electricity use implied by our mid-range scenario is roughly equivalent to the annual output of the four nuclear plants operating in Virginia.

3.2.4   Industrial
Industrial sales declined in the period since the early 2000s. Recently, industrial sales have been largely flat. They have shown no sign of renewed growth in recent years despite reasonably robust growth in the economy overall.
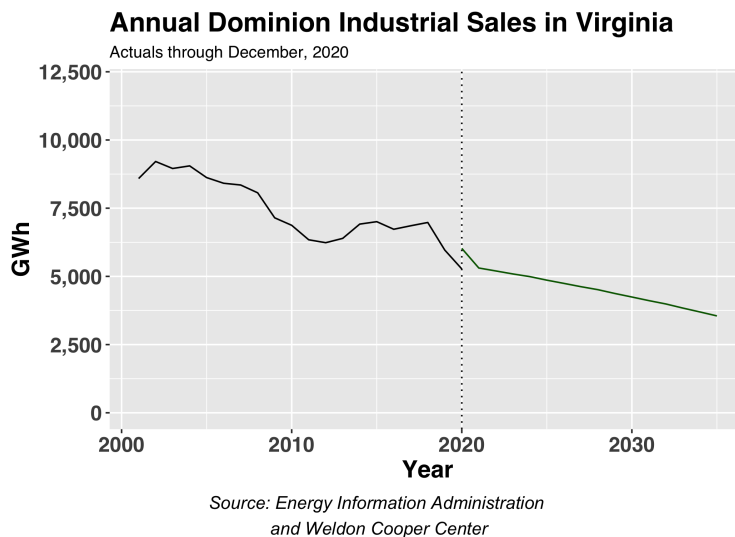
Annual Dominion Industrial Sales in Virginia
Actuals through December, 2020

*Source: Energy Information Administration
and Weldon Cooper Center*

Figure 21

3.2.5   Dominion Total Sales
Adding the separate components together, Figure 22 shows the estimate for total annual electricity sales for Dominion Energy. The forecast shown uses the mid-range estimate for data center growth but does not include likely increases in electricity use for battery electric vehicles.[7]

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[7]We expect to undertake a separate estimate of sales to the transportation sector in a subsequent analysis.

Total Annual Dominion Retail Sales in Virginia

Does not include potential increased use of electric vehicles

*Source: Energy Information Administration
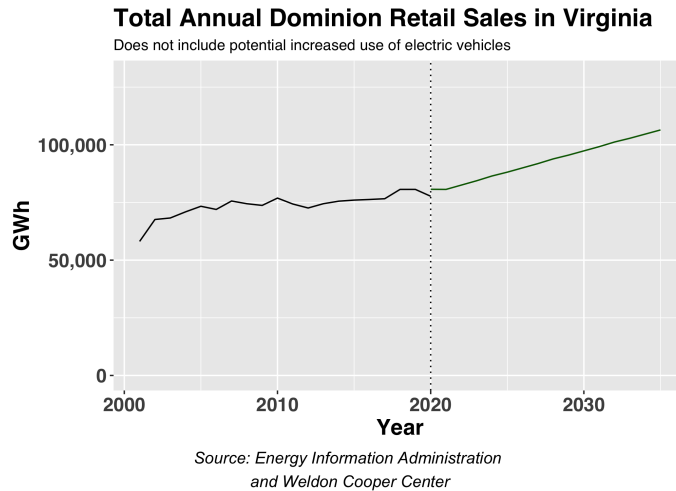and Weldon Cooper Center*

Figure 22

3.3   Rest of state (ex. Dominion and APCO)

Outside the service areas for Dominion and APCO, the rest of the state is served by smaller distribution companies, electricity co-ops and municipal utilities. While small, this aggregated sector is showing some growth. Some of this growth may be due to data center sales outside of the Dominion service area, but information on non-Dominion data center sales was not available for this forecast.
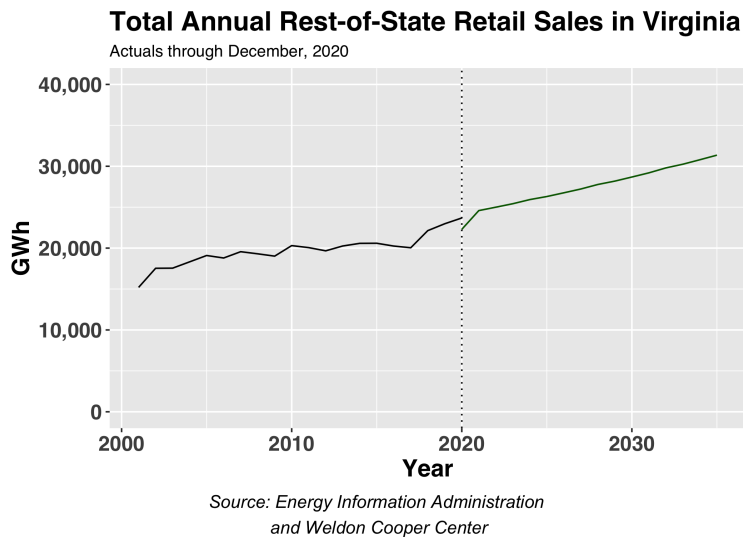
Total Annual Rest-of-State Retail Sales in Virginia

Actuals through December, 2020

*Source: Energy Information Administration
and Weldon Cooper Center*

Figure 23

3.4 Forecast of Total Virginia Electricity Sales

Putting all of the pieces together, Figure 24 shows the total annual electricity demand for Virginia from 2021 to 2050 for the three data center scenarios but without accounting for increased sales of electric vehicles. Table 1 summarizes the results. If the present trend in Dominion data center sales were to continue, annual electricity sales will rise from 115,585 GWh in 2020 to 162,000 GWh in 2035 or about 46,415 GWh, a 40% increase over 15 years, (about a 2.7% average rate of growth). Of this increase, all but 3,317 GWh can be attributed to data center sales growth. The mid-range scenario (constant growth) adds 34,000 GWh by 2035. Even if we assume a dramatic slowdown in data center sales growth, sales would increase by nearly 21,000 GWh (18%) by 2035.
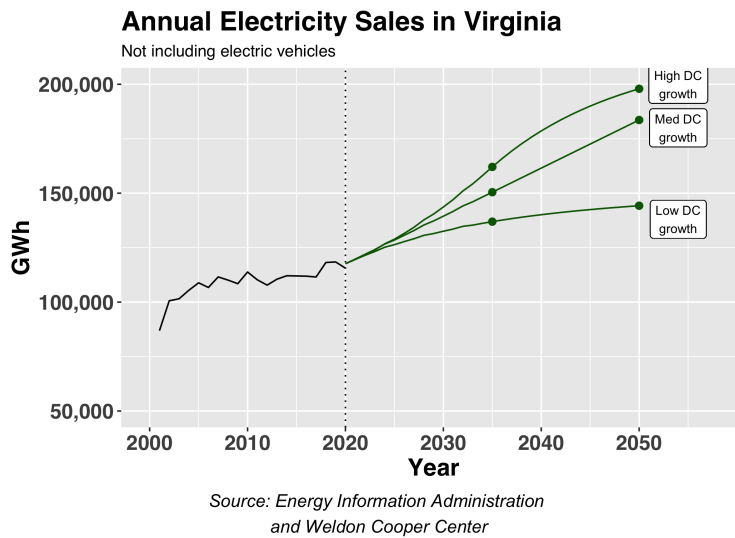
Annual Electricity Sales in Virginia
Not including electric vehicles

*Source: Energy Information Administration
and Weldon Cooper Center*

Figure 24

Table 1: Predicted Electricity Sales (GWh) - High, Medium, and Low Data Center Growth

	High	Medium	Low
2035 Total Sales	162,062	150,464	136,939
2035 Change from 2020	46,477	34,879	21,354
2035 % Change from 2020	40.2%	30.2%	18.5%
2050 Total Sales	197,934	183,599	144,240
2050 Change from 2020	82,349	68,014	28,655
2050 % Change from 2020	71.2%	58.8%	24.8%

NOTES: 2020 TOTAL SALES WERE 115,585 GWH

To put these figures in the context of the transition to renewable energy, each GW of installed solar capacity will generate just under 2,000 GWh per year. Our middle scenario

for data center growth would consume the output of about 16 GW of installed solar capacity, which is just under the 16.7 GW of anticipated solar capacity additions under the VCEA by 2035.[8]

3.4.1 Adding in electric cars and light trucks

Through the end of 2020, electric vehicle use was simply too small to have a measurable effect on electricity sales. This is likely to change dramatically over the next decade. Battery electric vehicles will take a rapidly increasing share of the new vehicle market. Virginia has now adopted a zero emission vehicle standard, which places a floor on the expected penetration of BEVs. We assume that BEV sales rise to reach the 8% required by the ZEV standard in 2024. For the low penetration scenario, we follow the ZEV standard through 2035 and then increase the percent of new vehicle sales so that they reach 100% by 2045. This results in 78% of all light duty cars and trucks on the road being EVs by 2050. For our rapid penetration scenario, the EV share of new vehicle sales reaches 30% in 2030 and 100% in 2037. The share of EVs in 2050 reaches 98%. We do not assume the direct electrification of a significant share of heavy freight transport, because it is not yet clear what technologies will be widely adopted for long-range heavy transport.

For EVs, we take the 2020 sales of light-duty cars and trucks, which we assume will increase at 0.6%, the current rate of population growth in Virginia. We then posit an increasing EV percentage of total sales. We also assume a similar, slow increase in daily vehicle miles traveled per vehicle. We assume, for our illustrative scenarios, that light-duty vehicles will average 3.5 miles/KWh. With these assumptions in place, BEVs will take an increasing share of total vehicle miles traveled over the next 30 years.

Complete conversion of light-duty vehicles from internal combustion engines to electric vehicles will add on the order of 30,000 GWh to annual electricity sales in Virginia. The more aggressive the transition, the sooner this addition to electricity demand will materialize.

3.4.2 Overall electricity sales forecasts

We can now suggest a reasonable range for future electricity sales, accounting for both rising data center sales and electric vehicle sales. By combining high ZEV and high data center growth for a high scenario

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[8]Since the passage of the VCEA, additions to electricity generation no longer implies increased CO_2 emissions. Virginia participates in the Regional Greenhouse Gas Initiative, which caps regional CO_2 emissions. Thus, increased data center use in Virginia implies emission reductions elsewhere in the RGGI region.

Annual electricity sales with electric vehicles
Based on the mid-range data center sales scenario

Source: Energy Information Administration
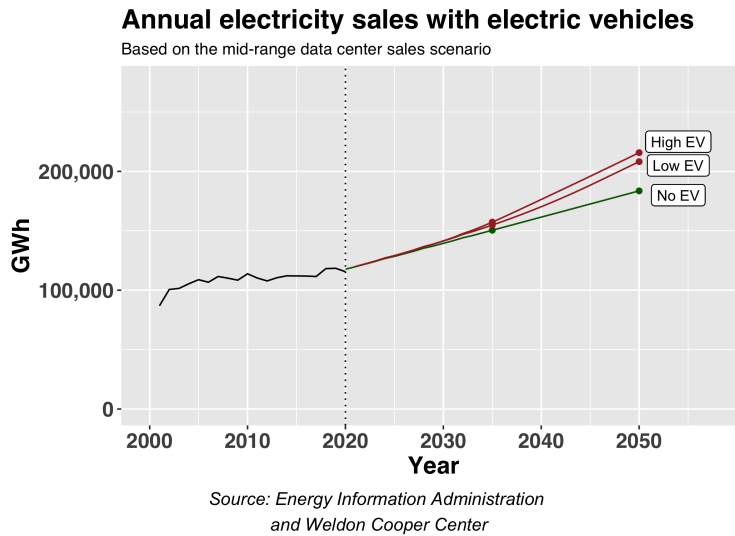and Weldon Cooper Center

Figure 25

and low ZEV and low data center growth for a low scenario, these two "pathways" may be thought of as a plausible range of electricity sales in the absence of large shifts in policies or in data center sales growth patterns. We expect that total electricity sales in 2035 will be between 141,000 GWh and 169,000 GWh and in 2050 will range between 169,000 and 230,000 GWh. Even the low growth scenario implies a substantial increase in Virginia electricity sales over the next 15 years and beyond.[9]

Table 2: Predicted Electricity Sales (GWh) - High and Low Sales Pathways

	High	Low
2035 Total Sales	168,904	141,304
2035 Change from 2020	53,319	25,719
2035 % Change from 2020	46.1%	22.3%
2050 Total Sales	230,104	168,849
2050 Change from 2020	114,519	53,264
2050 % Change from 2020	99.1%	46.1%

NOTES: 2020 TOTAL SALES WERE 115,585 GWH

These scenarios do not take into account any substantial reductions in the energy intensity of building and industry *beyond current trends*. These pathways also exclude any increases in electricity demand that would arise from policies to shift building and industry

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[9]While the future of both data center and electric vehicle demand are highly fluid, we believe that a combination of the mid-range data center scenario and the low-EV penetration case provide a reasonable central forecast at least to 2035. This gives a central estimate of 155,000 GWh/year in 2035 and 208,000 GWh/year in 2050. Yearly values for this case are given in Table 5. Beyond 2035, the uncertainty around the central estimate rises rapidly due to the potentially large shifts in technology, economy and public policy.

energy use from fossil fuels to electricity. The potential for future energy conservation initiatives complicates this picture because some strategies for reducing energy use in buildings involves increased use of electricity as a substitute for direct use of fossil fuels.
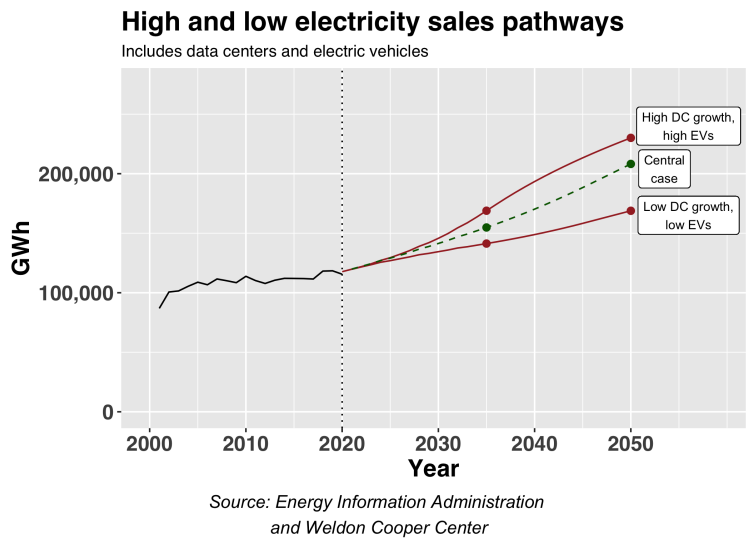
High and low electricity sales pathways
Includes data centers and electric vehicles

*Source: Energy Information Administration
and Weldon Cooper Center*

Figure 26

It seems to us likely that electricity demand will rise substantially over the next three decades due to some combination of increased data center activity and increased use of electric vehicles, although, as we have already noted, there is great uncertainty about the magnitude of the increase.

4   Conclusions

Electricity demand in Virginia will likely grow fairly rapidly between now and 2035, and this growth will probably speed up between 2035 and 2050 as the state accelerates its efforts to eliminate carbon emissions from the economy. Most of the shorter-term growth comes from increased demand from data centers in Virginia. In the longer-run, electric vehicles will likely become an increasingly important contributor to growth. Electricity demand could rise even faster than our forecast suggests, depending on how quickly the state moves to decarbonize its energy economy. Aside from electric vehicles, a more rapid decarbonization pathway would imply increased electricity use beyond what is included in the forecast presented here. That increased use will occur in both industry and in buildings.

Forecast summary

Most electricity use sectors are not growing. Commercial and industrial demand for electricity in Virginia have both been falling for several years, and we can expect this to continue for some time. Residential sales are growing very slowly due to slower population growth and improved energy efficiency. The one growing sector of electricity demand in Virginia is sales to data centers. Data center use is growing nationally, and Virginia is a particularly attractive location for data center services. So data center electricity use is growing faster here than in most other states.

In 2020, electricity sales amounted to 115,585 GWh. Given a continuation of recent experience, we estimate that annual electricity sales will grow between 17% (20,000 GWh) and 38% (44,000 GWh) from 2020 to 2035. Our mid-range estimate is for a 30% (32,800 GWh) increase in electricity sales by 2035. This increase does not include increased electric vehicle sales but rather is nearly all due to increased data center use. The lower growth figure of 17% assumes a rapid reduction in the rate of growth of data center sales, well-below what the state has experienced in the last several years. A 30% growth is roughly equivalent to the output of the on-shore renewables generation mandated for 2035 by the Virginia Clean Economy Act.

Data Centers

Continued data center sales growth on their recent trajectory would imply *an increase in electricity use* of around 44,000 GWh/year between 2020 and 2035 which would imply a nearly 40% increase between 2020 and 2035. Recent experience notwithstanding, it seems unlikely that this accelerating growth is sustainable over the next 30 years. We

develop three alternative scenarios for data center sales growth. These imply a 71%, 56% and 22% growth respectively in electricity sales by 2050, all primarily due to growth in data center sales alone.

The actual data center sales through 2020 do not show any "saturation" in Virginia market. Some growth is likely to continue through the forecast period. Given this, we expect non-transportation electricity sales to be between 137,000 GWh/year and 162,000 GWh/year by 2035 and between 144,000 GWh/ year and 198,000 GWh/year by 2050. Our central estimate for 2050 is 184,000 GWh.

This forecast does not include some potentially important demand shifting circumstances. Aggressive energy conservation policies, if effectively implemented, can reduce the amount of energy required for a given level of economic value. Old buildings can be retrofitted for efficiency, and new buildings can be more efficient still. Much faster improvements in data center energy efficiency would lower the future growth path to some extent, although we should note that recent rapid growth in data center electricity use has occurred as the energy efficiency of data centers has improved.

Electric Vehicles

The increased use of EVs (light-duty cars and trucks) will add to these totals. Assuming that Virginia's new Zero Emission Vehicle standard is in place, we can expect to add about 5,000 GWh per year to these totals in 2035. Light-duty EVs could add between 25,000 and 32,000 GWh to demand by 2050, assuming that these vehicles are battery electric vehicles.

Covid-19 and Electricity Sales in 2020

The Covid-19 pandemic reduced total electricity sales in Virginia by 2.1% during 2020. An increase in sales to residences and to data centers compensated partially for significant and persistent drops in industrial and commercial sales.

After correcting for the effect of weather on residential electricity sales, it appears that the pandemic resulted in a 5.5% *increase* in residential electricity sales during the months of the pandemic. An 8% drop in April was followed by a 6.8% increase in residential electricity use in the last 8 months of 2020 compared to what was expected.

Commercial and industrial sales fell 20% during the heart of the pandemic compared to the weather adjusted forecast. Industrial sales had not recovered appreciably by the end of the year. Commercial sales ended the year with a 13% reduction for the April through

December period.

Data center sales increased 4% during the months of May through December, compared to what was otherwise expected.

Because its overall effect on electricity sales was small, the pandemic did not change the 2035 and 2050 demand forecasts. These remained remarkably stable after adding observations for 2020 to prior data.

5   References

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List of Tables

A   Appendix

A.1   Forecast Methodology

We have specified a parsimonious, but flexible, model of future electricity sales that depends only on an estimated trend plus a set of seasonality measures. Our trend variable is a monthly measure of Virginia economic activity. Seasonality is accounted for with measures of heating and cooling demand along with month indicator variables. We have avoided the use of predictor variables that are not easily measured and for which changes are not readily anticipated.

Parsimony of specification is particularly important in forecasting models. Including a large number of predictor variables can improve the "fit" of the model while degrading the accuracy of the forecast. This happens because the fit of the model to past data, even if quite good, does not reflect the uncertainty that we face in determining future values of the predictor variables. For example, in the case of electricity sales, we expect that future sales will depend on the future stock and quality of electricity-using appliances. Using appliance stock and quality estimates in the forecast equation will introduce two sources of error into the forecast. First, our estimates of past values for appliance use will be subject to considerable error. Second, forecasts of future appliance quality and saturation introduce a second, and probably larger, source of error, that is due to our very rudimentary understanding of how electricity intensity of specific uses evolves over time. Here, it is almost certainly better to avoid using appliance electricity intensity as a predictor variable and to let the effects of this hard-to-measure predictor variable operate on the forecast through the trend variable.

Trend: As we previously noted, electricity use tends to show longer-term patterns of growth and decline due to many interacting factors including population growth, household formation, economic activity and the energy intensity of the many services for which people use electricity. Since electricity is an input to essentially all production and consumption in the economy, electricity sales grow with economic activity so long as the energy intensity of the economy stays the same. This suggests that we can use the level of economic activity as a helpful forecaster of future electricity sales. With the exception of our forecast of data center sales, we use the Virginia Coincident Index of Economic Activity for estimating the trend in electricity sales.[10]

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[10]For future years, economic activity is assumed to grow at 2% per year.

Seasonality: Electricity sales are highly seasonal because they are responsive to various exogenous seasonal factors such as cloud cover, temperature, and day length. These factors affect heating, cooling and lighting loads along with patterns of indoor and outdoor activities. We use heating and cooling "degree days" to capture the direct effect of temperature on electricity sales. A degree day is the difference between the average observed temperature and the benchmark temperature of 65 degrees. For example, a day on which the average daily temperature was 63 degrees would accrue 2 heating degree days. A day with an average temperature of 67 would accrue 2 cooling degree days. As with economic activity, we would expect the relationship between degree days and electricity sales to change over time, so allowing the estimated relationship to change over time can improve forecasting accuracy.

Even after controlling for temperature, there are regular monthly variations in sales arising from differences in people's activities from month to month. Our forecast model includes an indicator variable for each month to capture this variation.

Time varying parameters: The estimated relationship between electricity sales and the trend and seasonal factors we use for our forecast changes over time due to changes in consumer behavior and in the stock of buildings and appliances. The parameters that we estimate statistically will tend to vary systematically over different time periods in the data. In forecasting jargon, the model exhibits parameter instability. Because of the changes in the way electricity was consumed over the past 20 to 30 years, we would expect to observe different parameter estimates for the trend and seasonality variables depending on the time period used for the estimation; that is, our estimates would exhibit parameter instability.

The assumption of a constant relationship between electricity use and economic activity clearly does not hold, as we have shown earlier. In the 1980s and 1990s, population growth, along with the increased use of electricity appliances, especially heating and air conditioning, resulted in relatively rapid growth in electricity sales. The pattern of rapid growth shifted after 2000. By 2005, the rapid growth started to slow dramatically as the population growth rate fell and the use of energy-intensive devices began to reach a high level of saturation. This was also a time when significant increases in the efficiency of many electric appliances began to have noticeable effects on electricity use. Dramatic improvements in the efficiency of electric lighting started to lower the amount of electricity used for lighting as well as the amount used to remove waste heat from homes during the air conditioning season. Refrigerators, heat pumps and washing machines all saw impressive gains in efficiency. These improvements affect electricity use both as the stock

of existing appliances turns over and also because it results in a smaller increment to sales with the formation of each new household and business establishment.

We use a standard statistical test for the stability of the relationship between electricity sales and economic activity.[11] We estimate a model with a measure of economic activity as the trend variable and test to see whether the measured relationship between sales and economic activity is subject to statistically significant change over time. Our test shows a clear break in trend for residential and commercial demand around 2008. This break is visually apparent in Figure 6. The relationship between electricity sales and GSP changed substantially around this time and has not returned to its earlier value. As we will show, the relationships between electricity sales and heating and cooling degree days have also changed. These parameter estimates are also subject to parameter instability.

One easy, if informal, way to deal with parameter instability is simply to not use old data, rather to only use newer data in estimating the model. A more modern approach, a time-varying parameters (TVP) model, uses statistical procedures that allow the parameter estimates in a statistical model to change over time based on the observations in the sample. This estimation approach implicitly acknowledges that we have a limited understanding of the underlying process that changes electricity demand over time. For each new observation in the sample, the procedure updates the estimate of the parameter values so that it more accurately reflects the recent relationships between the predictor variables and the current level of electricity sales.

We estimate a dynamic linear model using a state-space specification.[12] A somewhat informal explanation of this procedure is as follows: The predictor variables, X_t include the economic activity index, heating and cooling degree days and monthly indicator variables (the latter, often referred to as "dummy" variables).[13] The parameter estimates, β_t, are assumed to follow a random process (Equation 2 below). If new data is widely inconsistent with patterns we observed in previous periods, then we might begin to think that the relationship represented by β_t has changed, so we start to update our expectations about the value of β_t. If more of these inconsistent observations crop up, then we become more and more sure that the value of β_t has changed and it gets updated accordingly.

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[11]We use the Quandt statistic with Andrews critical values to test for structural stability. The test rejects the hypothesis of structural stability with 99% confidence. The break point occurs in 2008. A description of this test may be found in Hansen (2001).

[12]See Durbin and Koopman (2012) for a detailed exposition of state-space methods.

[13]The forecast of Dominion data center sales uses a somewhat different specification of the trend variable. Trend is specified as a simple linear trend and a squared trend term. This formulation allows for a quadratic growth process.

The model is estimated using the Kalman filter. For each new observation in the sample, the Kalman filter allocates the error in the step-ahead forecast between the model error (e_t) and parameter error (ν_t). The procedure then updates the parameter values based on the portion of the forecast error that could be identified with the parameter error rather than the model error.

$$y_t = X_t\beta_t + e_t \tag{1}$$

$$\beta_t = \bar{u} + F\beta_{t-1} + \nu_t \tag{2}$$

where

$$e_t \sim i.i.d. N(O, R)$$

$$\nu_t \sim i.i.d. N(O, Q)$$

Electric Vehicle Electricity Sales Scenarios: In order to estimate the effect of increased electrification of the vehicle fleet, we specify two scenarios for increased penetration of battery electric light-duty cars and trucks. We have not included heavy trucks in our analysis because it is not yet clear how heavy-duty transport will be fueled in the future.

Our scenarios (Figure 27) are constructed so that the percent of EV vehicle miles traveled as a share of all vehicle miles traveled in 2050 are equal to about 75% and 98% respectively. The low EV penetration scenario implies that the Virginia ZEV standard is binding until 2035 and then ramps up to 100% of new vehicles sold by 2045. The higher penetration scenario envisions a relatively more rapid transition of new vehicle sales to ZEVs along with policies that induce the early retirement of older internal combustion vehicles. We emphasize that these are not forecasts, but rather illustrative pathways that show the range of effects that ZEVs may have on electricity sales.
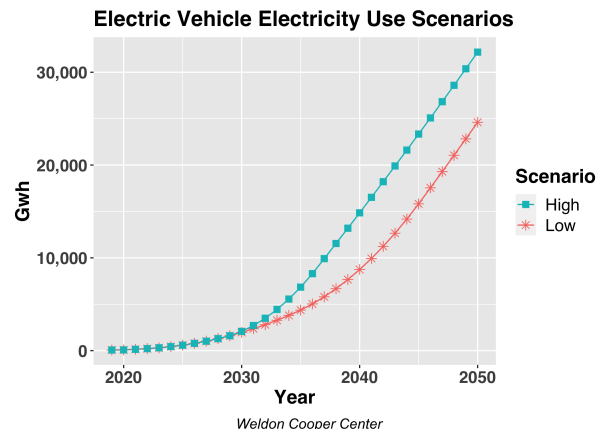
Figure 27

Weather Normalization: Our forecast of 2020 electricity sales assumed that temperatures in each month of the year would be the average temperature for that month. Temperature drives a large share of the monthly variation in residential and commercial sales. Once we have the actual data for 2020, we can calculate what we would have forecast if we had known what the actual weather would have been. This process is know

as 'weather normalization'. If weather is the primary driver of the forecast error, then the normalized forecast will be closer to the actuals observed than was the original forecast. If weather is not an important factor, then the original forecast and the normed forecast will be closer together because the original forecast error was due to something other than weather.

In the case of 2020, January, February and March were warmer than normal, so actual sales would tend to be lower than the forecast. Once the forecast is normalized for the actual weather that occurred, the normalized forecast should be closer to the actual observed sales. July was also warmer than normal in 2020, but higher than normal summer temperatures increase electricity sales. In this case, the forecast of sales should be lower than actual sales, but the weather-normed forecast should be closer to the actual data. Finally, October and November were especially mild with the unadjusted forecast being high while the normed forecast is closer to the actual sales.

Figure 11 shows the actual sales (circles) and the normed forecast (triangles). The effect of covid (and other unexpected events) would show up as a divergence between the weather normed forecast and the actual sales. In 2020, the difference between the actual sales and the weather normalized sales are concentrated in April, May and, to a lesser extent, June. The normalized and actual sales are much closer to each other during the rest of the year, with the possible exception of October. As we shall see shortly, since actual sales were very close to the normed forecast for the last six months of 2020, the reduced sales from April to June, did not affect the long-range forecast of electricity sales.

A.2 Tables

Table 3: Realized Annual Electricity Sales (GWh)

Year	Virginia Total	APCO Total	Rest of State Total	Dominion Total	Dominion Commercial	Dominion Residential	Dominion Industrial	Dominion Data Centers
2001	86,877	13,556	15,200	58,122	29,012	20,524	8,586	454
2002	100,619	15,466	17,535	67,617	32,879	25,526	9,211	585
2003	101,510	15,691	17,550	68,269	33,541	25,772	8,955	677
2004	105,424	16,166	18,322	70,936	35,061	26,824	9,051	796
2005	108,850	16,402	19,096	73,351	36,467	28,263	8,621	936
2006	106,721	15,953	18,791	71,977	36,514	27,050	8,414	1,089
2007	111,570	16,377	19,562	75,631	38,408	28,873	8,350	1,283
2008	110,106	16,350	19,303	74,453	38,307	28,082	8,064	1,490
2009	108,462	15,718	19,020	73,725	38,237	28,340	7,147	1,739
2010	113,806	16,605	20,306	76,896	39,202	30,822	6,872	2,081
2011	110,228	15,845	20,059	74,324	38,838	29,144	6,342	2,485
2012	107,795	15,524	19,667	72,604	38,697	27,672	6,235	2,822
2013	110,512	15,783	20,259	74,469	39,273	28,802	6,394	3,192
2014	112,098	15,954	20,581	75,563	39,240	29,406	6,916	3,767
2015	112,009	15,391	20,593	76,025	39,726	29,293	7,006	4,310
2016	111,910	15,368	20,251	76,291	40,912	28,652	6,727	5,353
2017	111,530	14,868	20,042	76,619	41,714	28,050	6,856	6,416
2018	118,187	15,389	22,135	80,662	43,249	30,437	6,976	7,483
2019	118,435	14,794	22,978	80,663	44,870	29,829	5,965	9,546
2020	115,585	14,212	23,681	77,691	42,703	29,715	5,274	11,627

Table 4: Forecasted Annual Electricity Sales 1 (GWh)

Year	Dominion Data Centers	Dominion Commercial Minus Data Centers	Dominion Residential	Dominion Industrial	APCO Total	ROS Total	Dominion Total
2020	11,448	34,548	28,506	6,027	14,618	22,291	80,530
2021	13,598	31,480	30,144	5,307	14,507	24,584	80,529
2022	15,613	31,236	30,273	5,200	14,395	24,999	82,323
2023	17,771	30,987	30,406	5,090	14,279	25,424	84,253
2024	20,122	30,820	30,635	4,992	14,207	25,929	86,569
2025	22,511	30,470	30,680	4,862	14,041	26,303	88,523
2026	25,093	30,203	30,822	4,744	13,918	26,758	90,862
2027	27,818	29,930	30,967	4,623	13,791	27,223	93,338
2028	30,766	29,735	31,211	4,513	13,706	27,776	96,226
2029	33,693	29,364	31,268	4,373	13,530	28,187	98,698
2030	36,844	29,071	31,423	4,244	13,395	28,686	101,582
2031	40,136	28,771	31,582	4,112	13,256	29,196	104,602
2032	43,686	28,547	31,842	3,989	13,157	29,800	108,064
2033	47,147	28,151	31,912	3,838	12,970	30,252	111,047
2034	50,865	27,829	32,082	3,696	12,821	30,799	114,473
2035	54,725	27,501	32,257	3,551	12,670	31,358	118,034

Table 5: Forecasted Annual Electricity Sales 2 (GWh)

Year	Electric Vehicles Low Scenario	Electric Vehicles High Scenario	Virginia Total No Data Center Growth	Dominion Low Data Center Growth	Dominion Middle Data Center Growth	Dominion Total High Data Center Growth	Virginia Total Low Data Center Growth	Virginia Total Middle Data Center Growth	Virginia Total High Data Center Growth	Virginia Total Low EV Scenario	Virginia Total Middle EV Scenario	Virginia Total High EV Scenario
2020	79	79	117,618	11,627	11,627	11,627	117,618	117,618	117,618	117,698	117,698	117,698
2021	143	143	117,649	13,571	13,727	13,727	119,594	119,749	119,620	119,737	119,892	119,764
2022	215	215	117,730	15,372	15,827	15,613	121,474	121,930	121,716	121,689	122,144	121,931
2023	306	306	117,812	17,039	17,927	17,771	123,224	124,112	123,956	123,530	124,418	124,261
2024	433	433	118,210	18,582	20,027	20,122	125,166	126,610	126,705	125,599	127,044	127,139
2025	589	589	117,983	20,012	22,127	22,511	126,367	128,483	128,866	126,957	129,072	129,456
2026	784	784	118,071	21,335	24,227	25,093	127,779	130,671	131,537	128,563	131,455	132,321
2027	1,017	1,017	118,161	22,560	26,560	27,818	129,095	132,861	134,353	130,112	133,879	135,370
2028	1,291	1,291	118,569	23,695	28,427	30,766	130,637	135,369	137,707	131,927	136,660	138,998
2029	1,604	1,604	118,348	24,745	30,527	33,693	131,467	137,248	140,415	133,071	138,853	142,019
2030	1,959	1,959	118,445	25,718	32,627	36,844	132,536	139,445	143,662	134,495	141,404	145,736
2031	2,355	2,702	118,544	26,619	34,727	40,136	133,536	141,644	147,054	135,891	143,999	149,755
2032	2,793	3,490	118,962	27,453	36,827	43,686	134,787	144,162	151,021	137,580	146,954	154,511
2033	3,273	4,441	118,749	28,225	38,927	47,147	135,347	146,049	154,269	138,620	149,322	158,710
2034	3,797	5,557	118,855	28,940	41,027	50,865	136,168	148,255	158,093	139,965	152,052	163,651
2035	4,365	6,842	118,964	29,602	43,127	54,725	136,939	150,464	162,062	141,303	154,829	168,904
2036	5,033	8,296	119,073	30,215	45,227	58,429	137,661	152,673	165,875	142,694	157,706	174,171
2037	5,803	9,915	119,182	30,782	47,327	61,858	138,337	154,882	169,413	144,140	160,685	179,328
2038	6,676	11,547	119,291	31,308	49,427	65,033	138,972	157,091	172,697	145,648	163,767	184,244
2039	7,655	13,192	119,400	31,795	51,527	67,973	139,568	159,300	175,747	147,223	166,955	188,938
2040	8,740	14,850	119,509	32,245	53,627	70,696	140,127	161,509	178,578	148,867	170,249	193,428
2041	9,933	16,521	119,618	32,662	55,727	73,217	140,653	163,718	181,208	150,586	173,651	197,729
2042	11,235	18,205	119,727	33,049	57,827	75,550	141,149	165,927	183,650	152,384	177,162	201,856
2043	12,649	19,903	119,836	33,406	59,927	77,712	141,615	168,136	185,921	154,264	180,785	205,824
2044	14,176	21,614	119,945	33,737	62,027	79,713	142,055	170,345	188,031	156,231	184,521	209,645
2045	15,816	23,339	120,054	34,044	64,127	81,565	142,471	172,554	189,992	158,287	188,370	213,331
2046	17,547	25,077	120,163	34,328	66,227	83,281	142,864	174,763	191,817	160,411	192,310	216,894
2047	19,292	26,829	120,272	34,591	68,327	84,869	143,236	176,972	193,514	162,528	196,264	220,344
2048	21,050	28,595	120,381	34,834	70,427	86,340	143,588	179,181	195,094	164,638	200,231	223,690
2049	22,822	30,375	120,490	35,060	72,527	87,702	143,923	181,390	196,565	166,745	204,212	226,940
2050	24,609	32,169	120,599	35,268	74,627	88,963	144,240	183,599	197,935	168,849	208,208	230,104

The Energy Transition Initiative

The Energy Transition Initiative at the University of Virginia consists of a team of researchers at UVA's Weldon Cooper Center for Public Service exploring clean energy sourcing in response to new legislation mandating net carbon emission neutrality in Virginia by 2050. We advance these goals by researching clean energy and sustainability practices; by developing and maintaining tools to help localities understand the process, costs, and benefits of adopting cleaner energy technologies; and by engaging directly with policymakers, energy providers, entrepreneurs, consumers, and other interested stakeholders to smooth the transition to a sustainable energy economy.

The Weldon Cooper Center for Public Service

In every project we undertake and every community we serve, the Weldon Cooper Center draws on eighty years of experience and expertise from across the organization to support the needs of our clients and partners. Cooper Center professionals embrace mission- and impact-driven service to individuals, organizations, governmental bodies, and communities seeking to serve the public good. We conduct advanced and applied research in collaboration with clients so they may make a difference in governance and community life. We offer training programs and expert assistance to public leaders and skill development for political leaders who seek to work cooperatively with others. Our values of access, collaboration, commitment to community, and impact guide our work. We welcome partnerships and invite conversation about your goals and needs.