Evaluation of Dominion Energy’s 2018 Integrated Resource Plan

Prepared for
Virginia Advanced Energy Economy

Analysis by
5 Lakes Energy

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About Virginia Advanced Energy Economy

Virginia Advanced Energy Economy (Virginia AEE) is a coalition of businesses that seek to make the Commonwealth's energy more secure, clean, and affordable, bolstering Virginia's economy. Virginia AEE aims to drive the development of advanced energy by identifying growth opportunities, removing policy barriers, encouraging market-based policies, establishing partnerships, and serving as the voice of innovative companies in the advanced energy sector.

About 5 Lakes Energy

5 Lakes Energy is a Michigan-based policy consulting firm dedicated to advancing policies and programs that promote clean energy, sustainability and the environment. The team has decades of experience in research, modeling and analysis. From public policy design to reviewing policy implementations around the country and world, 5 Lakes Energy has the deep knowledge base necessary to review, analyze, and recommend models for optimizing the deployment of clean energy.

Executive Summary

In May of 2018, the Virginia Electric and Power Company – i.e. Dominion Energy – submitted their 2018 Integrated Resource Plan (IRP) to the State Corporation Commission (SCC). The IRP puts forward a set of plans intended to serve current and anticipated load over the next 15 years. Therein, Dominion evaluated five scenarios that represent a range of potential CO_2 regulatory regimes.

Virginia Advanced Energy Economy (Virginia AEE) contracted Five Lakes Energy to review Dominion's analysis and determine whether, and to what extent, the use of advanced energy resources could improve projected outcomes. To conduct this analysis, Five Lakes used the State Tool for Electricity Planning (STEP), a least cost resource-modeling tool specifically tailored to reflect Virginia's energy system.

This analysis was developed using the same set of assumptions – reflected in scenarios A through E – regarding future carbon regulations. Five Lakes also employed Dominion's projections regarding future load growth, fuel prices, and emission allowances. Maintaining these assumptions allows us parse out the specific impacts advanced energy has on system costs, carbon prices, and electricity imports. To establish a baseline Five Lakes initial analysis, as show in Tables 2.A and 2.B, adheres to the same three parameters Dominion employed into their IRP:

- New capacity is only added as needed. Even if a new resource becomes more cost-effective than and existing one, that resource would only be added in response to reliability requirements and load growth.
- No more than 480 MW of solar may be brought online each year.
- Energy efficiency (EE) reduces energy consumption in 2033 (i.e. the end year of the 15 year model) by 0.9%

Five Lakes then relaxed two of three parameters above, and incorporated industry data regarding prices and EE potential, to examine how greater utilization of advanced energy might change outcomes.

When the analysts relax solely the second parameter, by allowing the amount of solar deployed each year to rise to 1,000 MW and incorporating the latest data on wind and solar (displayed in Tables 3.A and 3.B), the build-out of combustion turbine capacity shrinks notably. By contrast, solar capacity grows significantly, demonstrating the cost competitiveness of renewable generation and that the 480 MW cap constrains the utility's IRP options. In this analysis, system-wide costs fall across the board between $400 million and $700 million. Net imports of energy drop in three of the five scenarios, while remaining constant in a fourth.

When analysts relax both the second and third parameters - allowing greater utilization of renewable generation and greater load reductions through more EE

– the changes in capacity development and generation, as displayed in table 4.A, are likewise significant. The build-out of new combustion turbine capacity shrinks more substantially than in the prior analysis and the baseline. Solar capacity grows to a greater extent than in the baseline analysis, though less than the prior analysis. The total amount of generation in 2033, measured in gigawatt-hours, also falls – the result of greater EE utilization.

The outcomes for consumers and the energy system in this analysis are also significant, as shown in Table 4.B. System costs fall in all five scenarios between $700M and $1.7B, creating cost savings for consumers when compared with the baseline. Energy imports fall in four of five scenarios, in some cases significantly, and rise only negligibly in scenario E. At the same time, we see CO_2 emissions drop in all scenarios, even those in which carbon regulations are not established or are delayed until 2026. The price of carbon allowances in scenarios B, C, and D is lower, stemming from the influx of low-cost EE. In Scenario E the federal government sets the price on carbon, so Virginia's actions do not impact it.

The conclusions from this analysis are clear. The increased utilization of advanced energy, specifically energy efficiency and renewables, results in lower costs when compared with the plans proposed by the utility in this IRP. This should translate to reduced rate impacts, and potentially (through great EE utilization) lower bills, for Virginia families and businesses.

As this analysis also demonstrates, the integration of more advanced energy likewise has the tendency to reduce energy imports, keeping more ratepayer dollars in the state. It also has the effect reducing the cost of compliance with potential CO_2 regulations when compared with the baseline. Indeed, when both renewables and efficiency are fully deployed we see a drop in the overall price of carbon in all three scenarios where Virginia's actions may have an impact.

Five Lakes' report also touches upon the opportunities presented by three advanced energy technologies otherwise not encompassed by this analysis: Volt-VAR control, cogeneration (CHP) and energy storage. Volt-VAR and CHP both present the opportunity to reduce overall demand by several hundred megawatts by, respectively, improving grid and industrial efficiency.

Meanwhile, as noted herein, energy storage including thermal storage presents the opportunity to reduce the curtailment of renewable resources – a small but statistically significant issue as the level of renewables penetration increases. This is just one way in which storage can create new value for the energy system. Unfortunately, neither energy storage including thermal storage, nor Volt-VAR control, nor CHP were given the thorough analysis we believe they deserve in the utility's 2018 IRP.

Introduction

This report provides insights regarding an Integrated Resource Plan ("IRP") submitted to the Virginia State Corporation Commission by Dominion Energy on May 1, 2018 found through application of the STEP model by 5 Lakes Energy under engagement by Virginia Advanced Energy Economy.

Overview of the Dominion Energy IRP

The Dominion Energy IRP proposes a short-term action plan based on the Company's analysis of five principal scenarios. Those scenarios are mainly concerned with carbon emissions policy:

> "Plan A: No CO2 Tax. Plan A is based on a scenario of a future without any new regulation of or restrictions on power station carbon emissions. Plan A serves as a least-cost baseline for comparing the costs of the other plans.
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> Plan B: Virginia RGGI (Unlimited Imports). Plan B, the second Alternative Plan, assumes implementation of the DEQ's draft carbon reduction regulations published in the Virginia Register in January 2018. The draft proposal links Virginia to RGGI. Plan B assumes that the Company's compliance with this regulation is achieved largely through the use of more carbon intensive out-of-state energy and generating capacity.
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> Plan C: RGGI (Unlimited Imports). Plan C assumes Virginia will become a full member of RGGI. It also assumes that the Company's compliance with RGGI is met largely through the use of more carbon intensive out-of-state energy and capacity. The Company presents Plan C as a comparison against Plan B. Plan C reflects the higher cost of allowance purchases if Virginia becomes a full member of RGGI, with no offsetting payments as would occur under the DEQ's draft carbon regulations modeled in Plan B.
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> Plan D: RGGI (Limited Imports). Like Plan C, Plan D assumes Virginia will become a full member of RGGI. However, Plan D assumes the Company's compliance with RGGI will be achieved primarily through generation built in Virginia and limited imports of more carbon-intensive power. Like Plan C, Plan D reflects the higher cost of allowance purchases with no offsetting payments.
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> Plan E: Federal C02 Program. Plan E assumes that Virginia does not implement any CO2 reduction program, but also assumes that federal CO2 legislation is enacted imposing restrictions beginning in 2026."[1]

The short-term action plan proposed by the Company reflects the near-term implementation of the common elements of the Company's resource plans for each of these Plans, which are summarized as:

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[1] May 1, 2018 cover letter from Dominion Energy to the Virginia State Corporation Commission, submitting the IRP., page 3.

"Solar: Development of 4,720 MW of solar PV generation by 2033.

Solar (Non-Utility Generators): The addition of 760 MW of solar PV capacity owned by nonutility generators ("NUGs") under long-term contracts with the Company in Virginia and North Carolina by 2020.

Wind: Construction and operation of the Coastal Virginia Offshore Wind demonstration project with a generating capacity of 12 MW by 2021. The project is to be located approximately 27 miles off the coast of Virginia Beach.

Nuclear: Twenty-year operating license extensions for the four Company-owned nuclear units at the Surry and North Anna Power Stations. The Suny units would be relicensed by 2032 and 2033, and the North Anna units by 2038 and 2040.

Natural Gas: Additional natural gas-fired generation, including completion of the 1,585 MW Greensville County Power Station using energy efficient, low-emission combined cycle technology, scheduled to begin service by 2019. All of the Alternative Plans also call for the addition of eight natural gas-powered facilities using CT technology with a combined capacity of approximately 3,664 MW by 2033.

Demand-Side Management: Implementation of demand-side management programs, both already approved by or currently submitted to the Commission, capable of reducing overall annual customer energy usage by 805 GWh and system peak demand by 304 MW by 2033.

Potential Retirements (Fossil Fuels): The potential retirement of 2,785 MW of generation powered by older, less efficient coal, oil, and natural gas technology by 2021 or 2022 at six Virginia sites. The Company announced earlier this year that 1,209 MW of this generation at five sites would be placed in cold reserve by December 2018. All generation retirements presented in the Alternative Plans should be considered tentative, with the Company's final decision being made at a future date after further analysis.

Potential Retirements (Biomass): The potential retirement of 83 MW of biomass-powered generation using waste wood at Pittsylvania Power Station by 2021. The Pittsylvania facility is also scheduled to be placed in cold reserve in August 2018."[2]

"In addition to the common elements listed above, the various Alternative Plans contain additional resources and potential retirements by 2033, the end of the 15-year planning period.

Plan A includes one additional CT facility with a total generating capacity of 458 MW.

[2] Ibid, page 4

Plan B includes three additional CT facilities with a total capacity of 1,374 MW; two CT Aero-derivatives ("Aero") units with a capacity of approximately 238 MW; and an additional 1,920 MW of solar capacity.

Plan C includes three additional CT plants totaling 1,374 MW; two CT Aero units generating 238 MW; and an additional 1,920 MW of solar capacity.

Plan D calls for one natural gas-powered combined cycle facility using 2x1 technology of approximately 1,062 MW; one additional CT plant/of approximately 458 MW; one CT Aero unit of approximately 119 MW; and an additional 1,920 MW of solar capacity.

Plan E calls for an additional 1,280 MW of solar capacity.

Finally, Plans B, C, and D include the potential retirement of 1,445 MW of additional coal units: Chesterfield Unit 5 (336 MW) and Unit 6 (670 MW) by 2023 and Clover Unit 1 (220 MW) and Unit 2 (219 MW) by 2025."[3]

Although the IRP includes a risk analysis that focusses primarily on natural gas cost risks, the Company's core analysis of the five Plans focuses on a projected path of fuel costs, carbon emissions regime, and level of electricity imports determined by Dominion Energy for each of the Plans and then examines the resource mix that the Company finds best for each of these plans. The path of fuel costs, carbon emissions allowance prices, and level of electricity imports were determined externally from the IRP modeling performed by Dominion Energy.

Overview of the STEP Model

5 Lakes Energy previously worked with researchers at the University of Michigan to develop a power system model to help states comply with the Clean Power Plan[4]. The initial model, called STEER (State Tool for Electricity Emissions Reduction), recommends a least-cost plan to meet required greenhouse gas emissions targets. Because it ensures that energy and capacity needs are met over time, STEER can be used to evaluate different scenarios in support of integrated resource planning (IRP). The model has since been modified to improve its functionality for stakeholders engaged in IRP efforts. This newer version of the model, called STEP (State Tool for Electricity Planning), incorporates lessons derived from using STEER as well as more current knowledge about the state of the world. As a result, STEP delivers even more capable and realistic modeling of the power system.

While typically applied at the state level, STEP can be configured to represent

[3] Ibid, pages 4-5.

[4] The Clean Power Plan was an Obama administration policy aimed at reducing U.S. greenhouse gas emissions, which is in abeyance due to court injunction. The Trump administration is attempting to repeal the policy through executive order and EPA action.

the power system at other scales such as a single utility's territory, an area within a state, or a multi-state region. The modeling team is committed to making STEP accessible and user-friendly for anyone wishing to apply the model. STEP itself is a large, integrated, and highly functional Excel spreadsheet. Its numerous data elements, formulas, and assumptions are transparent and adjustable by the user. Default settings for each parameter come from sources that are publicly available. A reference manual was developed for the original version of STEER and is being updated to reflect all subsequent changes now reflected in STEP.

STEP can evaluate the full range of resource options found in most integrated resource planning models:

- Heat rate improvements at existing power plants;
- Changes in dispatch order in response to fuel prices and environmental allowances;
- Development of new wind, solar, biomass, and hydropower generation;
- Adoption of energy efficiency measures by utility customers; and
- Development of new gas-fired combustion turbine plants, new NGCC plants, and new conventional combined heat and power (CHP) plants;
- Development of new nuclear plants;
- Geothermal plants;
- Biomass co-firing in existing coal plants;
- Fuel cell cogeneration;
- Demand response;
- Smart grid technologies;
- Integration of electric vehicles;
- Existing pumped storage; and
- Battery storage.

To facilitate comparison between different IRP scenarios, STEP users can select any of the resource options listed above to be evaluated by the model.

STEP is capable of projecting future hourly load out to the planning horizon. Using hourly load data from twenty-four representative days in 2015, adjustments are then made for annual sales growth and any changes to the load profile resulting from new energy efficiency measures, electric vehicle adoption, and selected demand response, battery storage and smart grid programs.

STEP includes a module of existing generators using performance data found in the U.S. Energy Information Administration's extensive EIA-860 dataset. If a power plant has multiple units, these are considered as separate generators. STEP also determines the cost-based dispatch order, or Merit Order of these units. Dispatch cost is calculated as the price of fuel plus the cost impact associated with air and water emissions and water withdrawal. Units in the generator module are ranked up to their cumulative net capacity from lowest to highest dispatch cost.

In determining whether to assign a new resource to the power system, STEP computes the net cost per unit of effective load-carrying capacity for all available resource options.[5] It then ranks and selects the most cost-effective resources until capacity requirements are met for any given hour as set by the forecasted load plus required reserve margin.

To calculate the net cost per capacity for a resource, STEP determines the annualized capital cost based on initial investment, payback period, and other financial parameters. From this it subtracts the marginal rent which is the difference between the market value of energy minus the variable cost of operating the resource. For market value of energy, STEP uses Merit Order dispatch to determine how much energy must be supplied in the given hour, and the marginal price (LMP) for that hour. Experience with both STEER and STEP have verified that LMP values delivered by the model approximate actual historical LMP data.

Costs and effects of heat rate improvements to existing units default to the assumptions reflected in the U.S. EPA's previous Clean Power Plan draft rule for existing power plants. However, users can modify these default settings with plant-specific assumptions in accordance with actual engineering data.

Data for the various renewable energy resource options are based on inventories developed by the U.S. DOE's National Renewable Energy Laboratory (NREL). Wind resources include sites identified in NREL's Eastern Wind Integration and Transmission Study, updated for modern wind values and wind turbine technologies and are modeled with hourly generation based on site-specific 10-minute-interval wind data. Solar resources include six cities from across each state and are modeled for both fixed-mount distributed generation and single-axis-tracking utility-scale generation based on actual hourly insolation. Capacity factors, capacity credits, and hence the power system value of wind and solar generation are therefore calculated with site-specific data rather than generic assumptions. Biomass resource flows are modeled for eight categories including municipal waste, landfill gas, and timber residuals, and others.

The energy efficiency resource in STEP is comprised of multiple EE measures across residential and commercial customer segments. The performance and cost of each measure is characterized for different potential levels: economic potential, achievable potential, and constrained achievable potential. To model the effect on hourly load profile, each measure is classified as affecting all load or peak load only. In calculating actual potential, STEP considers the expected life of EE measures within the context of how many years are being examined. For example, for a 10-year measure during a 5-year study timeframe, only half the measure's total potential will be made available for the model to select.

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[5] Effective load-carrying capacity incorporates forced outage rates; therefore, it is typically less than nameplate capacity.

In addition to these core features of the power system, STEP can incorporate existing pumped storage and battery storage facilities, and it considers power imports and exports subject to current transmission limitations established by regional transmission organizations (RTOs). A user can change the default settings for import and exports to match their situation.

STEER's original approach to modeling combined heat and power (CHP) as a dispatchable resource has been modified. STEP now reflects that CHP is usually operated to match a host facility's requirement for on-site heat. Therefore, the CHP resource is treated similarly to wind and solar in that it cannot be called upon by a power system operator but is instead accepted into the grid as it is generated. CHP resources are evaluated on the basis of net value by considering only the net costs and benefits of electricity generation given assumed heat generation and excluding standby rates, resilience values, and other factors that affect the division of costs and benefits between the utility and the CHP host.

A STEP user can examine details of the model's calculations if they wish, but to facilitate use the modeled performance of the power system is conveniently summarized across the categories of cost to ratepayers, generation mix, capacity portfolio, fuel consumption, emissions, and health and environmental damages. Regarding environmental damages, the user can decide whether the societal cost of emissions such as carbon dioxide is considered by the model in choosing different resource options, independently of whether emissions allowances are required and of the prices of those allowances.

STEP gives users the ability to retire existing generating units and provides the capacity factors, dispatch order, air emissions, and other information that might be considered in deciding whether to retire a unit. Cost projections based on retirements reflect the need to pay for any remaining book value of retired plants, and this assumes the method of securitization. Retirement decisions are left to the user and are not automated in the least-cost planning algorithm because those decisions are usually based on a variety of considerations that are not explicitly modeled.

As with any model, there are important simplifications that can affect modeling results. Two are important to the interpretation of STEP modeling results. The first is that the model assumes there are no binding transmission constraints within a state. Standard transmission costs are included in the model, but it is possible that the model would partly replace generation from a fossil fuel plant with renewables in a remote location. New natural gas and biomass plants are not assigned to specific sites, so their locations can reflect transmission availability and support requirements. Actual model results do not appear to be distorted as a result of this simplification.

The second simplification is that the model calculates the best plan for a single year, chosen by the user, and does not aggregate year-by-year results into the optimum plan over a period of time. Thus, based on projected conditions in 2020, the model might calculate that the least-cost plan uses a new natural gas combined cycle plant but calculate, based on projected conditions in 2030, that a combination of wind generation and a combustion turbine plant is best. The model does not attempt to resolve these different conclusions by solving the dynamic programming problem of how best to act over the full life- cycle of each generator.

With these simplifications in mind, the STEP model is a useful strategic planning tool, enabling rapid consideration of a wide range of alternatives and providing transparency as to why the model calculates its recommendations in a particular scenario. It can serve as an all-stakeholder screening tool to identify compliance plans for further analysis and refinement using their more cumbersome, expensive, and proprietary modeling tools. In its current form, STEP represents an improvement over the previous STEER model and can better support stakeholder engagement in IRP efforts.

STEP is available at no cost to any stakeholder. STEP must be populated with data appropriate to the scope of analysis, typically a State, which can potentially be done by anyone. 5 Lakes Energy provides this service at a modest cost. STEP is currently available for Michigan, Ohio, Pennsylvania, and Virginia.

STEP Model Application to Dominion Energy's IRP

STEP Virginia is a statewide model of Virginia's power system and includes but is not limited to Dominion Energy's Virginia service territory and generation resources. We therefore began by verifying that STEP Virginia predicts current generation mix that reasonably approximates current generation in Virginia. The following table shows 2017 net generation in Virginia by resource type[6] and the generation mix predicted by STEP Virginia given 2017 fuel and allowance prices.

[6] Obtained from the US Department of Energy' Energy Information Administration Electricity Data Browser, at https://www.eia.gov/electricity/data/browser/#/topic/0?agg=2,0,1&fuel=vtvv&geo=00000001&sec=g&linechart=ELEC.GEN.ALL-VA-99.A&columnchart=ELEC.GEN.ALL-VA-99.A&map=ELEC.GEN.ALL-VA-99.A&freq=A&ctype=linechart&ltype=pin&rtype=s&pin=&rse=0&maptype=0, on 10 September 2018.

Table 1.

Resource Type	2017 Virginia Generation (GWh)	2017 STEP Virginia Results (GWh)
Coal	10,809	13,700
Natural Gas	46,736	40,800
Nuclear	30,544	31,500
Wind	0	0
Solar	442	450
Biomass, Biogas	4.035	6,000
Hydropower	1,617	1,200
Other	440	
TOTAL	93,500	93,750
CO2 Emissions (million metric tons)	36.056	33.058

Since STEP Virginia is based on expected rather than actual plant availability, annual prices rather than short-term fuel prices, and similar approximations to reality, these results are reasonable. It is also notable that STEP Virginia shows that a $0.01 decrease in the price of natural gas from that used in the model produces an approximately 6,000 GWh reduction in coal generation and increase in natural gas generation relative to the STEP results shown above. This "knife-edge" behavior is normal behavior for an economic dispatch model and when fuel prices and demand are approximately at equilibrium between competing fuels.

In keeping with Dominion Energy's 15-year planning horizon, we used STEP Virginia to find the optimum generation portfolio and performance metrics in 2033.

As noted earlier, Dominion Energy's IRP modeling appears to be based on load, fuel price, emissions allowance, and electricity import projections made external to their resource portfolio modeling tool through an engagement with ICF. We therefore specified load, fuel price and electricity import projections based on Dominion Energy's projections for each of these. Because there are some differences in logic and assumptions in STEP Virginia and Dominion Energy's PLEXOS modeling, and because Dominion Energy used carbon emissions allowance processes that were calibrated to achieve Virginia's carbon emissions goal, we used carbon emissions allowance pricing to calibrate annual carbon emissions to 23.8 million tons carbon dioxide. We also assumed the same plant retirements described by Dominion Energy for each of the Plans.

Dominion Energy apparently imposed three constraints on its integration resource planning solutions that we also implemented in STEP Virginia when replicating Dominion Energy's analysis. The first of these constraints is that they used a capacity additions model, meaning that new capacity is only added when capacity is needed to meet planning reserve requirements and after subtracting requirements met through imports. A resource will not be added if capacity is not needed even if it is economically desirable. Thus, at some time in the future, the levelized cost of energy from a wind farm might be less than the cost of operating natural gas plants for comparable electricity generation in the times and quantities that would be produced by the wind farm, but the IRP model would not add the wind farm on that basis unless there was also a need for capacity.

The second constraint in Dominion Energy's IRP modeling was that Dominion Energy limited the pace of utility-scale solar development to 480 MW (nameplate) per year throughout the period until 2033 or 7.2 GW capacity. However, since 7.2 GW (nameplate) solar also is approximately the amount that would be added given Dominion's load projections, retirements, and import assumptions, the limit on the pace of solar development to 480 MW per year mainly served to delay rather than limit the ultimate amount of solar selected by STEP Virginia. It also likely caused Dominion Energy to select additional combustion turbine capacity in earlier years of its resource plan that it might not have selected with more rapid solar deployment.

The third constraint in Dominion Energy's IRP modeling was that Dominion Energy assumed a fixed level of energy efficiency programming, reflecting approved and planned programs. Expressed as a percentage of projected 2033 load, this assumption is that efficiency will reduce load by only 0.9%. Dominion did not provide a supply curve or series of supply levels for energy efficiency and allow its IRP modeling to select the most cost-effective level. Later in this paper, we show the effects of allowing STEP Virginia to choose an optimum level of energy efficiency programming.

STEP modeling did not assume Dominion Energy's resource options except those already under construction and the pilot offshore wind development. STEP made its own resource selections. The following table shows STEP Virginia's optimum statewide generation capacity in GW under the assumptions of each of Dominion Energy's Plans.

Table 2.A.

Resource Type	Current & Under Construction	2033 STEP DOM Plan A	2033 STEP DOM Plan B	2033 STEP DOM Plan C	2033 STEP DOM Plan D	2033 STEP DOM Plan E
Coal	4.7	3.7	1.8	1.8	1.8	3.7
Natural Gas	16.3	20.2	22.0	22.0	22.7	19.5
Nuclear	3.7	3.7	3.7	3.7	3.7	3.7
Wind	0.0	0.1	0.1	0.1	0.1	0.1
Solar	0.2	5.6	7.2	7.2	7.3	7.2
Biomass, Biogas	1.0	1.0	1.0	1.0	1.0	1.0
Hydropower	3.9	3.9	3.9	3.9	3.9	3.9
TOTAL	29.7	38.3	39.8	39.8	41.3	39.1

The following table shows STEP Virginia's optimum statewide generation in GWh, as well as total system costs, carbon emissions, and power imports under each of the Plans.

Table 2.B.

Resource Type	2033 STEP DOM Plan A	2033 STEP DOM Plan B	2033 STEP DOM Plan C	2033 STEP DOM Plan D	2033 STEP DOM Plan E
Coal	29.1	2.1	2.1	0.6	14.3
Natural Gas	48.4	44.0	43.9	59.5	47.4
Nuclear	31.5	31.5	31.5	31.5	31.5
Wind	0.3	0.3	0.3	0.3	0.3
Solar	8.4	10.8	10.9	10.9	10.8
Biomass, Biogas	8.3	7.0	7.0	6.1	7.1
Hydropower	1.2	1.2	1.2	1.2	1.2
TOTAL	127.3	96.8	96.8	110.2	112.7
Efficiency % Load	0.9	0.9	0.9	0.9	0.9
MMT CO2 Emissions	56.478	23.703	23.703	24.007	37.994
Cost 2018$ Billions	12.558	11.541	11.754	11.894	11.938
Carbon Price 2018$ per MT	0	9.00	9.00	10.00	8.00
Imports (GWh)	29.4	59.8	59.8	47.0	44.0

While these results are statewide and not directly comparable to Dominion Energy's results for its own portfolio, they are directionally and quantitatively quite similar.

STEP Model Application to Advanced Energy Alternative to Dominion Energy's IRP

Having validated that STEP Virginia produces results similar to those provided by Dominion Energy in its IRP, we next evaluated the effects of alternative assumptions regarding generation alternatives. We retained the core assumptions behind each of Dominion Energy's Plans but modified assumptions about wind resources to match the testimony of Hannah Hunt and modified assumptions about solar resources to match the testimony of Michael Volpe, each in Case No. PUR-2018-00065.

With respect to wind, we modified the capital cost of wind to $1,669 per kW nameplate capacity with about 2% annual improvements, which is the upper end of the range shown in the National Renewable Energy Laboratory's Annual

Technology Baseline for 2018 (“ATB”). With respect to solar, we used the ATB middle-scenario value of $1,065 per nameplate kW with about 6% annual improvements. Per Mr. Volpe’s testimony, we increased the amount of solar that could be deployed annually to 1000 MW (1 GW).

The following tables show the results of these scenarios, similar to the analyses of Dominion Energy’s plans shown above.

Table 3.A.

Resource Type	Current & Under Construction	2033 STEP AEE Plan A	2033 STEP AEE Plan B	2033 STEP AEE Plan C	2033 STEP AEE Plan D	2033 STEP AEE Plan E
Coal	4.7	3.7	1.8	1.8	1.8	3.7
Natural Gas	16.3	16.3	18.5	18.5	18.5	16.3
Nuclear	3.7	3.7	3.7	3.7	3.7	3.7
Wind	0.0	0.1	0.1	0.1	0.1	0.1
Solar	0.2	13.8	13.8	13.8	13.8	13.8
Biomass, Biogas	1.0	1.0	1.0	1.0	1.0	1.0
Hydropower	3.9	3.9	3.9	3.9	3.9	3.9
TOTAL	29.7	42.5	42.8	42.8	42.8	42.5

Table 3.B.

Resource Type	2033 STEP AEE Plan A	2033 STEP AEE Plan B	2033 STEP AEE Plan C	2033 STEP AEE Plan D	2033 STEP AEE Plan E
Coal	27.3	2.3	2.3	2.3	12.6
Natural Gas	38.9	43.3	43.4	44.3	39.4
Nuclear	31.3	30.7	30.7	30.7	30.9
Wind	0.3	0.3	0.3	0.3	0.3
Solar	21.2	21.2	21.2	21.2	21.2
Biomass, Biogas	8.1	6.8	6.7	6.5	6.9
Hydropower	1.2	1.2	1.2	1.2	1.2
TOTAL	128.4	105.9	105.9	106.7	112.6
Efficiency % Load	0.9	0.9	0.9	0.9	0.9
MMT CO2 Emissions	50.041	23.701	23.703	23.802	32.537
Cost 2018$ Billions	11.943	11.245	11.565	11.508	11.547
Carbon Price 2018$ per MT	0	9.00	9.00	10.00	8.00
Imports (GWh)	28.2	50.8	50.8	50.1	44.0

Thus, it appears that Dominion Energy's assumption that only 480 MW (nominal) solar can be deployed annually is constraining their IRP solutions and that the main effect of allowing 1000 MW (nominal) solar per year is to reduce imports when Virginia carbon emissions are limited and to reduce combustion turbine build-out.

STEP Model Application to Selecting Energy Efficiency Program Levels

In order to illustrate the importance of considering energy efficiency in Integrated Resource Planning, we evaluated each of Dominion Energy's Plans with available energy efficiency programming at 1% first-year savings per year, which we judged to be a level that Dominion Energy could aspire to achieve based on its current commitment to spend $870 million for energy efficiency programming over 10 years.[7] This level of energy efficiency programming is likely less than optimal, but optimization would require an energy efficiency potential study for Virginia designed to determine the costs of various increasing levels of program performance. In STEP, energy efficiency programming is not forced but is chosen up to the available level if it is cost-effective. As can be seen below, a consistent 12% of 2033 demand was reduced when this resource was made available.

Table 4.A.

Resource Type	Current & Under Construction	2033 STEP AEE Plan A	2033 STEP AEE Plan B	2033 STEP AEE Plan C	2033 STEP AEE Plan D	2033 STEP AEE Plan E
Coal	4.7	3.7	1.8	1.8	1.8	3.7
Natural Gas	16.3	14.7	18.0	18.0	18.0	14.7
Nuclear	3.7	3.7	3.7	3.7	3.7	3.7
Wind	0.0	0.1	0.1	0.1	0.1	0.1
Solar	0.2	13.8	11.3	11.3	11.3	13.8
Biomass, Biogas	1.0	1.0	1.0	1.0	1.0	1.0
Hydropower	3.9	3.9	3.9	3.9	3.9	3.9
TOTAL	29.7	40.9	39.8	39.8	42.8	40.9

[7] Enactment Clause 15 of SB. 966, approved March 9, 2018. https://lis.virginia.gov/cgi-bin/legp604.exe?181+sum+SB966

Table 4.B.

Resource Type	2033 STEP AEE Plan A	2033 STEP AEE Plan B	2033 STEP AEE Plan C	2033 STEP AEE Plan D	2033 STEP AEE Plan E
Coal	25.2	9.3	9.4	8.3	9.6
Natural Gas	24.5	25.4	25.7	27.8	26.5
Nuclear	30.6	30.7	30.7	30.8	30.0
Wind	0.3	0.3	0.3	0.3	0.3
Solar	21.2	17.2	17.2	17.2	21.2
Biomass, Biogas	8.0	7.3	7.3	7.3	6.6
Hydropower	1.2	1.2	1.2	1.2	1.2
TOTAL	111.0	91.4	91.8	92.9	95.5
Efficiency % Load	12.0%	12.0%	12.0%	12.0%	12.0%
MMT CO2 Emissions	41.072	23.741	23.939	23.724	23.4
Cost 2018$ Billions	10.882	10.831	10.922	10.951	10.782
Carbon Price 2018$ per MT	0	3.50	3.50	4.00	8.00
Imports (GWh)	28.2	50.8	47.0	45.9	44.4

Additional Observations from STEP Model Application to Dominion Energy's IRP

In the course of using STEP to evaluate Dominion Energy's IRP, we noted several items of interest, which we summarize below.

Volt-VAR Control: Dynamic Volt-VAR control in the distribution system and conservation voltage reduction can materially reduce both energy and peak loads at costs comparable to or lower than end-use energy efficiency and at much less cost than generation. STEP estimates that statewide application of this technology in Virginia would reduce statewide demand by as much as 567 MW.

Cogeneration: Virginia has significant opportunities for cost-effective cogeneration. To the extent that natural gas will be used for power generation, the incremental fuel required to cogenerate electricity is less than the fuel required to operate a combined cycle plant. In most natural gas and emissions allowance price regimes, STEP finds some cogeneration to be less costly and selects this resource. In our analyses for this paper, we did not allow selection of cogeneration. The IRP did not evaluate the opportunities for significantly increased cogeneration in Dominion Energy's service territory. Although we did not undertake to model all Plan scenarios with new cogeneration as an available resource, it is possible to determine within our present modeling results the types and sizes of cogeneration that appear to be cost-effective. For example, using Dominion Energy's Plan B assumptions but with both advanced energy renewable assumptions and 1% per year energy efficiency programming, cogeneration with steam turbines greater than 3 MW (with total Virginia technical potential of 314 MW) appear to be cost-effective, and reciprocating engines greater than 9 MW (with Virginia technical potential of 177 MW) are nearly cost-effective.

Storage. We did not model new storage in this analysis of Dominion Energy's Integrated Resource Plan but noted that it is likely that new storage becomes cost effective for managing bulk power within the planning horizon. Assuming current transmission limits, the maximum solar build-out we modeled, limited ability to make hourly adjustments in coal and nuclear output, and existing pumped storage, approximately 1% curtailment of solar generation does appear in the model. Curtailment is not the major driver of storage economics but the appearance of curtailment is indicative that further analysis of storage is warranted.

Conclusions

Evaluation of Dominion Energy's Integrated Resource Plan using STEP Virginia clearly demonstrates several important considerations:

1. Dominion Energy's assumption that only 480 MW nameplate utility-scale solar can be deployed per year significantly constrained their results. Optimization allowing up to 1000 MW led to most of that being built in most scenarios we modeled. Increased utility-scale solar deployment reduced combustion turbine additions and reduced power imports and reduced Virginia carbon emissions, at reduced total system cost, in scenarios that enforced Virginia's proposed carbon emissions cap.

2. Allowing increased energy efficiency programming was chosen when made available in the model and resulted in lower total system cost (including energy efficiency program costs) under all Plan scenarios. In the cases where Virginia carbon emissions were constrained, there was a reduced carbon emissions allowance price and reduced importation of power, with less shift from coal to natural gas generation as a result of the reduced carbon emissions allowance price.