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Decarbonizing Virginia's Economy: Pathways to 2050

Executive Summary

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EVOLVED ENERGY RESEARCH

How can Virginia reach carbon neutrality by 2050?

This report explores four strategies for decarbonization in Virginia: efficiency in energy use, eliminating fossil fuels from electricity generation, electrifying transportation services and building energy use, and capturing and sequestering remaining CO_2 emissions. The authors recognize that reaching carbon neutrality by mid-century will require aggressive deployment of low-carbon technologies.

ABOUT THE AUTHORS

FROM THE UNIVERSITY OF VIRGINIA WELDON COOPER CENTER FOR PUBLIC SERVICE

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FROM EVOLVED ENERGY RESEARCH — SAN FRANCISCO, CALIFORNIA

Ben Haley is a co-founder of Evolved Energy Research, where he develops energy system models to help guide the energy transformation decisions of government officials, utilities and other companies, and researchers.

Gabe Kwok is a principal at Evolved Energy Research, where he utilizes his modeling expertise and institutional and technical knowledge to holistically address decarbonization problems.

ENERGY TRANSITION INITIATIVE
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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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The Weldon Cooper Center for Public Service combines decades of knowledge about government, communities, and the people of Virginia with contemporary and advanced research, analytical expertise, and focused training for high performance in order to deliver public impact research and multi-sector leadership development to build the capacity of Virginia's communities, organizations, and institutions to serve the Commonwealth.

EVOLVED ENERGY RESEARCH

Evolved Energy Research (EER) develops tools and models to analyze energy sector questions posed by policy goals and new technology developments. EER takes a fundamentally new approach to examining energy systems by performing analyses that explicitly acknowledge the connectedness of the new energy economy, leverage technology in the pursuit of understanding, and embrace complexity as a means to confront uncertainty.

EXECUTIVE SUMMARY

Recent policy initiatives in Virginia reflect an increased urgency in addressing the state's contribution to global warming. This report presents results from the first study to analyze quantitatively and comprehensively the actions needed to make Virginia's economy carbon neutral by 2050.

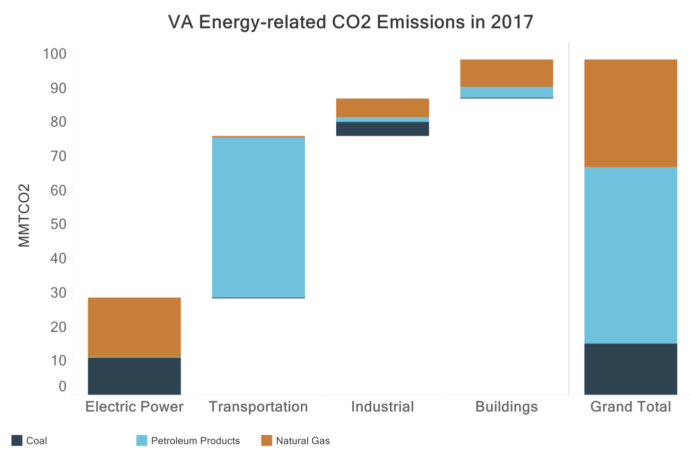

Figure 1: Transportation, buildings, and electricity generation dominate Virginia's current energy-related emissions.

Eliminating greenhouse gas emissions from Virginia's energy system will drive major changes in how the Commonwealth generates its electricity, heats its buildings, powers its vehicles, and charts its economic future. But decarbonization is achievable and affordable. The effort to decarbonize brings with it ancillary benefits in public health and in the reduced need to import energy resources from elsewhere. But the shift away from fossil fuels will not be fast enough or deep enough to achieve mid-century decarbonization targets without careful planning and policy design.

The Virginia Clean Economy Act (VCEA) focused on reducing emissions from electricity generation, which accounts for about 30% of Virginia's CO_2 emissions. Transportation accounts for nearly half, buildings and industry for the remaining 20%. Getting to net zero requires reducing emissions from transportation, buildings, and industry, as well as the electricity sector. Eliminating carbon emissions will require long-term energy storage, producing non-emitting liquid and gaseous fuels and even some amount of CO_2 removal from the atmosphere.

Key Results

The analysis supports several broad findings about Virginia's decarbonization options.

- *Decarbonization by 2050 is* achievable *and* affordable*.* Steep declines in costs for renewable electricity generation and other energy technologies open multiple pathways for bringing Virginia's energy-related carbon emissions to net zero by 2050. In all scenarios analyzed, *Virginia's expenditures on energy, as a share of Virginia's economy, will be lower than in the recent past.*

- *The economic benefits in improved health, reduced global warming and greater domestic energy production outweigh the costs*

- *Virginia has multiple options for achieving decarbonization.* Different policies and priorities imply different resource mixes and different costs. Least-cost options involve aggressive deployment of utility-scale solar and (in later years) off-shore wind, along with other non-emitting generation assets.

- *A quicker start means lower long-run costs; delay is costly.*

- *Careful planning and policy design pay big dividends.*

- *Coordination between state and local governments is essential.*

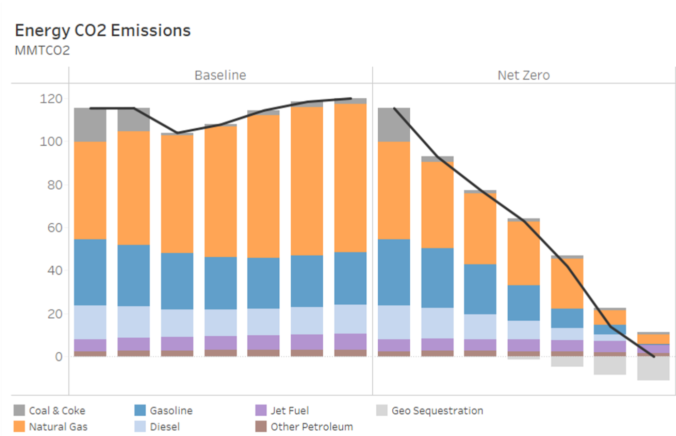

Figure 2: Emissions Trajectory for Baseline and Net Zero scenarios

> Decarbonization is achievable and affordable, and will lead to improved health and reduced global warming. But the shift will not be fast enough or deep enough to achieve mid-century decarbonization targets without careful planning and policy design.

Modeling Approach

We developed four scenarios to illustrate some of the trade-offs and uncertainties faced in planning for a large-scale restructuring of Virginia's energy economy over the next 30 years. All of the scenarios assume that we meet the 2050 goal of net zero carbon emissions for the entire Virginia economy. These scenarios illustrate the feasibility of achieving the net zero goal and the advantage of technological innovation in lowering costs. They also illustrate the costs of delay and the costs of constraints on the availability of some energy resources.

The Scenarios

Our four 2050 decarbonization scenarios:

1. **Net Zero:** Identifies the least-cost pathway, given the available resources and the most likely case for available technology.
2. **Constrained Land and Nuclear:** Explores the energy resource trade-offs and increased costs that occur when solar and new nuclear face additional constraints.
3. **Slow Consumer Adoption:** Shows the cost of delay in initiating the transition in the large existing stock of vehicles and buildings.
4. **Rapid Innovation:** Illustrates the effects of higher rates of innovation in clean energy technologies on energy costs and resource mix.

The scenarios were modeled using a suite of energy system and pathways models, RIO and EnergyPATHWAYS respectively, developed by Evolved Energy Research. These models were calibrated for Virginia, taking into account detailed information about Virginia's energy economy. For each scenario, the model performs an energy system optimization given the scenario assumptions. We take as given the current economic and policy environment, which includes 2020 legislation. Technology is assumed to develop in line with historical patterns.

> Our four decarbonization scenarios illustrate different approaches we can take to reach net zero. They are not forecasts, but potential pathways meant to highlight the costs and benefits of different choices we may make and of acting quickly.

Findings This study, and others like it demonstrate that there are four essential components of any cost-effective decarbonization strategy:

- Efficiency in energy end-use -
  - Reducing the energy intensity of providing services like transportation, heating and cooling, etc.
- Decarbonization of energy sources, especially electricity -
  - Replacing fossil fuel generation with non-emitting sources such as solar, wind and nuclear. Deep penetration of renewables will require investments in energy storage, including longer-term storage using hydrogen or synthetic fuels.
- Electrification of energy services in buildings, vehicles and factories -
  - Shifting from direct use of fossil fuels to non-emitting electricity
- Carbon capture and sequestration for residual emissions -
  - Capturing and sequestering some emissions avoids expensive replacement of fossil fuels in some industrial applications.

Even though *electricity* demand can be expected to nearly double by 2050, total *energy* demand in Virginia is not projected to increase in most of our scenarios, because increased electrification of buildings and transportation brings with it substantial efficiencies in energy use.

In feasible decarbonization scenarios, electricity replaces most other energy sources in buildings and in transportation. Electricity is generated using renewables, primarily utility-scale solar and off-shore wind, along with the existing fleet of nuclear plants. Coal is no longer used to produce electricity. Some of our existing natural gas generation fleet will be needed to ensure reliability of electricity service but will be converted to use a zero carbon fuel and will operate infrequently (that is, at low capacity factors). Increasing the share of renewables will require an array of energy storage technologies including batteries, hydrogen and synthetic fuels. Additional sources of dispatchable non-emitting electricity, such as advanced nuclear or bioenergy with carbon capture and sequestration, help keep the costs of transition down. Locally produced hydrogen and imported zero carbon liquid fuels will be used in applications where electrification is difficult or long-term storage is needed.

Some fossil fuel use in industry will be very expensive to replace, so we will need some carbon capture and sequestration (negative emissions) to balance any remaining GHG emissions. Given current technology forecasts, sequestration will likely take one of two forms: (1) natural sequestration in fields, forests and coastal ecosystems and (2) bioenergy with carbon capture and sequestration, where wood waste is gasified to generate hydrogen, and the CO_2 emissions are captured and geologically sequestered.

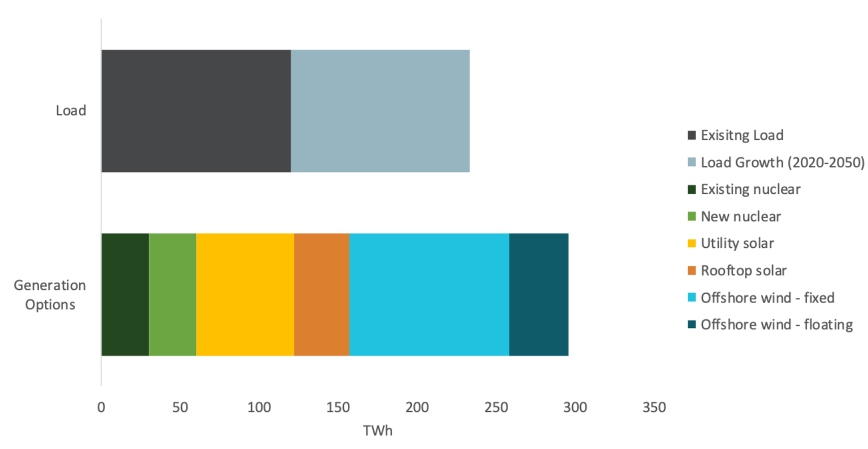

Figure 3: Generation options for meeting projected growth in electricity load

Because of its substantially higher cost, distributed solar energy from rooftops is not a major source of electricity except in cases where other resources are constrained or where rapid innovation reduces its cost relative to other energy sources. Initiatives that lower the installed cost of rooftop solar and provide efficient price signals to consumers could increase the contribution of distributed solar and cost-effectively diversify Virginia's clean energy resource mix.

Costs (and Benefits) of Deep Decarbonization

Decarbonization increases energy expenditures in some areas and reduces them in others. New investment in local clean electricity and end-use equipment, such as electric vehicles and building HVAC systems reduces spending on imported natural gas and petroleum products. Compared to the business as usual baseline, additional annual expenditures on energy in the Net Zero scenario amount to between $2.3 and $3.1 billion ($2018) rising to between $4.5 and $11.6 billion ($2018).[1] Expenditures remain well under 1% of gross state product (GSP) and are less than the current share of GSP spent on energy services and equipment. Costs are significantly higher in the Constrained Land and Nuclear scenario and the Slow Consumer Adoption scenario. The Rapid Innovation scenario shows that attention to research, development and diffusion of clean energy innovations could result in net energy cost savings from implementing decarbonization.

[1]The range of estimates is based on uncertainty over future fossil fuel prices. These next expenditure calculations do not include health, climate and other benefits.

If implemented efficiently, the economic benefits of decarbonization, in reduced health and climate costs, will be greater than the costs of achieving it. There will also be broader economic gains from substituting cost-effective local production for imported fuels and from reduced exposure to price volatility in international oil markets. For cost-effective approaches to the transition, economic multiplier effects from increased in-state investment could yield additional net benefits for Virginia.

Essential State Policy Initiatives

Since 2007, GHG emissions attributable to retail sales of electricty in Virginia have fallen dramatically. This recent trend does not mean that Virginia's emissions would reach the near zero levels needed to protect the climate without a substantial push from public policy. Recent reductions in emissions have been driven by the substitution of natural gas for coal in generation, and this process is now nearing completion.

Transportation: The reduction in emissions has not touched the transportation sector, the largest source of CO_2 emissions. Virginia should explore policies to ensure the rapid build-out of charging stations for electric vehicles. As electric vehicle costs fall and the EV charging infrastructure becomes more fully developed, placing transportation GHG emissions under a cap, as proposed by the Transportation and Climate Initiative, would accelerate the electrification of the transportation sector, without imposing unreasonable costs on households or businesses in Virginia.

Buildings: Building codes will need to be updated and infrastructure investments will need to be redirected away from fossil fuels towards non-emitting resources. Policies should encourage replacing the direct use of natural gas for HVAC and water-heating applications in buildings with energy efficient electric heat pumps and water heaters, which are already cost effective in Virginia.

Electricity generation: Virginia has already begun decarbonization of the electricity sector by joining the Regional Greenhouse Gas Initiative (RGGI) cap on emission and by accelerating renewables deployment.

Administrative capacity: Achieving cost-effective decarbonization requires establishing the administrative capacity within Virginia state government to plan and coordinate the state's actions across numerous state government agencies and local jurisdictions. In addition to gathering data and advising policy makers, the agency would need to:

- Arrange for pilots of new technologies, programs and policies and evaluate their effectiveness
- Coordinate actions across state agencies in cooperation with federal programs
- Provide assistance to localities
- Study frictions slowing renewables development
- Develop strategies for implementing carbon sequestration

To conclude, we present a schedule of policy initiatives that need to be implemented to achieve full decarbonization by 2050. Some items on this list are urgent, with the path for implementation clear. Others are off into the future and are far less certain.

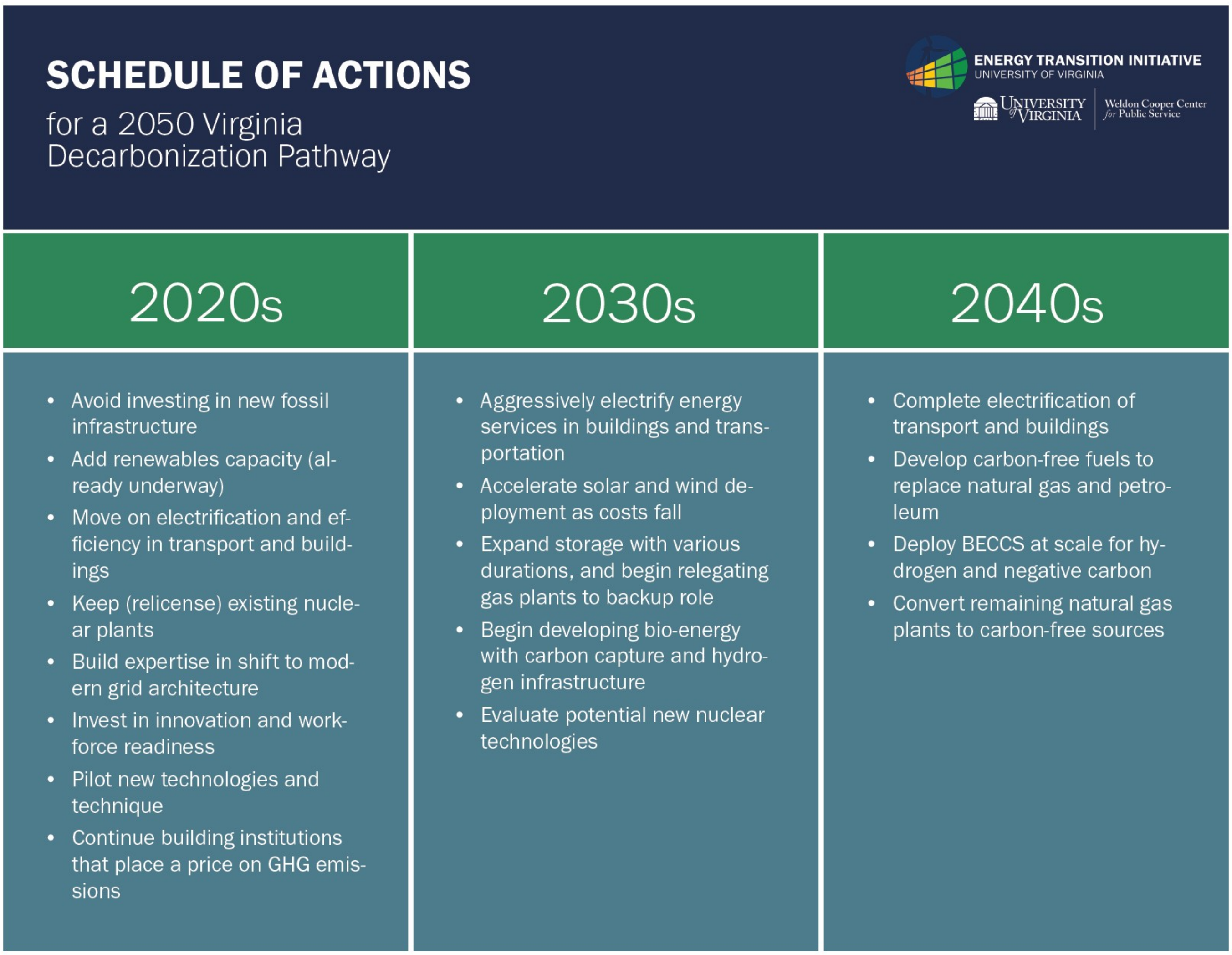

Figure 4: 2050 Virginia Decarbonization Pathway: Schedule of Actions

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.

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