

SECTION 4 - RENEWABLES

Renewable energy is defined by Virginia statute to include:

- Solar
- Wind
- Hydroelectric, not including pumped storage
- Biomass
- Energy from waste, including municipal solid waste
- Landfill gas
- Wave motion and tides
- Geothermal

Virginia's viable and existing renewable resources include:

- Biomass
- Waste-to-energy, landfill and waste water treatment gas
- Wind, both offshore and on-shore
- Hydroelectric, not including pumped storage
- Low temperature geothermal (not including geothermal heat pumps)
- Solar thermal for heating air and water
- Solar photovoltaic



In 2010, these resources provided about 6.2 percent of the electricity capacity in Virginia and about 5.1 percent of the electricity generated.¹ Virginia is ranked 26th in the nation for renewable capacity, with just under 1.5 gigawatts of net summer renewable generating capacity.²

Most forms of renewable energy emit zero carbon dioxide in the production of electricity. Therefore, the use of these sources as a substitute to high carbon producing coal will significantly reduce Virginia's carbon intensity.

Electricity generated from renewables in Virginia is used in several ways:

- The primary use of renewable electricity has been on-site distributed generation using primarily grid connected solar photovoltaic or small wind systems. While exact counts are not available, a small number of off-grid homes use solar and/or small wind systems coupled with battery storage. Typically, however, even systems with battery storage are grid connected and the batteries add a measure of energy security in the event of power outages.
- Virginia's electric utilities own renewable generation assets, or purchase renewable energy from non-utility renewable energy projects to meet their service obligation and Virginia's voluntary renewable energy portfolio goals.

¹ Energy Information Administration, Virginia Renewable Energy Profile 2010 <http://www.eia.gov/renewable/state/virginia/>

² Energy Information Administration, State Renewable Electricity Profiles: <http://www.eia.gov/renewable/state>

Financial incentives
such as state or
federal tax credits can
significantly affect the
levelized cost
estimate.

Cost of Renewables Compared to Other Generation

Table 4.1 provides the average national levelized costs for the generating technologies represented in the U.S Energy Information Administration's 2014 *Annual Energy Outlook*.

Financial incentives such as state or federal tax credits can significantly affect the levelized cost estimate. For example, new solar and wind power systems are eligible to receive a 30-percent investment tax credit on capital expenditures if placed in service before the end of 2016, and 10 percent thereafter.

New wind, geothermal, biomass, hydroelectric, and landfill gas plants are eligible to receive from the federal government, either: (1) \$21.50 per MWh (\$10.70 per MWh for technologies other than wind, geothermal, and closed-loop biomass) inflation-adjusted production tax credit over the plant's first ten years of service or, (2) a 30-percent investment tax credit, if under construction before the end of 2013.



Table 4-1: Estimated Levelized Cost for New Generation Resources Entering Service in 2019³

U.S. average levelized costs (2012 \$/MWh) for plants entering service in 2019								
Plant type	Capacity factor (%)	Levelized capital cost	Fixed O&M	Variable O&M (including fuel)	Transmission investment	Total system LCOE	Subsidy ¹	Total LCOE including Subsidy
Dispatchable Technologies								
Conventional Coal	85	60.0	4.2	30.3	1.2	95.6		
Integrated Coal-Gasification Combined Cycle (IGCC)	85	76.1	6.9	31.7	1.2	115.9		
IGCC with CCS	85	97.8	9.8	38.6	1.2	147.4		
Natural Gas-fired								
Conventional Combined Cycle	87	14.3	1.7	49.1	1.2	66.3		
Advanced Combined Cycle	87	15.7	2.0	45.5	1.2	64.4		
Advanced CC with CCS	87	30.3	4.2	55.6	1.2	91.3		
Conventional Combustion Turbine	30	40.2	2.8	82.0	3.4	128.4		
Advanced Combustion Turbine	30	27.3	2.7	70.3	3.4	103.8		
Advanced Nuclear	90	71.4	11.8	11.8	1.1	96.1	-10.0	86.1
Geothermal	92	34.2	12.2	0.0	1.4	47.9	-3.4	44.5
Biomass	83	47.4	14.5	39.5	1.2	102.6		
Non-Dispatchable Technologies								
Wind	35	64.1	13.0	0.0	3.2	80.3		
Wind-Offshore	37	175.4	22.8	0.0	5.8	204.1		
Solar PV ²	25	114.5	11.4	0.0	4.1	130.0	-11.5	118.6
Solar Thermal	20	195.0	42.1	0.0	6.0	243.1	-19.5	223.6
Hydro ³	53	72.0	4.1	6.4	2.0	84.5		

¹The subsidy component is based on targeted tax credits such as the production or investment tax credit available for some technologies. It only reflects subsidies available in 2019, which include a permanent 10% investment tax credit for geothermal and solar technologies, and the \$18.0/MWh production tax credit for up to 6 GW of advanced nuclear plants, based on the Energy Policy Acts of 1992 and 2005. EIA models tax credit expiration as in current laws and regulations: A new solar thermal and PV plants are eligible to receive a 30% investment tax credit on capital expenditures if placed in service before the end of 2016, and 10% thereafter. New wind, geothermal, biomass, hydroelectric, and landfill gas plants are eligible to receive either: (1) a \$21.5/MWh (\$10.7/MWh for technologies other than wind, geothermal and closed-loop biomass) inflation-adjusted production tax credit over the plant's first ten years of service or (2) a 30% investment tax credit, if they are under construction before the end of 2013.

²Costs are expressed in terms of net AC power available to the grid for the installed capacity.

³As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2014*, April 30, 2014, DOE/EIA-0383(2014).

³ Energy Information Administration, *Annual Energy Outlook 2014*, April 30, 2014, DOE/EIA-0383(2014)

Because of regional differences in the cost of labor, fuel, and other factors that affect the levelized generation cost, the cost for generation technologies will vary by location. Table 4.2 gives the range in the levelized cost based on these regional differences.

Table 4-2: Regional Variation in Levelized Cost of New Generation, 2017⁴

Plant type	Range for total system LCOE (2012 \$/MWh)			Range for total LCOE with subsidies ¹ (2012 \$/MWh)		
	Minimum	Average	Maximum	Minimum	Average	Maximum
Dispatchable Technologies						
Conventional Coal	87.0	95.6	114.4			
IGCC	106.4	115.9	131.5			
IGCC with CCS	137.3	147.4	163.3			
Natural Gas-fired						
Conventional Combined Cycle	61.1	66.3	75.8			
Advanced Combined Cycle	59.6	64.4	73.6			
Advanced CC with CCS	85.5	91.3	105.0			
Conventional Combustion Turbine	106.0	128.4	149.4			
Advanced Combustion Turbine	96.9	103.8	119.8			
Advanced Nuclear	92.6	96.1	102.0	82.6	86.1	92.0
Geothermal	46.2	47.9	50.3	43.1	44.5	46.4
Biomass	92.3	102.6	122.9			
Non-Dispatchable Technologies						
Wind	71.3	80.3	90.3			
Wind-Offshore	168.7	204.1	271.0			
Solar PV ²	101.4	130.0	200.9	92.6	118.6	182.6
Solar Thermal	176.8	243.1	388.0	162.6	233.6	356.7
Hydro ³	61.6	84.5	137.7			

¹Levelized cost with subsidies reflects subsidies available in 2019, which include a permanent 10% investment tax credit for geothermal and solar technologies, and the \$18.0/MWh production tax credit for up to 6 GW of advanced nuclear plants, based on the Energy Policy Acts of 1992 and 2005.

² Costs are expressed in terms of net AC power available to the grid for the installed capacity.

³As modeled, hydroelectric is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.

Note: The levelized costs for non-dispatchable technologies are calculated based on the capacity factor for the marginal site modeled in each region, which can vary significantly by region. The capacity factor ranges for these technologies are as follows: Wind – 31% to 45%, Wind Offshore – 33% to 42%, Solar PV- 22% to 32%, Solar Thermal – 11% to 26%, and Hydroelectric – 30% to 65%. The levelized costs are also affected by regional variations in construction labor rates and capital costs as well as resource availability.

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2014*, April 30, DOE/EIA-0383(2014)

⁴ Energy Information Administration, *Annual Energy Outlook 2014*, April 30, 2014, DOE/EIA-0383(2014)

Table 4.3 shows a comparison of estimated capital cost for new generation capacity for various technologies. It should be noted that even though there are no utility-scale photovoltaic systems in Virginia, the cost reduction for residential-sized systems has shown to be comparable to those shown in Table 4.3. In the two-year period between 2010 and 2012 that the Virginia Solar and Wind Power Rebate Program was active,⁵ the installed cost for residential and small commercial photovoltaic systems went from an average of \$8.20 per watt installed to \$5.70 per watt, or around a 30 percent reduction.

Table 4-3: Comparison of 2011 Updated Plant Costs to 2010 Plant Costs⁶

	Overnight Capital Costs (2012 \$/kW)		
	2013 Report	2010 Report	% Difference
Coal			
Single Unit Advanced PC	\$3,246	\$3,292	-1%
Dual Unit Advanced PC	\$2,934	\$2,956	-1%
Single Unit Advanced PC with CCS	\$5,227	\$5,300	-1%
Dual Unit Advanced PC with CCS	\$4,724	\$4,760	-1%
Single Unit IGCC	\$4,400	\$3,706	19%
Dual Unit IGCC	\$3,784	\$3,348	13%
Single Unit IGCC with CCS	\$6,599	\$5,559	19%
Natural Gas			
Conventional CC	\$917	\$1,017	-10%
Advanced CC	\$1,023	\$1,043	-2%
Advanced CC with CCS	\$2,095	\$2,141	-2%
Conventional CT	\$973	\$1,012	-4%
Advanced CT	\$676	\$691	-2%
Fuel Cells	\$7,108	\$7,105	0%
Uranium			
Dual Unit Nuclear	\$5,530	\$5,546	0%
Biomass			
Biomass CC	\$8,180	\$8,205	0%
Biomass BFB	\$4,114	\$4,012	3%
Wind			
Onshore Wind	\$2,213	\$2,534	-13%
Offshore Wind	\$6,230	\$6,211	0%
Solar			
Solar Thermal	\$5,067	\$4,877	4%
Solar Photovoltaic (7 MW)	N/A	\$6,289	N/A
Solar Photovoltaic (20 MW)	\$4,183	N/A	N/A
Solar Photovoltaic (150 MW)	\$3,873	\$4,943	-22%
Geothermal			
Geothermal – Dual Flash	\$6,243	\$5,798	8%
Geothermal – Binary	\$4,362	\$4,304	1%
Municipal Solid Waste			
Municipal SolidWaste	\$8,312	\$8,557	-3%
Hydroelectric			
Conventional Hydroelectric	\$2,936	\$3,197	-8%
Pumped Storage	\$5,288	\$5,816	-9%

⁵ Implemented by the Virginia Department of Mines, Minerals and Energy and funded through the American Recovery and Reinvestment Act (ARRA)

⁶ U.S. Energy Information Administration, Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants, April 2013

Virginia currently has several programs and policies intended to enable the growth of renewable energy, including:

Voluntary Renewable Energy Standard

- Voluntary renewable energy goals calling for 15 percent of 2007 baseline electric production to come from renewable sources by 2025. Utilities are eligible to receive an enhanced rate-of-return for investments in renewable electric generating facilities. Both onshore wind and solar power count as double credit toward meeting a utility's renewable energy goals. Offshore wind counts as triple credit.

Net Metering

- Under Virginia's *net metering* law, residential electric consumers may generate up to 20 kilowatts (kW) of grid-connected renewable power to offset their load. Non-residential consumers may generate up to 500 kW, with an option to generate more at the discretion of the non-residential customer's electric utility.

For both residential and non-residential renewable generators, excess electricity generated at the end of the monthly billing period is credited to the customer at the retail rate. Upon the written request of the net metering customer, the customer's electricity supplier must enter into a power purchase agreement for any excess generation at the end of the net metering period (the anniversary of the date of interconnection). Consumers entering into a power purchase arrangement with their utility are not paid the retail rate, but what is essentially the utility's wholesale rate.



In 2012, the legislature amended the net metering law to allow utilities to charge stand-by fees to residential net metering customers. Retail electric rates include charges for transmission and distribution infrastructure. To avoid cross subsidization of transmission and distribution infrastructure by all other ratepayers, residential consumers with a system capacity greater than 10 kilowatts must now pay \$2.79 a kW in monthly distribution standby charges and \$1.40 kW in monthly transmission standby charges. Non-residential consumers with grid-connected renewable generation are exempt from these additional charges. Advocates of distributed generation from renewables such as solar or small wind power argue that the standby charges are a disincentive and that the value of solar generation in particular, especially at peak times, more than makes up for any lost transmission and distribution fees.

In 2013, the net metering law was again amended to allow for *agricultural net metering*, for certain types of energy production systems, thereby allowing the output of a renewable energy system up to 500 kilowatts in capacity to be shared with multiple metered facilities at contiguous sites on the agricultural facility's property.

Sale of Renewable Energy Credits

Renewable energy system owners can sell their Renewable Energy Credits (RECs) as an additional revenue stream. Renewable energy credits, also known as renewable energy certificates, green certificates, green tags, or tradable renewable certificates, represent the environmental attributes of the power produced from renewable energy projects and are sold separate from commodity electricity. Customers can buy green certificates whether or not they have access to green power through their local utility or a competitive electricity marketer; and they can purchase renewable energy certificates without having to switch electricity suppliers.

At one time, Virginia citizens could sell their solar RECs, also known as SRECs, in North Carolina, Maryland, Pennsylvania, and Washington, DC, to help electric utilities in those states and the District meet their renewable portfolio mandates. However, at this time, Maryland and the District of Columbia no longer allow out-of-state SRECs, and limit SRECs to those generated within their borders or to solar energy systems connected to a distribution feeder serving them.

One-Stop Permitting

In 2009, the Virginia General Assembly enacted legislation directing the Department of Environmental Quality to develop regulations for the construction and operation of renewable energy projects in Virginia. A Regulatory Advisory Panel (RAP) made up of key stakeholders developed a streamlined Permit by Rule (PBR) process for the review and approval of renewable energy projects 100 megawatts and smaller, or up to 20 megawatts for combustion projects such as biomass, landfill gas, or municipal solid waste.

The PBR process is intended to offer project developers regulatory certainty and a finite time frame for permit issuance. The first PBR tackled by the RAP was for wind energy projects in 2009-10 and went into effect in December 2010. The solar PBR became effective on July 18, 2012. The combustion PBR for renewables such as biomass, landfill gas, and municipal solid waste became effective on August 28, 2013.

After careful consideration of the issues, the Water-Related Regulatory Advisory Panel recommended, and the DEQ director agreed, that it is not necessary or appropriate at this time and under current conditions for DEQ to develop a PBR regulation for projects that generate electricity from falling water, wave motion, tides, or geothermal resources.

Siting of Renewable Energy Projects

Virginia local governments bear the chief responsibility for siting renewable energy projects. In response to questions raised by local governments and others, the Virginia Department of Environmental Quality convened an informal stakeholder group comprised of representatives from state and local government, planning officials, industry, and non-governmental organizations, and others to develop model ordinances and other information that local governments may choose to consult when addressing the issue of where

to locate renewable energy facilities. A model utility scale wind ordinance and other resources are available at <http://www.deq.virginia.gov/Programs/RenewableEnergy/ModelOrdinances.aspx>.

Other Supporting Policies

- In 2014, the VA General Assembly passed legislation allowing commercially owned solar energy property to be classified as pollution control equipment, thereby exempting it from state and local taxation.
- Also in 2014, the VA General Assembly passed a bill making it easier for homeowners in community associations to install solar panels on their property. Homeowners Associations can only ban solar panels if the ban is contained within their original recorded declarations.

Virginia has an onshore wind resource potential of 1,793 MW at an 80 meter "hub height" capable of providing clean renewable power to thousands of Virginia homes and businesses.

Onshore Wind Power in Virginia

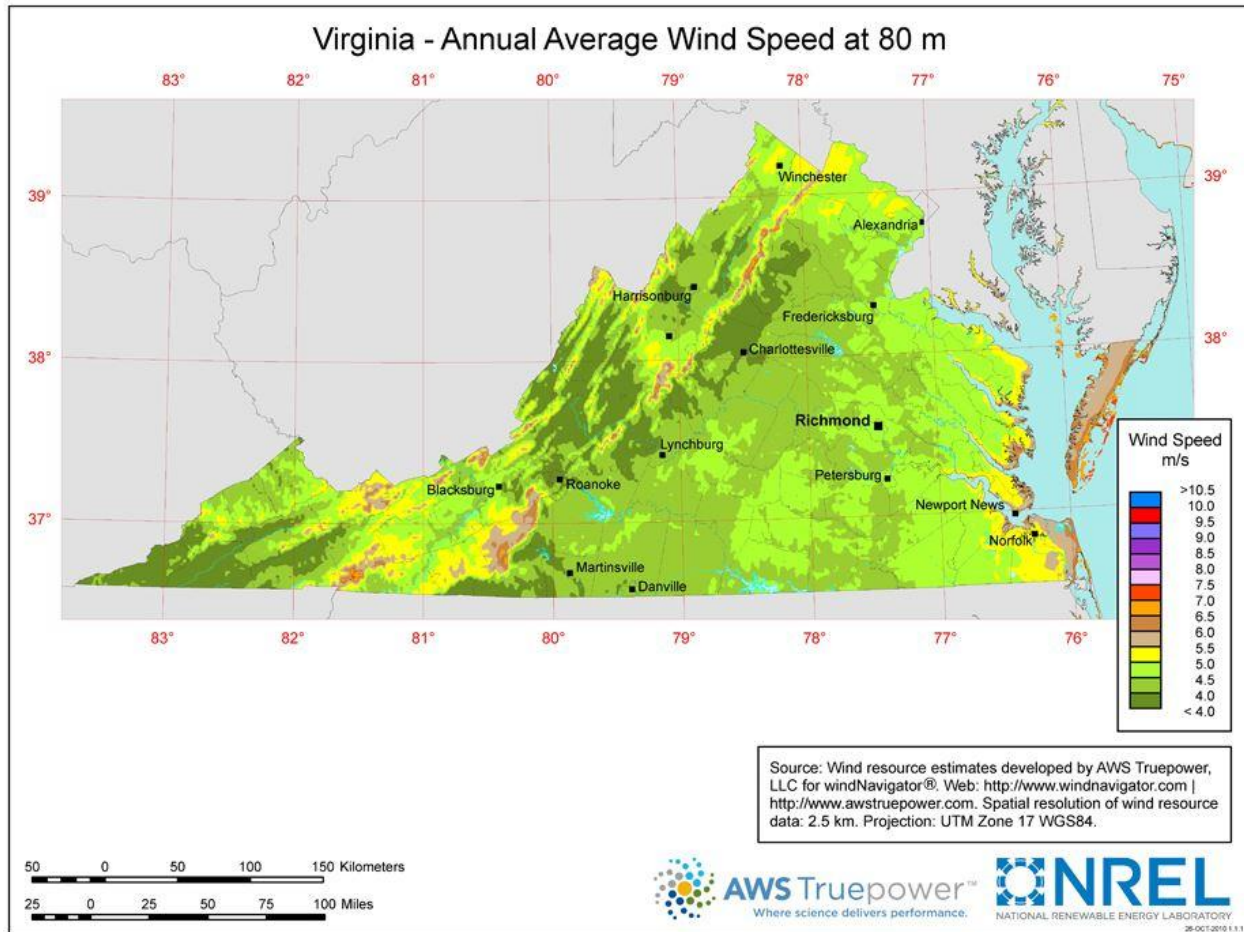
Virginia has an onshore wind resource potential of 1,793 MW at an 80 meter "hub height"⁷ capable of providing clean renewable power to thousands of Virginia homes and businesses. The most promising onshore wind resources are in the Western part of the State along mountain ridges. The hub height is defined as the distance from the center axis of a wind turbine rotor to the ground. A hub height of 80 meters is not uncommon for modern utility-scale wind turbines, and the future looks towards hub heights of upwards of 100 meters.

In general, wind speed increases as the height above the ground increases and the amount of clearance of obstructions like trees and buildings increases. This is important because the power output of a wind generator is proportional to the cube of the wind speed. For example, if you double the wind speed, the power output from the wind turbine will increase by a factor of eight.



⁷ American Wind Energy Association's Virginia Wind Energy Fact Sheet" <http://www.awea.org/Resources/state.aspx?ItemNumber=5180>

Figure 4-1: Virginia Wind Speeds – 80 meter height⁸



To date, the only onshore wind power project to receive regulatory approval is the 39 megawatt Highland New Wind project in Highland County, which received final approval to begin construction in 2008. A number of other developers, including Dominion have been exploring projects in several Virginia counties.

Dominion Virginia Power currently operates two wind power generation facilities that serve Virginia load. These include 1) a fifty percent interest in the 264 megawatt NedPower Mount Storm facility in Grant County, West Virginia, and 2) a fifty percent interest in the 300 megawatt Fowler Ridge I facility located in Benton County, Indiana.⁹

Appalachian Power Company purchases 75 megawatts worth of renewable energy certificates from the Camp Grove wind facility in Illinois and 100 megawatts from the Fowler Ridge II project in Indiana.¹⁰

⁸ U.S. DOE WINDEXchange: http://apps2.eere.energy.gov/wind/windexchange/wind_resource_maps.asp?stateab=va

⁹ <http://www.dom.com/about/environment/report/renewable-energy-and-green-power.jsp>

¹⁰ Virginia State Corporation Commission, "Report to the Commission on Electric Utility Regulation of the Virginia General Assembly", http://www.scc.virginia.gov/comm/reports/2010_veur.pdf, June 24, 2011

To support the development of wind power in Virginia, the Virginia Center for Wind Energy at James Madison University (JMU) has created several programs to assist in assessing the suitability of sites for land-based residential and utility-scale wind projects. This assistance to local governments, state agencies, landowners, academia, non-governmental organizations, and businesses includes wind resource measurements, economic modeling, education & outreach, energy policy analysis, assessment of technical specifications, Geographic Information Systems analysis, and the strategic deployment of wind power within the Commonwealth and beyond.

More information on JMU's wind power activities is available at: <http://wind.jmu.edu>.

Onshore wind is a well-established technology and industry. In 2013, the U.S. had 61,091 MW of onshore wind capacity, second only to China.¹¹ Wind only generates electricity when wind speeds are sufficient to turn the turbine blades, and because wind is intermittent and unpredictable, sufficient other generation assets must be available to ensure capacity requirements are met. Typical capacity factors for onshore wind range between 30 percent and 45 percent, with a median of 39 percent.¹² The percent of time a wind turbine generates power is called its capacity factor

Wind projects have relatively high capital costs, but benefits from low operating costs and zero fuel costs for the life of the project. Because the fuel (wind) is free, electricity from wind is not subject to escalating fuel costs.

In 2012, the capacity-weighted average installed project cost stood at roughly \$1,940/kW, down almost \$200/kW from the reported average cost in 2011, and down almost \$300/kW from the apparent peak in average reported costs in 2009 and 2010.¹³

After topping out at nearly \$70/MWh for power purchase agreements (PPAs) executed in 2009, the average levelized price of wind PPAs signed in 2011/2012—many of which were for projects built in 2012—fell to around \$40/MWh nationwide, which rivals previous lows set back in the 2000–2005 period.¹⁴

Offshore Wind Power

Offshore wind has the potential to provide the largest, scalable renewable energy resource for Virginia. The State currently does not have any utility-scale wind power in operation

Virginia is unique with a shallow continental shelf that extends out 30 miles. With its proximity to load centers, supply chain infrastructure, a trained work force and best in class ports, offshore wind can provide substantial benefits to the State.



¹¹ Global Wind Statistics 2013. Global Wind Energy Council. May 5, 2014. p. 3.

¹² Transparent Cost Database. OpenEI. Retrieved from <http://en.openei.org/apps/TCDB/>, May 27, 2014.

¹³ http://www1.eere.energy.gov/library/asset_handler.aspx?src=http://wind.energy.gov/pdfs/2012_wind_technologies_market_report.pdf&id=6436

¹⁴ Ibid.

In 2013, Dominion Virginia Power won a federal lease for 112,800 acres off the Virginia coast to develop offshore wind power with the potential to generate up to 2000 megawatts, or enough to electricity to power 500,000 homes.¹⁵

The Chesapeake Bay and state waters within 3 nautical miles off the coast of Virginia are dominated by Class 4 winds (7 to 7.5 meters per second).

Federal waters on Virginia's Outer Continental Shelf (OCS) are dominated by Class 5 and Class 6 winds (7.5 to 8.8 meters per second).

The total potential wind power generation capacity in Class 5 and Class 6 winds on Virginia's OCS between 3 and 50 nautical miles offshore is 47,900 MW, having a maximum potential annual energy output of 176 million megawatt-hours per year.

Offshore wind has the potential to provide the largest, scalable renewable energy resource for Virginia.

It is estimated that there are more than 3,000 megawatts of offshore wind capacity in waters with depth less than 30 meters. This depth is important as it allows use of conventional, commercially available foundation technologies, improving the cost effectiveness of offshore installations.¹⁶

The Virginia Department of Mines, Minerals and Energy submitted 2 unsolicited applications for research leases.

Research Lease 1 was initially intended for siting of meteorological ocean and environmental monitoring platforms, however, final details on the specific research activities have not yet been determined.

Research Lease 2 was secured for the development of Dominion Virginia Power's *Virginia Offshore Wind Technology Advancement Project* (VOWTAP). The VOWTAP will culminate in the construction of two, 6 megawatt Alstom Haliade™ wind turbines. The primary objectives of the VOWTAP are:

- To design, develop, and demonstrate a state-of-the art grid-connected 12 megawatt (MW) offshore wind research facility off the coast of Virginia
- Employ technology innovations and research that will inform and benefit future commercial scale offshore wind developments in the United States
- Develop technologies and process solutions that will contribute to establishing offshore wind as a cost-effective renewable energy solution for the United States

¹⁵ Dominion Virginia Power: <https://www.dom.com/about/stations/renewable/offshore-wind-power.jsp>

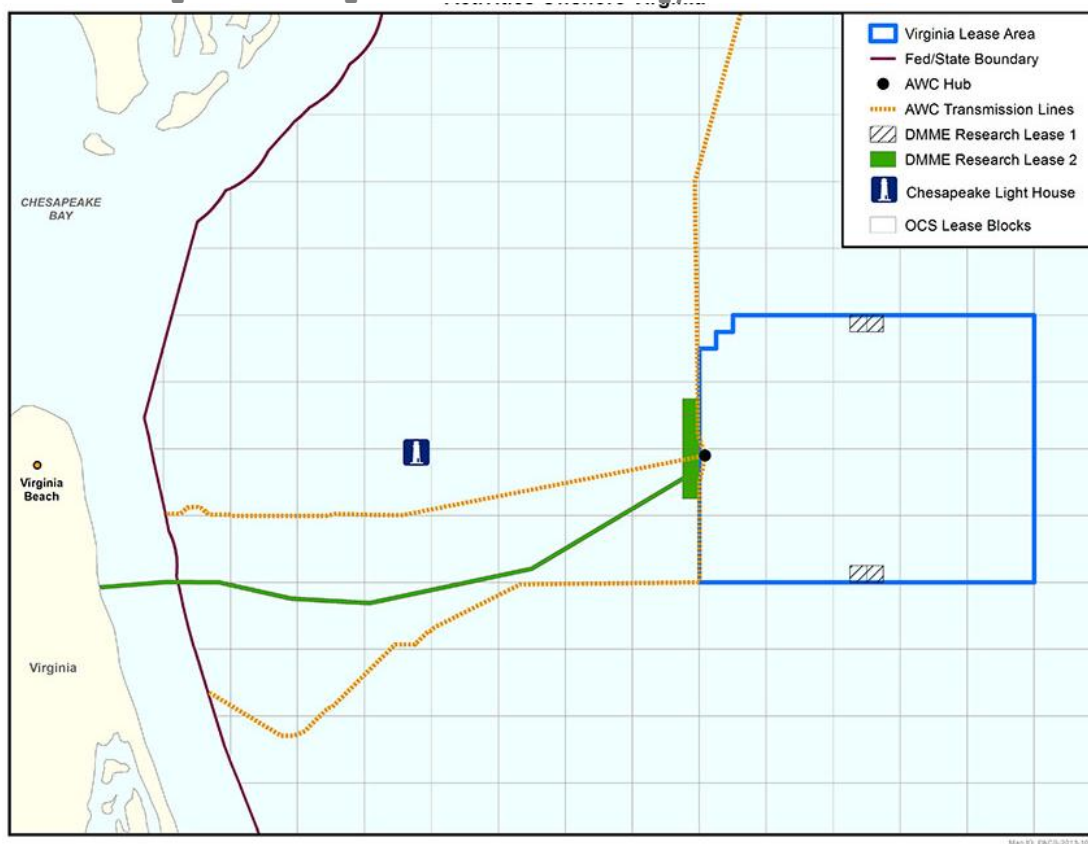
¹⁶ VCERC Virginia Offshore Wind Studies, July 2007 to March 2010 Final Report
http://www.vcerc.org/VCERC_Final_Report_Offshore_Wind_Studies_Full_Report_newest.pdf

In May of 2014, Dominion's VOWTAP was one of three projects nationally selected by the U.S. Department of Energy to receive up to \$47 million, each, over a four-year period for construction of offshore wind demonstration projects. To be eligible to receive funding, the projects must be operational by the end of 2017. The power produced by the VOWTAP project will be tied to the grid and distributed to Virginia residents, subject to approval of the costs by the State Corporation Commission. Once approved, up to 3000 homes and businesses will benefit from this clean, renewable energy.



Additional information on the Virginia Wind Energy Area and the two Research Leases is available at <http://www.boem.gov/State-Activities-Virginia>.

Figure 4-2: Virginia Offshore Wind Energy Area and Two Research Leases



In 2010, the General Assembly adopted legislation to create the Virginia Offshore Wind Development Authority (VOWDA). The mission of the Authority is to facilitate, coordinate, and

support development of Virginia's offshore wind energy industry, offshore wind energy projects, and supply chain vendors by:

- Collecting metocean and environmental data
- Identifying regulatory and administrative barriers
- Working with local, state, and federal government agencies to upgrade port and logistic facilities and sites
- Ensuring that development is compatible with other ocean uses and avian/marine wildlife
- Recommending ways to encourage and expedite offshore wind industry development through public-private partnerships with developers

More information on VOWDA activities and reports is available at:

<http://wind.jmu.edu/offshore/vowda/index.html>.

Dominion Virginia Power developed a report for VOWDA exploring the feasibility for offshore wind energy transmission in South Hampton Roads. The results indicate that it is technically possible to interconnect up to 4500 MW of offshore wind generation with the existing transmission system in the Virginia Beach area, but that above 2700 MW, transmission upgrades will be necessary to prevent wind power operators from having to curtail generation (and to lose revenue) during certain times. It is estimated that depending on the level of wind generation injected into the local grid, these transmission upgrades will cost between \$30 million and \$70 million.



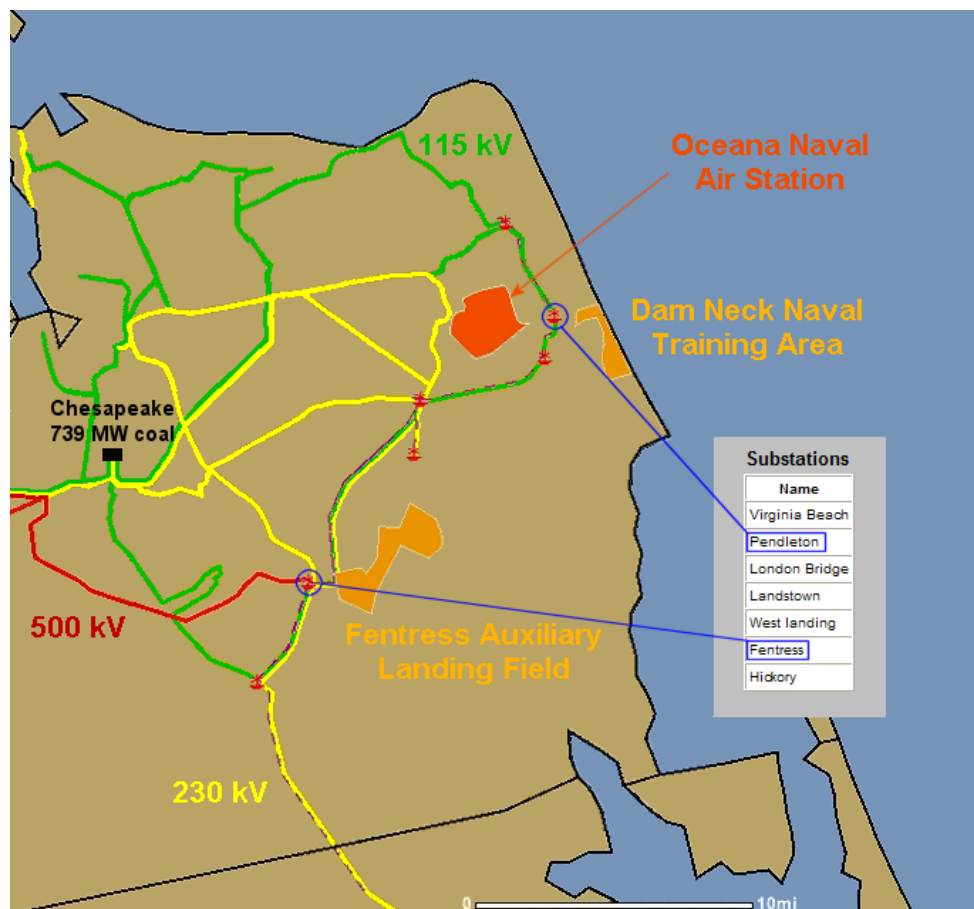
The legislature also created the Virginia Coastal Energy Research Consortium (VCERC) to develop coastal energy technologies. VCERC provides the research and development required for the commercialization and implementation of new coastal energy resources, including offshore wind power through multidisciplinary research collaborations between seven Virginia universities:

- [Virginia Tech Advanced Research Institute](#)
- [James Madison University](#)
- [Norfolk State University](#)
- [Virginia Commonwealth University](#)
- [University of Virginia](#)
- [Hampton University](#)
- [George Mason University](#)

VCERC has mapped Virginia's offshore wind resource and prepared other research and reports to help inform decision makers, and is assisting the Commonwealth with a plan for use of proposed research leases and other R&D opportunities.¹⁷

¹⁷ Ibid.

Figure 4-3: Virginia Offshore Wind Grid Access Points¹⁸



In October 2010, the independent transmission company Trans-Elect, in partnership with Good Energies Capital, Google, and the Marubeni Corporation, announced their proposed Atlantic Wind Connection (AWC) backbone transmission project, a high-voltage direct current transmission system that will allow the interconnection of offshore wind power installations from New Jersey to Virginia.

The AWC project is designed to link Offshore Wind Energy Areas identified by the Bureau of Ocean Energy Management (BOEM), and it is the first offshore backbone electric transmission system proposed in the United States.

¹⁸ Presentation at the Virginia Manufacturing Association, 2010 Energy Summit, VIRGINIA WIND POWER OPPORTUNITIES - JOBS FOR VIRGINIA, March 2010

Offshore Wind and Economic Development

Wind energy development off the coast of Virginia has the potential to become a \$15 billion dollar industry over the next ten years and can support new jobs in project construction and operation, and in supply chain businesses. According to VCERC, *“within two decades, 9,700 to 11,600 career-length jobs can be created, solely associated with developing the 3,200 megawatts of offshore wind potential that VCERC has identified in shallow waters beyond the visual horizon off Virginia Beach.”*¹⁹

The Port of Hampton Roads offers highly suitable port, manufacturing, and project development sites to support offshore wind development, as well as wind turbine and supply chain manufacturing. Because of its central location in the mid-Atlantic, Virginia has the potential to play a major role in offshore wind development along the entire east coast.¹

Challenges to Offshore Wind

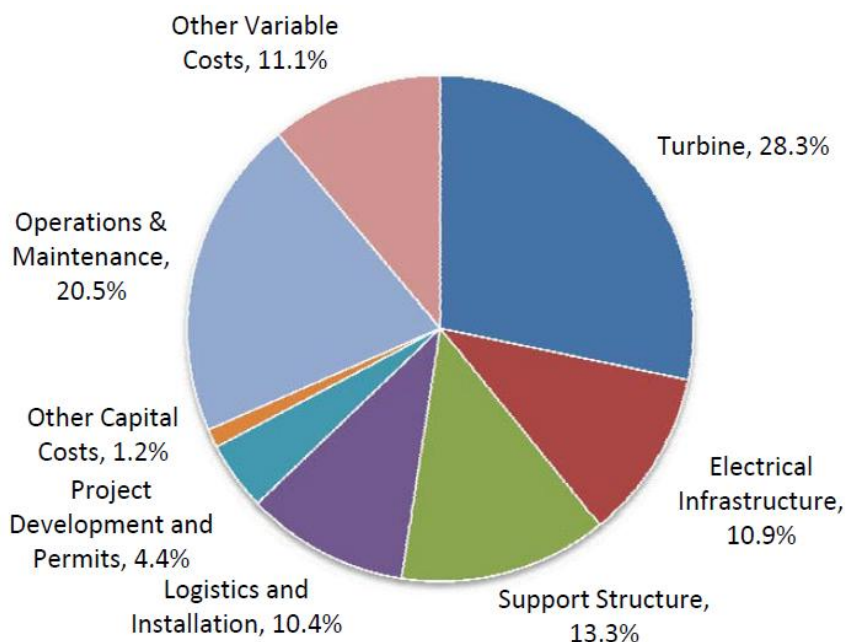
Offshore wind technology is estimated to cost between \$125 and \$225 per megawatt hour (12.5 to 22.5 cents per kilowatt hour). This would not be competitive with other power sources in today's market, although costs are likely to come down as construction begins and economies of scale allow for lower equipment and installation costs.

As shown in Figure 4-4, capital costs for offshore projects are estimated to be more than double those for land-based wind projects. These higher costs accrue from specialized offshore turbine support structures, offshore electrical infrastructure construction, the high cost of building at sea, operations and maintenance (O&M) warranty risk adjustments, turbine cost premiums for marinization (designed and built to survive in a harsh marine environment), and a decommissioning contingency. These costs can be partially offset by increased energy production from higher wind speeds and capacity factors.²⁰

¹⁹ http://www.vcerc.org/VCERC_Final_Report_Offshore_Wind_Studies_Full_Report_newest.pdf

²⁰ W. Musial, R. Thresher, B. Ram. *Large-Scale Offshore Wind Energy for the United States: Assessment of Opportunities and Barriers*. CO, Golden: National Renewable Energy Laboratory, 2010

Figure 4-4: Estimated Life-Cycle Cost Breakdown for a Typical Offshore Wind Project²¹



In addition to cost challenges, offshore wind has numerous technical, infrastructure, and permitting challenges associated with it. For example, the offshore wind resource is not yet well-characterized, which can negatively affect financing costs. Current wind data is based on computer models, while lenders typically require physical measurement of wind speeds at the location wind installations will occur. Gathering this “bankable” data will require the installation of meteorological equipment, such as LIDAR (a system that uses lasers to detect wind speed and direction based on the time delay of the laser beam reflected by airborne aerosols) in the Wind Energy Area.

Offshore wind turbines also require specialized vessels which are not readily available in the U.S. While foreign-flagged turbine installation and maintenance vessels exist, for example in Europe, the Jones Act limits the ability of these vessels to operate in U.S. waters. On the other hand, shipyards in the Hampton Roads area are well positioned to build these specialized vessels for not only Virginia offshore wind projects, but for projects along the entire east coast.

On June 2, 2014, the United States Environmental Protection Agency (EPA) released the *Clean Power Plan Proposed Rule*, with the goal of reducing carbon dioxide (CO₂) emissions from existing fossil electric generating units. EPA created emissions intensity reduction targets for each state, measured as a reduction in the pounds of carbon dioxide per megawatt hour (MWh) of electricity produced in the state. For Virginia, the proposed target will require a 38 percent reduction from the 2012 level of 810 pounds of carbon dioxide per megawatt hour, by 2030. Increasing the use of renewables, especially solar and wind (both offshore and on land), can significantly help the State reach this goal.

²¹ Ibid.

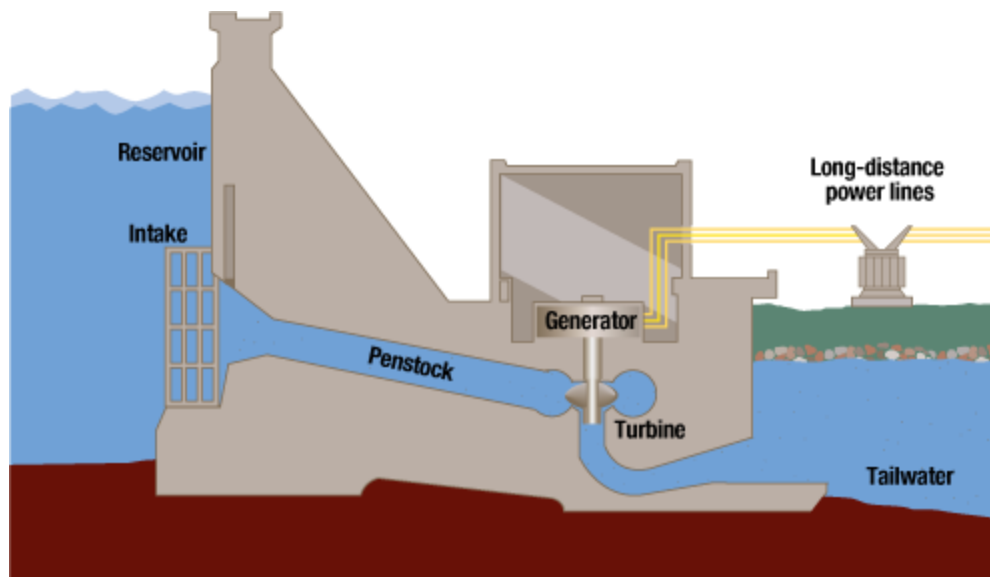
Hydroelectric Power

Hydro projects are long-lived assets, with a few projects operating for 100+ years. Nationally, water is currently the leading renewable energy source used by electric utilities to generate electric power.

Like solar and wind they have no direct fuel costs, so delivered energy costs depend on the capital equipment and water availability. Once installed, these generators emit no greenhouse gas or other pollutants and do not generate solid or hazardous wastes. Dam operations do have implications for water consumption, which are usually detailed in their operating plans in terms of recreational, fish and wildlife, agriculture, and potable water uses of their reservoirs and their priority assigned to power generation compared to competing uses.

There are several types of hydroelectric facilities currently used. The most common hydroelectric plant uses a dam across a river to create a reservoir at a higher elevation than that of the undammed river. This height differential allows water to flow at high pressure and velocity through the blades of a turbine connected by a shaft to an electric generator that creates electricity. The water then exits the facility at the lower elevation of the original river.

Figure 4-5: Hydroelectric Facility Diagram



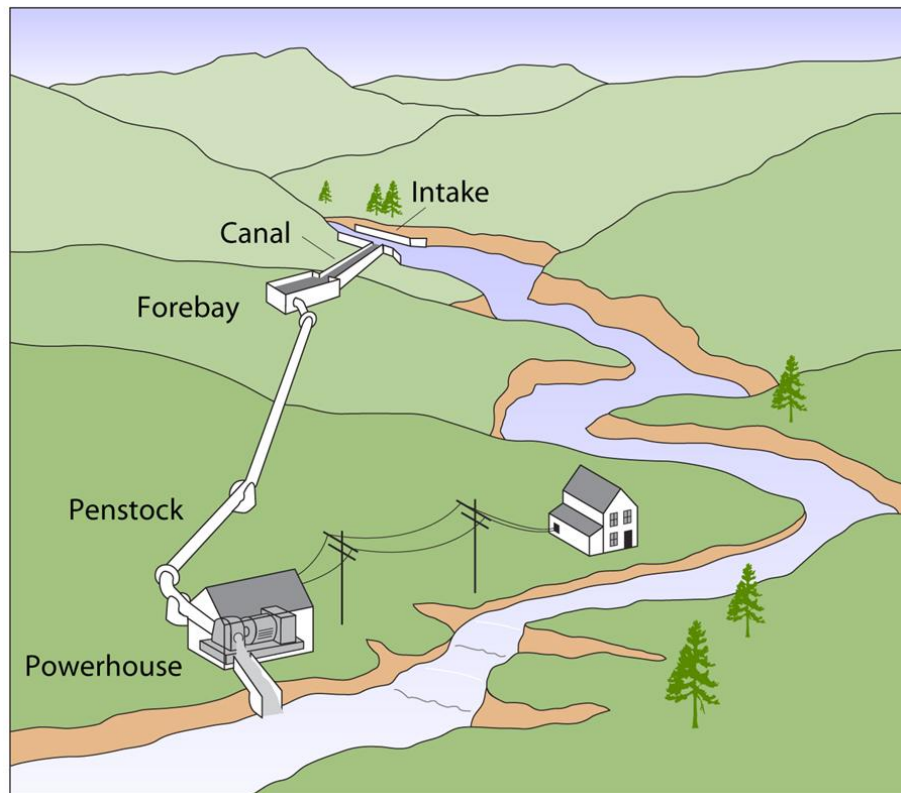
Source: Tennessee Valley Authority

In a “pumped-storage” plant, two reservoirs at different elevations are used. To generate electricity, water flows through the turbine to turn a generator and exits into the lower reservoir. During periods of low electric demand, however, such as at nights, the turbines, using electricity from the grid, act as pumps to move water from the lower back up to the upper reservoir. Because power, typically from non-renewable sources, is used for pumping mode, only the net generation over and above what is used to pump the water can be considered renewable. Pumped storage is a way to smooth out the intermittent nature of other renewables like solar and wind.

A third type of hydroelectric plant is called “run-of-river”, in which a portion of a river is diverted to flow through a channel or a pressurized pipeline, or *penstock*, to turn a turbine. Because run-of-river

plants typically do not involve large dams, they are considered more environmentally-friendly because they don't require flooding valleys to create large reservoirs.

Figure 4-6: Run-of-River Power Plant



In this run-of-river microhydropower system, water is diverted into the penstock and exits down-river from the intake.

Generating electricity using water has several advantages. A major advantage is that water is a source of cheap power. Like solar and wind power, the “fuel” is free, and since there is no fuel combustion, there is no air pollution.

Like other energy sources, the use of water for generation has limitations, including environmental impacts caused by damming rivers and streams, which affects the habitats of the local plant, fish, and animal life.

Virginia is home to 24 conventional hydropower facilities with a combined capacity of 439 megawatts, and two pumped storage facilities with a combined capacity of 3659 megawatts. The Bath County Pumped Storage Facility, jointly owned by Dominion and the operating companies of the Allegheny Power System, make up the bulk of Virginia's pumped storage, and is the second largest pumped storage facility in the world.

Figure 4-7: Conventional Hydroelectric Facilities in Virginia

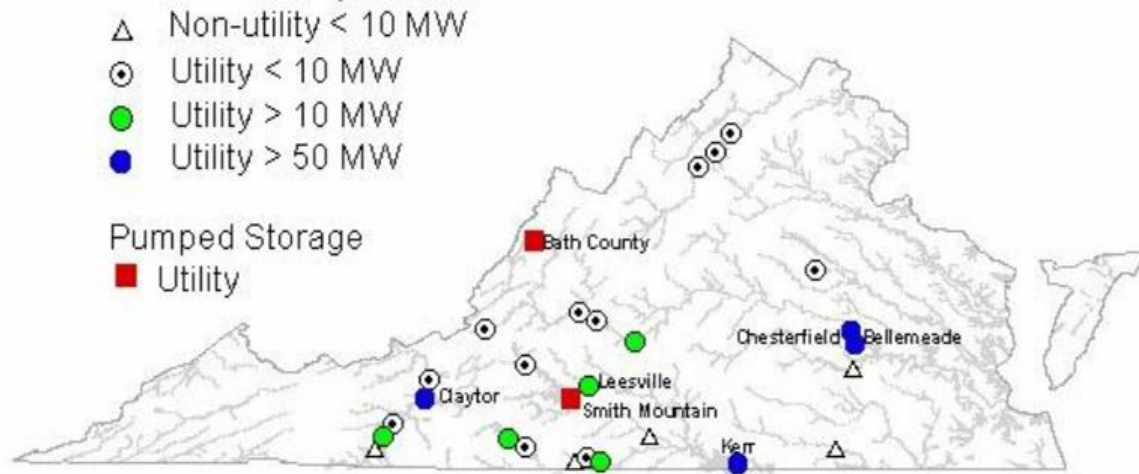


Table 4-4: Virginia's Hydroelectric Facilities (Pumped Storage in Red)

Owner	Name	County	Summer Capacity (MW)
Allegheny Energy Supply Co LLC	Luray	Page	1.6
Allegheny Energy Supply Co LLC	Newport	Page	1.4
Appalachian Power Co	Buck	Carroll	8.4
Appalachian Power Co	Byllesby 2	Carroll	21.6
Appalachian Power Co	Claytor	Pulaski	74.8
Appalachian Power Co	Leesville	Campbell	40
Appalachian Power Co	Niagara	Roanoke	3.6
Appalachian Power Co	Reusens	Campbell	22.5
Appalachian Power Co	Smith Mountain Dam	Franklin	656
Appomattox River Associates LP	Brasfield	Appomattox	3
Aquenergy Systems Inc	Fries Hydroelectric Project	Grayson	5.4
Bedford City of	Snowden	Amherst	5
Danville City of	Pinnacles	Patrick	11.1
Dominion Virginia Power	Bath Pumped Storage	Bath	3003
Dominion Virginia Power	Cushaw	Amherst	7.5
Dominion Virginia Power	North Anna	Louisa	1
Georgia Pacific Corp-Big Island Mill	Georgia Pacific Big Island	Bedford	0.4
Holcomb Rock Company	Coleman Falls	Bedford	1.5
Holcomb Rock Company	Holcomb Rock	Bedford	1.8
Martinsville City of	Martinsville	Henry	1.3

Radford City of	Radford	Pulaski	1
Ridgewood Power Management LLC	Emporia	Greensville	2.4
Ridgewood Power Management LLC	Halifax	Halifax	1.6
STS HydroPower Ltd	Schoolfield Dam	Pittsylvania	4.5
USCE-Wilmington District	John H Kerr	Mecklenburg	204
USCE-Wilmington District	Philpott Lake	Henry	14

Upgrades at Existing Hydropower Facilities

The Federal Energy Regulatory Commission (FERC) compiles a list of hydropower projects that have been certified to receive the production tax credit (PTC).²² Projects that add capacity or make efficiency improvements qualify. The most recent update available as of the end of December 2013 shows there have been 128 projects certified, with an average generation increase of about 9.5 percent. Individual increases have ranged from under 1 percent to over 60 percent. This list demonstrates the potential to further maximize the output of existing hydropower facilities, through replacement of equipment with new technologies, as well as through expansion opportunities.

The Bath County facility is one Virginia project that has filed in recent years and was certified. There may be similar opportunities for other projects in the State.

Powering Non-Powered Dams

In April 2012, the DOE/Oak Ridge Laboratory released a report titled, “An Assessment of Energy Potential at Non-Powered Dams in the United States.” See:

http://energy.gov/sites/prod/files/2013/12/f5/npd_report_0.pdf.

Of the 80,000 dams in the U.S., only 3 percent have hydropower generating facilities. The remaining 97 percent were built for other purposes, such as flood control, navigation, irrigation, municipal water supply, etc. For Virginia, the report found 50 MW of potential output from these facilities in the State.

New Stream-Reach Development

In April 2014, the DOE/Oak Ridge Laboratory released another report titled, “New Stream-Reach Development: a Comprehensive Assessment of Energy Potential in the United States.”²³

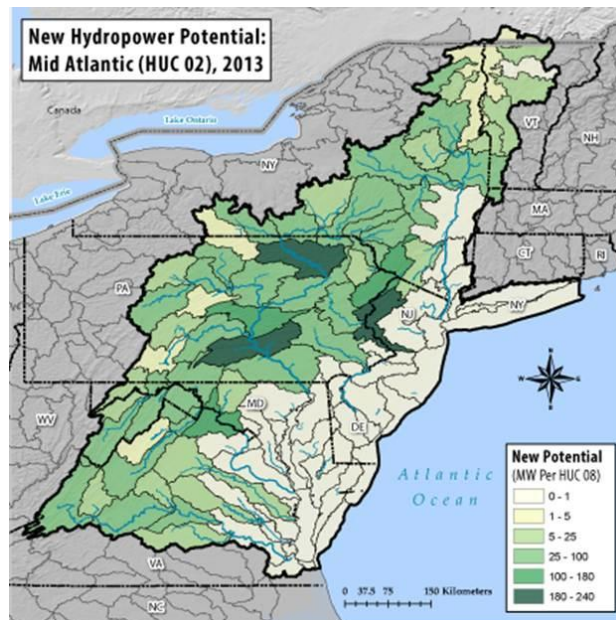
This report provides the technical potential (and does not make recommendations for any individual project) for new hydropower development that involves new dam infrastructure. The report categorizes potential by regions, not by states. Virginia crosses four regions: Mid-Atlantic, South Atlantic-Gulf, Ohio Region, and Tennessee Region. An example is provided immediately below.

²² See <http://www.hydro.org/wp-content/uploads/2014/01/PTCs-Issued-as-of-December-2013.pdf>

²³ See: http://nhaap.ornl.gov/sites/default/files/ORNL_NSD_FY14_Final_Report.pdf.

Also see the fact sheet at: http://nhaap.ornl.gov/sites/default/files/NSD_overall_fact_sheet.pdf

Figure 4-8: New Hydropower Potential



Projects That Have Filed For a Preliminary Permit at FERC

On FERC's website are listed those projects that have filed for preliminary permits to begin examining sites for development. Currently, Virginia has two such preliminary permit applications on file for small projects at the Commission, totaling 5 MW. Information on these projects can be found by going into the FERC e-Library and searching by project number (example: P-14425).

Table 4-5: Conventional Hydroelectric Facilities

Docket Number	Project Name	Expiration Date	Authorized Capacity (KW)	Licence	Waterway	ST	Description
P-14425	Scott's Mill	11/30/15	4800	Liberty University	James River	VA	Conventional Permit
P-14526	Danville Union Dam	2/28/17	620	KC Small Hdyro LLC	Dan River	VA	Conventional Permit

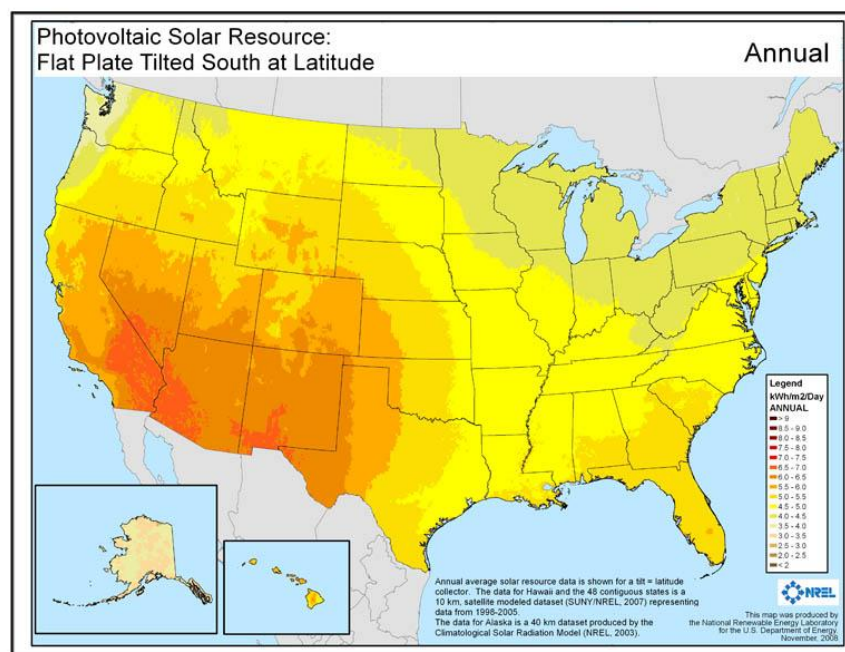
A total of 36 projects are listed with a combined authorized capacity of about 3632 MW. Project types include conventional hydropower (large and small), hydropower pumped storage, and conduit power projects. Conduit power projects tap water flows in man-made channels or pipes, as for instance, the flows from elevated potable water reservoirs.

Navigant Consulting conducted a study in 2009-2010 that looked at the job creation benefits that are derived from the hydropower industry.²⁴ The report estimated that the U.S. hydro industry employs overall up to 300,000 workers. The U.S. hydropower industry could install 23,000 MW to 60,000 MW of new capacity by 2025, representing only 6-15 percent of the total untapped hydropower resource potential in the U.S. The total jobs required to meet these targets would be in the range of 230,000 to 700,000 jobs.

Solar Power

Photovoltaics ("PV") are a well-established, commercial technology that converts sunlight into direct current (DC) electricity. PV devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain types of material, called semiconductors. Thin-film PV is a fast-growing but small part of the commercial solar market. These are generally less efficient, but often cheaper than c-Si modules. Solar heating & cooling (SHC) technologies collect the thermal energy from the sun and use this heat to provide hot water, space heating, cooling, and pool heating for residential, commercial, and industrial applications. The SHC technologies displace the need to use electricity or natural gas.

Figure 4-9: Solar Resources Map



Sunlight can also be used effectively to heat water or air using solar thermal collectors. A typical solar water heating system for a family of four delivers 4 kilowatts of electrical equivalent thermal power under full sun, and defers up to 0.5 kilowatts of peak demand.²⁵

²⁴ See <http://www.hydro.org/why-hydro/job-creation/navigant-study/> for the full report, highlights, state-by-state breakdowns

²⁵ Solar Rating and Certification Corporation Fact Sheet: http://www.solar-rating.org/facts/Energy_Production.pdf

Large community swimming pools heated using oil or propane and institutional facilities such as prisons and health care facilities are ideal applications of solar thermal systems.

Photovoltaic (PV) energy is produced using semiconductor materials. Unlike solar thermal systems for heating air or water, PV does not use the sun's heat to make electricity. Instead, specially treated semiconductor materials interact with photons from the sun to free up electrons to flow in an electric current. There are numerous semiconductor technologies used to manufacture PV products. The most common is silicon, which is a primary component in sand, and the second most common element on earth.

PV is an evolving technology, with incremental efficiency gains each year. As technology and manufacturing methods improve, costs continue to come down.

PV industry jobs include work in cell and module manufacturing; assembly and installation, sales and distribution; and project development. In 2013, the U.S. solar industry directly employed over 142,000 people, with the largest concentration in installation (21 percent), sales and distribution (14.2 percent), manufacturing (8.6 percent), project development (3 percent), and the remainder in various supporting activities (16.1 percent).

Solar generating capacity grew significantly in the past several years because of declining solar equipment costs. Between 2007 and 2012, it is estimated that solar manufacturing costs fell by between 70 and 80 percent²⁶.

When PV was first used commercially to power satellites in the 1950s, a 1W cell cost \$300. In 2013, residential system prices fell 8.8 percent from a year earlier to an average \$4.59/W; non-residential prices fell 16.3 percent to an average \$3.57/W; and utility systems declined to an average \$1.96/W. The lowest levelized costs of electricity for PV in the NREL Transparent Cost Database are \$0.10/kWh, with a median value of \$0.32/kWh and a U.S. Department of Energy (DOE) program estimate of \$0.20/kWh. Comparisons are highly dependent on whether the PV is competing against retail rates (residential and non-residential) or utility busbar rates, and how net metering and other policies impact the valuation of PV.

Solar module costs have dropped to the point where it is the non-hardware, balance of systems costs associated with solar energy systems keeping installed system costs as high as they currently are. These “soft costs” represent as much as 64 percent of the total installed system price²⁷ and include:

- [Customer Acquisition](#)
- [Financing and Contracting](#)
- [Permitting, Interconnection, and Inspection](#)
- [Installation and Performance](#)
- [Operations and Maintenance](#)

In 2011, the U.S. Department of Energy launched the "SunShot" initiative to reduce the total costs of photovoltaic solar energy systems by about 75 percent so that they are cost-competitive at large scale with other forms of energy without subsidies before the end of the decade. By reducing the cost for utility-scale installations by about 75 percent to roughly \$1 a watt—which would correspond to roughly 6 cents per kilowatt-hour—solar energy systems could be broadly deployed across the country.²⁸

²⁶ <http://reneweconomy.com.au/2014/solar-pv-continues-shoot-cost-curve-42386>

²⁷ <http://energy.gov/eere/sunshot/reducing-non-hardware-costs>

²⁸ http://www1.eere.energy.gov/solar/sunshot/news_detail.html?news_id=16701

As of June 2014, the total net metered capacity of solar photovoltaic systems in Virginia was just over 12 megawatts, with additional non-net metered solar totaling approximately four megawatts (mostly on military installations). This is far less than in neighboring Maryland, with 158 MW (MEA, 2014), District of Columbia with 14 MW at end of 2012 (Sherwood, 2013), and North Carolina with 592 MW (SEIA, 2014).

Virginia Legislation enacted in 2011 allows for the creation of utility distributed solar generation demonstration programs.

Pursuant to that legislation, Dominion plans to install up to 30 megawatts of company-owned distributed solar generation on leased commercial rooftops in strategically located areas of its service territory. This project will allow the utility to learn how to manage a larger scale intermittent resource and include such assets in its generation and reliability planning. Not only will this project increase the renewable power available to Virginia electricity customers, but it will provide an important research opportunity to support further expansion.

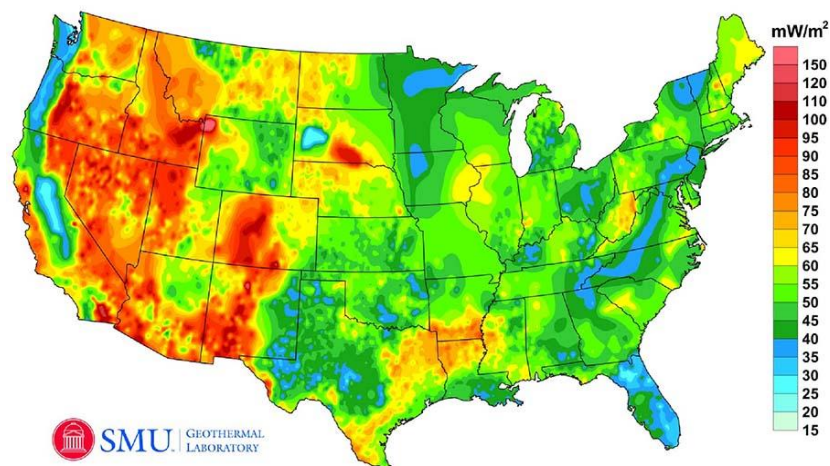
Currently, Virginia law does not allow a third party to install and own a renewable energy facility on a utility customer's property and sell the utility customer the renewable output of the renewable energy system.

However, in 2013, the Virginia General Assembly enacted legislation that would allow for a pilot program within Dominion Virginia Power's service territory to enable third party power purchase agreements for systems as large as one megawatt, up to an aggregate of 50 megawatts system wide.

Geothermal Energy

According to the Virginia Division of Geology and Mineral Resources, geothermal energy is the heat produced by and contained within the earth. It can be used as a clean, reliable, and renewable energy resource. Geothermal energy is an efficient heating and cooling alternative for residential, commercial, and industrial applications, and is potentially a significant source for electrical power generation in some regions of the United States.

Figure 4-10: Geothermal Resource Potential³⁰



Heat from Earth's mantle and crust is stored and transferred to Earth's surface differently depending on geologic setting.

In the western United States, geothermal energy is commonly associated with hot springs and geysers where high-temperature geothermal reservoirs form in areas of relatively recent volcanic and earthquake activity. In these locations, groundwater circulates deep into permeable bedrock picking up heat and bringing it close to the surface creating a high geothermal gradient. Several of these reservoirs have been developed for commercial applications including direct heating, food dehydration, aquaculture, and electrical power generation.

In the relatively stable geologic environment of the eastern United States, heat-generating rocks are much deeper and geothermal gradients tend to be lower. Yet opportunities exist for developing lower-temperature geothermal resources that may include direct use, geo-exchange systems, co-produced geothermal with oil and gas resources, and²⁹ enhanced geothermal systems (EGS).



Thermal springs, such as the Jefferson Pools in the town of Warm Springs, Virginia, have been a source for health and relaxation for Virginians for hundreds of years.

In Virginia, thermal springs in Bath and Alleghany Counties have long been utilized as spas and resorts, providing a direct use geothermal resource to the public since the 1760s. These hot springs originate from water that was heated deep within the Earth's crust and transported relatively quickly to the surface along geologic faults and fractures.

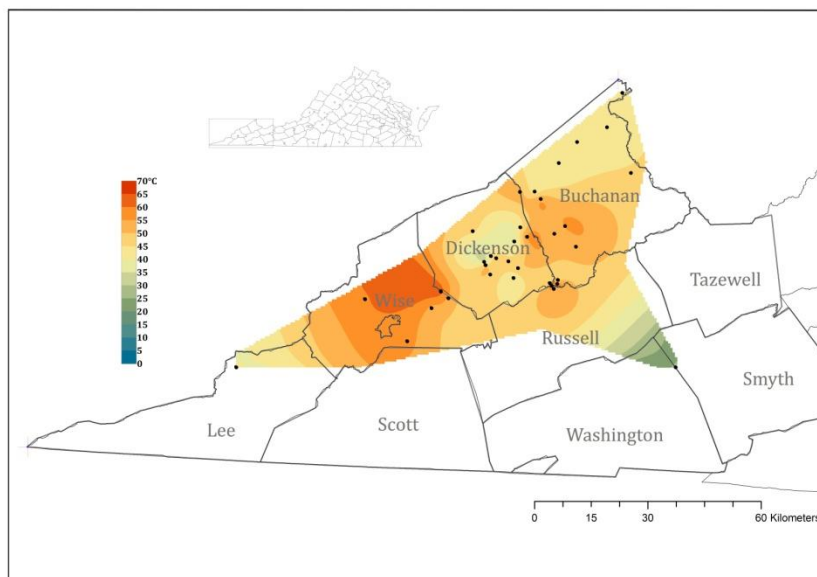
In Virginia's coal and gas producing regions, warm water is often a by-product of fossil fuel production and is generally considered a waste product. New developments in binary geothermal power generation utilizing lower temperature resources may make it feasible in the near future to co-produce geothermal energy along with traditional fossil fuel resources. Generally, the amount of water produced with natural gas in the Southwest Virginia Coalfield region is very small, yet the possibility of geothermal co-production from wells with higher water volumes, depleted gas wells, or underground mine sites remains untested.

The diverse geologic setting of Virginia provides possibilities for enhanced geothermal system (EGS) technologies. Heat-generating granitic rocks situated at depths beneath insulating layers of sedimentary

²⁹ <http://www.dmme.virginia.gov/dgmr/geothermal.shtml>

rocks, such as may occur in the Coastal Plain, can provide the necessary natural heat for geothermal development if permeability and/or groundwater supply and circulation can be artificially enhanced.

Figure 4-11: Ground Temperature Gradient in Southwest Virginia³¹



Color contoured temperature in °C at elevation -1,200 m (-3,937 ft) below sea level datum. Preliminary results based on temperature logs from gas wells in the Southwest Virginia Coalfield.

Geothermal Heating and Cooling in Buildings

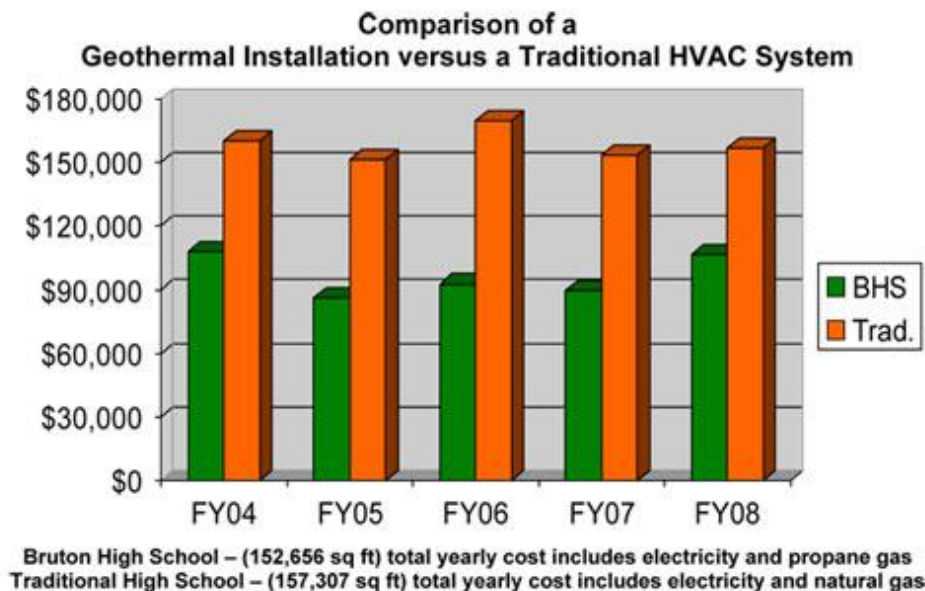
Geothermal energy can provide heating and cooling through use of geothermal heat pumps. Geothermal heat pumps are not truly a renewable energy technology, but instead a much more efficient heat pump that takes advantage of the relatively stable year-round temperature of the earth to extract heat from in the winter and throw off heat to in the summer. There are limited low-temperature geothermal resources in Bath County that may be suitable for water and space heating. Hot-rock geothermal resources are found near the Virginia Atlantic coastline. Due to the depth of these rocks, systems to exploit this heat source are not economical with current technology.

According to the York County Schools website³², the County uses geothermal system operating wells in nine county school facilities. In September of 2000, the York County School Division completed its first geothermal renovation at Tabb Middle School. The subsequent energy savings achieved at that site prompted similar renovations throughout the school division. Today, more than one third of the school buildings in the Division have been converted to geothermal heating and cooling systems. These renovations have reduced site energy consumption by up to 40 percent. Energy costs for a typical York County geothermal school were reduced by approximately \$60,000 per year.

³¹ <http://www.dmme.virginia.gov/DGMR/geothermal.shtml>

³² York County Schools, Green YCSD Geothermal Heating and Cooling, <http://yorkcountyschools.org/greenYCSD/geothermal.aspx>

Figure 4-12: Geothermal Heat Pump and Traditional Heating and Cooling Energy Costs at Bruton High School in York County³⁰



Biomass

Biomass is any organic material that can be used as a bioenergy feedstock. The *Code of Virginia*³¹ defines biomass as agricultural and forest-related materials, animal wastes, mill residues, urban woody wastes, purpose grown energy crops, landfill and wastewater gas, biosolids, and municipal solid waste. The moisture content of the material typically determines the way it can best be used. The higher the moisture content, the lower the heating value when used in combustion processes, as a portion of the energy in the fuel is expended in driving off the water. High moisture content feedstocks are more suitable for anaerobic digestion to generate biogas.

Biomass Resources in Virginia

Forest Residuals

Low moisture content biomass is often referred to as solid fuels. The latest data from the National Renewable Energy Lab³² estimates over seven million dry tonnes (1 tonne = metric ton = 1000 kg or ~ 2200 lbs) of forest residues, primary and secondary mill residues, urban wood wastes, and crop residues are available, annually, Statewide. Forest residues, most plentiful in Southside Virginia and in the Coastal Plain (Figure 4-13), are the tops and branches of trees harvested for timber, along with dead, diseased, poorly formed, and other non-merchantable trees that would otherwise be left in the woods.

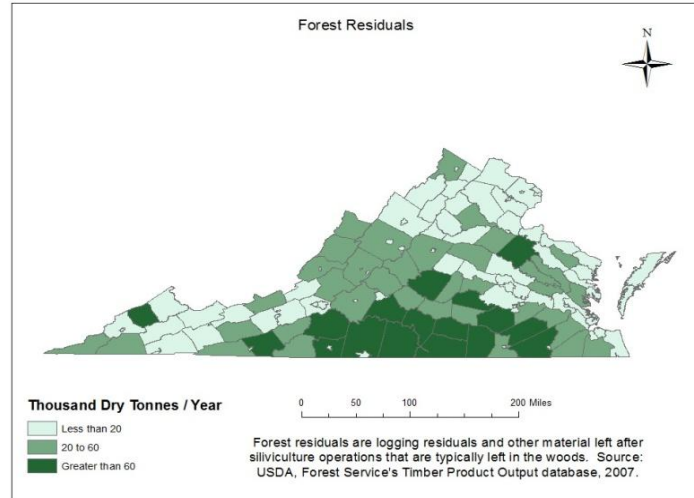


³⁰ York County Schools, Green YCSD Geothermal Heating and Cooling, <http://yorkcountyschools.org/greenYCSD/geothermal.aspx>

³¹ Biomass definition in the *Code of Virginia*: <http://lis.virginia.gov/cgi-bin/legp604.exe?000+cod+10.1-1308.1>

³² National Renewable Energy Laboratory Biomass Data: http://www.nrel.gov/gis/data_biomass.html

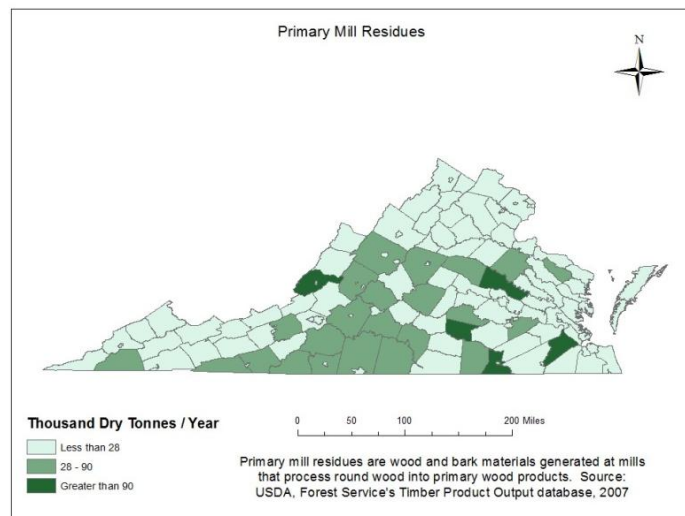
Figure 4-13: Availability of Forest Residuals in Thousand Dry Tonnes by County in Virginia³³



Mill Residues

Primary mills take harvested logs, called roundwood, and process these into primary wood products such as pulp, lumber, plywood, posts, etc. Primary mill residues include the coarse and fine wood material (slabs, edgings, trimmings, and sawdust) and bark remaining after initial processing. The Primary Forest Products Network³⁴ lists over 175 primary mills distributed throughout Virginia. The greatest volume of residues production is concentrated in Alleghany, Amelia, Greensville, Hanover, and Isle of Wight Counties (Figure 4-14). Primary mills will either use their residues as fuel in their own boilers or have secondary markets for fuel or raw materials at other locations. Recently harvested wood that is green has a relatively high moisture content, and consequently lower energy content.

Figure 4-14: Primary Mill Residues in Thousand Dry Tonnes per County in Virginia³⁵



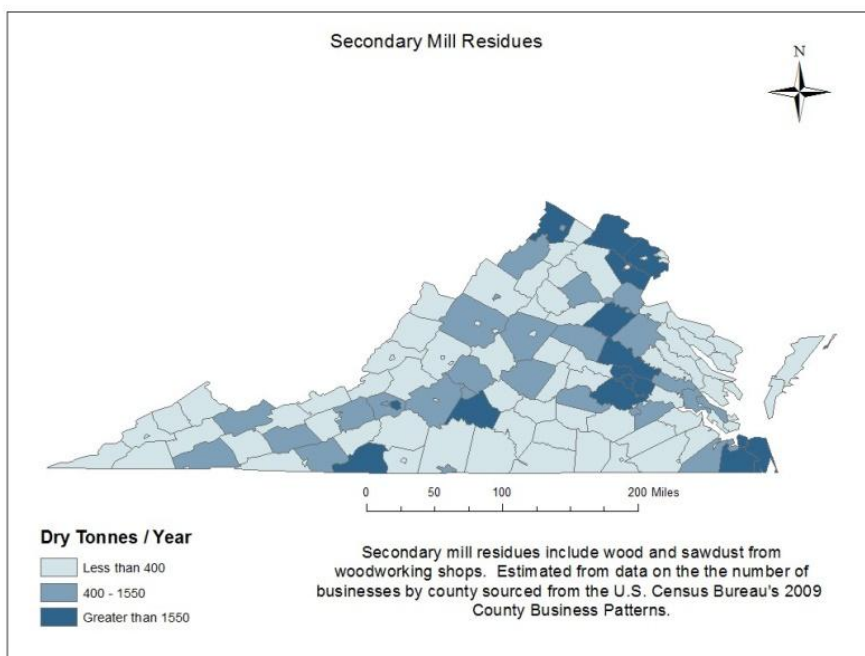
³³ Source: NREL Biomass Data, last updated 2008

³⁴ Primary Forest Products Network Forest Products Locator: <http://www.forestproductslocator.org/>

³⁵ Source: Compilation of Virginia Biomass Resources from NREL Biomass Data, last updated 2008

Secondary mill residues, when kiln-dried, have very low moisture content and accordingly are very desirable as a boiler fuel. Secondary mill residues include scraps and sawdust from furniture factories, millwork, wood containers, pallet mills, and lumberyards. In addition to use as boiler fuel, sawdust is in demand by the wood pellet and animal bedding industries. Secondary mill residues are available in limited quantities throughout Virginia (Figure 4-15) and can be purchased from individual mills.

Figure 4-15: Secondary Mill Residues in Dry Tonnes per County in Virginia³⁶



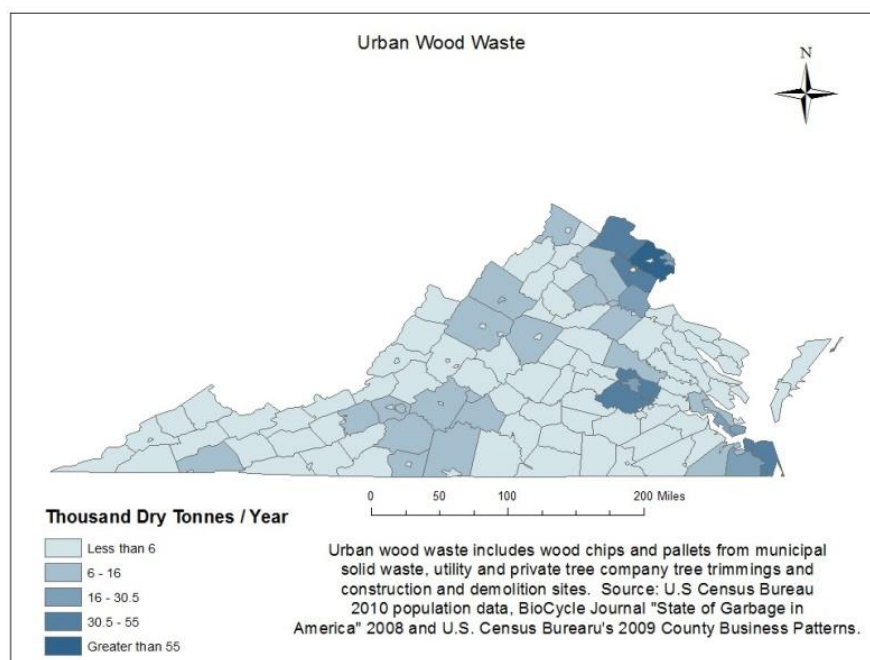
Urban Wood Wastes

Urbanization and parcelization (the subdivision of industrial forestland into smaller, privately held tracts), fragments forestland, thereby reducing the acreage available for timber production. Declining tract size increases the relative cost of harvest operations. Generally, lots of 20 acres or fewer are not profitable if commercially harvested; however, significant residuals are still generated from urban and suburban areas. Yard and other wood residues derived from municipal solid wastes (MSW), highway rights-of-way and utility clearings, debris from private tree companies, and construction and demolition (C&D) sites generate over a million dry tonnes of urban wood wastes, annually (Figure 4-16). The primary challenge with utilizing urban wood wastes is aggregating the material so that it can be processed and delivered to end-users.



³⁶ Source: Compilation of Virginia Biomass Resources from NREL Biomass Data, last updated 2012

Figure 4-16: Urban Wood Waste in Dry Tonnes per County in Virginia³⁷



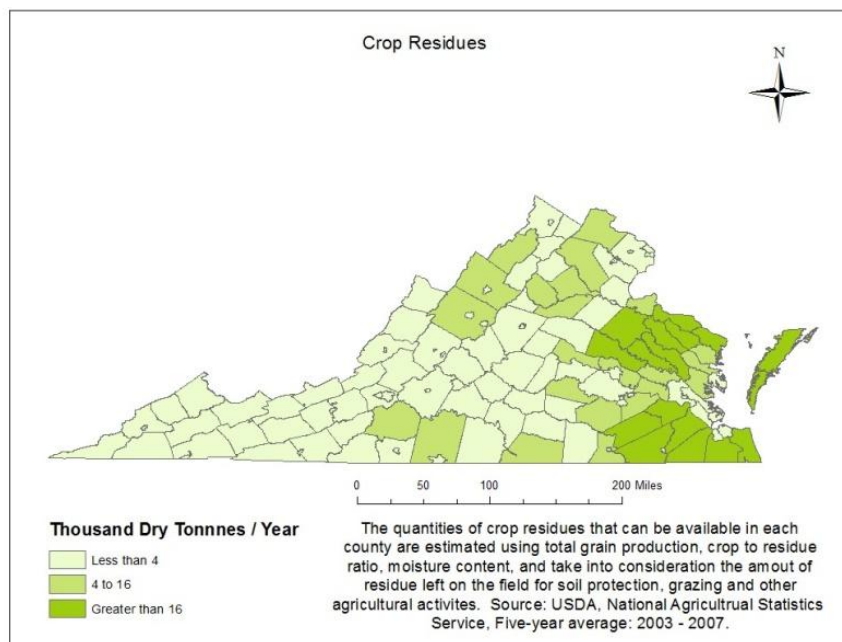
Agricultural Crop Residues

Crop residues comprise another sizable source of potential biomass fuels. Approximately 750 thousand dry tonnes of post-harvest residuals are generated annually from the production of barley, corn, oats, peanuts, sorghum, soybeans, and wheat (Figure 4-17). These residues include corn, peanut, sorghum, and soybean stover (leaves and stalks) and barley, oats, and wheat straw. Crop residues are typically used for grazing, animal bedding, and silage and, like forestry residuals, retention of crop residues on the land is important for soil health. Therefore, the NREL estimate assumes a 35 percent collection rate. In Virginia, the majority of these residuals would be available in the row crop agriculture regions of the Coastal Plain, Southern Piedmont, and the Shenandoah Valley.



³⁷ Source: Compilation of Virginia Biomass Resources from NREL Biomass Data, last updated 2012

Figure 4-17: Crop Residues in Dry Tonnes per County in Virginia³⁸



Residual Biomass Inventory of the Commonwealth of Virginia

Researchers at Virginia Tech and the Virginia Cooperative Extension released an updated and expanded *Residual Biomass Inventory of the Commonwealth of Virginia*, in 2011. In addition to the materials just discussed, their Study also included animal manures, food residuals, biosolids, and vegetative yard wastes with an estimated annual availability of over ten million bone dry tons of biomass residuals. The *Residual Biomass Inventory*³⁹ makes an important distinction between availability and recoverability. Not all the estimated biomass is economically or socially recoverable and these results should be seen as illustrative. Furthermore, materials that are readily recoverable may likely have an existing market. For example, there are at least 10 wood pellet mills operating in Virginia, producing over 1 million tons of wood pellets a year, mostly for the export market. Any project feasibility analysis should include both feedstock availability and an evaluation of competing market demand.

Energy Crops

In addition to the utilization of residuals, production of dedicated energy crops can increase the sustainable biomass energy supply and bring a revenue stream for landowners. The 2011 National Landcover Database⁴⁰ classified over four million acres of Virginia as hay and pasture-land, a million acres as croplands, six hundred-thousand acres as grasslands, and another seventy-thousand acres as barren land. Dedicated energy crops can also be grown on brownfields and minelands as part of remediation and restoration efforts. Potential energy tree crops include hybrid willows and poplars that can be produced on

³⁸ Source: Compilation of Virginia Biomass Resources from NREL Biomass Data, last updated 2008

³⁹ <http://www.dmmme.virginia.gov/DE/Biomass.shtml>

⁴⁰ Multi-Resolution Land Characteristics Consortium 2011 National Land Cover Database 2011. <http://www.mrlc.gov/nlcd2011.php>

rotations as short as four to six years. Other energy crops include the annual native warm season grasses, primarily switchgrass, and the exotic miscanthus.

In Southside Virginia, a nascent energy crop industry is developing in and around Nottoway County, led by the bioenergy pioneers at the Piedmont Geriatric Hospital (PGH). PGH, which has been heating with sawdust sourced from local mills for several decades, is switching to pelletized native warm season grasses, bringing considerable cost savings to the Commonwealth⁴¹. Grasses grown and harvested within 50 miles of Blackstone are brought to a processing center located just outside of Fort Pickett where they are aggregated, ground, and pelletized for use as boiler fuel and animal bedding. New markets for energy crops, whether grasses or trees, can expand acres of perennial land cover. In areas of the Commonwealth within the Chesapeake Bay Watershed, where local governments must develop strategies to meet total maximum daily load (TMDL)⁴² targets, bioenergy production could synergize with their compliance efforts (through establishment of riparian buffers and conversion of row crops to permanent land cover, as the most effective practices for improving water quality).

Wet Biomass

Since wetter material has a lower heating value when combusting, high moisture content biomass feedstocks are more appropriately suited for anaerobic digestion. Animal manures, the wet portion of municipal solid waste, and waste water treatment plant effluent can be anaerobically digested to produce a biogas that can be burned directly to generate heat or run through an internal combustion engine to generate electricity. Landfill gas projects are essentially large anaerobic digesters of municipal solid wastes. In addition to generating energy from these underutilized waste streams, the physical containment and enclosures required to capture the biogas serve as an effective mechanism for odor control and can facilitate enhanced nutrient management and recovery.

Animal Manures

The United States Department of Agriculture's *2012 Census of Agriculture for Virginia*⁴³ lists 574 farms with over 50 head of dairy cows, four of them with over 1000 animals. The *Census* also lists 47 farms with more than 200 hogs or pigs, five of them with between 1000 and 2000 animals, 18 with between two and five thousand animals, and six with over five thousand. Anaerobic digestion technologies can convert carbon in liquid manures (such as manure from dairy and hog production) into biogas. Digested manures have a reduced volume and odor, compared to raw manures, potentially expanding end-user markets; however, considering the capital costs associated with an anaerobic digestion installation, these projects tend to occur only on larger farms. To date, only one anaerobic digester has been installed on a dairy farm in Virginia.

Feedstocks for Liquid Fuels

Biofuels, a term which typically denotes liquid fuels, can be produced from many of the same biomass feedstocks, as discussed above. First-generation biofuels are produced with easily obtainable sugars and vegetable oils such as corn, sugar beets, sweet sorghum, and soybean. The use of food crops for biofuels production has been a source of contention highlighted by the "food vs fuel" debate. Advanced or second-generation biofuels are made from woody biomass, non-edible agriculture residues, or other waste biomass, avoiding the "food vs fuel" debate. While production of ethanol from cellulosic material is still in the demonstration phase in Virginia, there are two commercial biodiesel producers in the Richmond area that collect and process used restaurant grease (yellow grease) for making biodiesel.

⁴¹ A Cooperative Native Warm Season Grass Biofuel to Steam at Piedmont Geriatric Hospital. <http://www.youtube.com/watch?v=AVMt9B6nz00>

⁴² US Environmental Protection Agency, Total Maximum Daily Load Program. <http://water.epa.gov/lawsregs/lawsquidance/cwa/tmdl/>

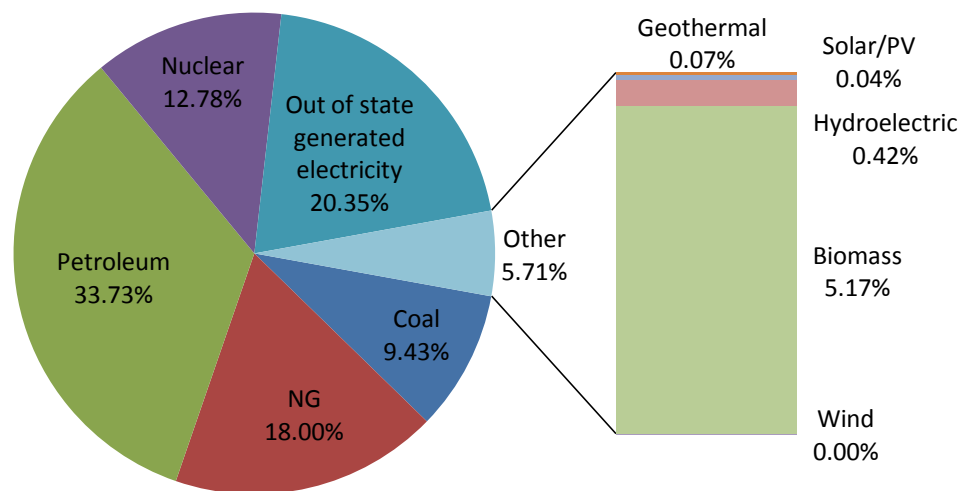
⁴³ USDA Census of Agriculture, 2014: 2012 Census Volume 1, Chapter 1: State Level Data (Virginia)
http://www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1_Chapter_1_State_Level/Virginia/

Biomass Utilization in Virginia

In 2012, the last year complete data was available, renewable energy supplied 5.7 percent of Virginia's overall energy mix (Figure 4-18). Biomass supplied 90 percent of the renewable component, contributing just over 5 percent to the Commonwealth's total energy supply. The biomass contribution to Virginia's renewable energy mix has remained relatively constant for over 20 years, supplying on average 89 percent of the renewable mix (Figure 4-19).

The 2012 figure for bioenergy consumption was 29 percent, in the form of liquid fuels for transportation, and 71 percent solid biomass was used for heat and/or power generation. By sector, as defined by the U.S. Energy Information Administration (EIA), 16 percent was consumed in the residential, 8 percent in the commercial, and 58 percent in the industrial sectors, while 18 percent was used in electric power generation. EIA's residential sector is principally private households, and the commercial sector includes institutional living quarters and public sector facilities such as government buildings and wastewater treatment plants. Energy consumption in the industrial sector is primarily used for process heating, cooling, and powering machinery. The electric power sector includes combined heat and power (CHP-- the generation and use of both thermal energy and power), where the thermal energy and/or electricity is sold to another party, in addition to stand alone generation.

Figure 4-18: Virginia Energy Mix, 2012⁴⁴

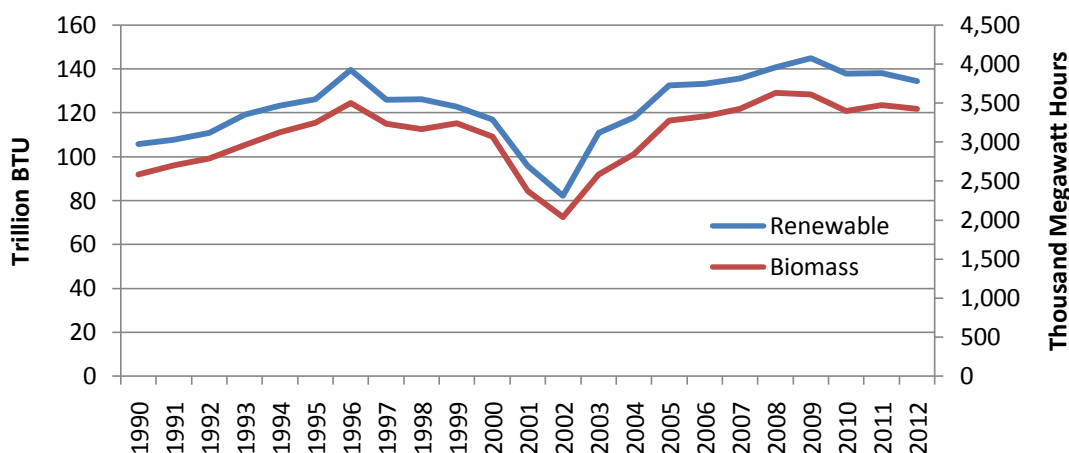


Applications of biomass energy include combustion of solid fuel (wood, waste wood, and other waste materials) for stand-alone electricity generation or combined heat and power; anaerobic digestion of animal manures and the organic component of industrial and municipal solid wastes; collection of landfill gas; and the production of liquid fuels. While electricity generation from woody biomass has seen large gains in

⁴⁴ Source: EIA SEDS Virginia 1960 - 2012 Primary Energy Consumption Estimates: <http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=VA>

recent years and utilization of municipal wastes (waste-to-energy, landfill gas, and waste water treatment plants) increased, installed generation is only about 16 percent of potential capacity.⁴⁵ Volatility in the prices of fuel oil and propane has renewed interest in the use of biomass as a heating fuel at the institutional and residential levels, as well. Fuel costs savings from conversion of these older systems to modern biomass heating systems suggest that growth in institutional solid fuel biomass thermal energy projects can now be expected in Virginia.

Figure 4-19: Renewable Energy Consumption in Virginia, 1990 – 2012.⁴⁶



Utility-Scale Biomass Energy

At the utility-scale, stand-alone power generation with woody biomass can meet base load demand, providing constant, steady power to the grid. Dominion has been generating electricity with woody biomass at their 83-megawatt Pittsylvania Power Station in Hurt, since 1994. The Company has also received approval from the Virginia State Corporation Commission to convert three 63-megawatt coal-fired power stations at Altavista, Hopewell, and Southampton to 51-megawatt woody biomass plants, one of which, Altavista, went online in 2013. Additionally, Dominion began co-firing woody biomass with coal at their new 600 megawatt Virginia City Hybrid Energy Center, in 2012. The Hybrid Energy Center is designed to burn up to 20 percent woody biomass, generating 117 megawatts of biomass energy. Co-firing with woody biomass diversifies their fuel supply and reduces sulfur and nitrogen oxide emissions. The Northern Virginia Electric Cooperative's 49.9-megawatt Halifax County Biomass Plant also began commercial operations in 2013, utilizing forest residues harvested within 75 miles of their South Boston location.

The use of biomass for stand-alone power generation has become a source of contention, however. Overall efficiencies of stand-alone power generation are around 30 percent and the waste heat is by definition not

⁴⁵ EIA assumes that other than biofuels, all renewable energy is consumed at the time of production; production data is presented as the aggregate of renewable energy consumption. While EIA breaks out biofuels from other forms of biomass energy, at this time biofuels is strictly ethanol, and they do not provide separate estimates for biodiesel or wood pellets. The raw materials for the approximately one million tons of wood pellets exported annually from Virginia originate in Virginia forests. If used domestically, the exported wood pellets could displace between 200 and 700 MW of power and thermal energy currently generated with fossil fuels.

⁴⁶ Source: EIA SEDS Virginia 1960 - 2011 Primary Energy Consumption Estimates. <http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=VA>

utilized. Concerns have been raised about the “carbon debt” of biomass power generation and the recent release of the EPA’s proposed Clean Power Plan to regulate carbon dioxide under section 111(d) of the Clean Air Act requires clarification on how biogenic (biomass) carbon emissions will be handled.

Combined Heat and Power

Combined heat and power (CHP) addresses some of these issues by utilizing the heat generated during combustion for other purposes, such as process or space heat. CHP facilities can achieve total systems efficiencies of 60 to 80 percent when producing both electricity and thermal energy. In 2012, there were five operational industrial-scale CHP facilities associated with pulp and paper mills, generating process heat for the plant and a combined 330 megawatts.

In addition to solid wood waste, these mills utilize black liquor, (the by-product of the kraft pulping process), which contains more than half the energy content of the original wood. A promising new application in combined heat and power is the incorporation of an Organic Rankine Cycle (ORC) which uses an organic, high molecular fluid with a lower boiling point than water to drive a turbine. One advantage of an ORC is that it permits work (in this case, the turning of a turbine for electricity production), to take place at a lower temperature than in a classic steam-driven turbine system, and allows for generation using much smaller systems. Another advantage of an ORC is that a non-corrosive organic fluid can be used, extending the operational life of the machinery and reducing operation and maintenance costs for the facility.

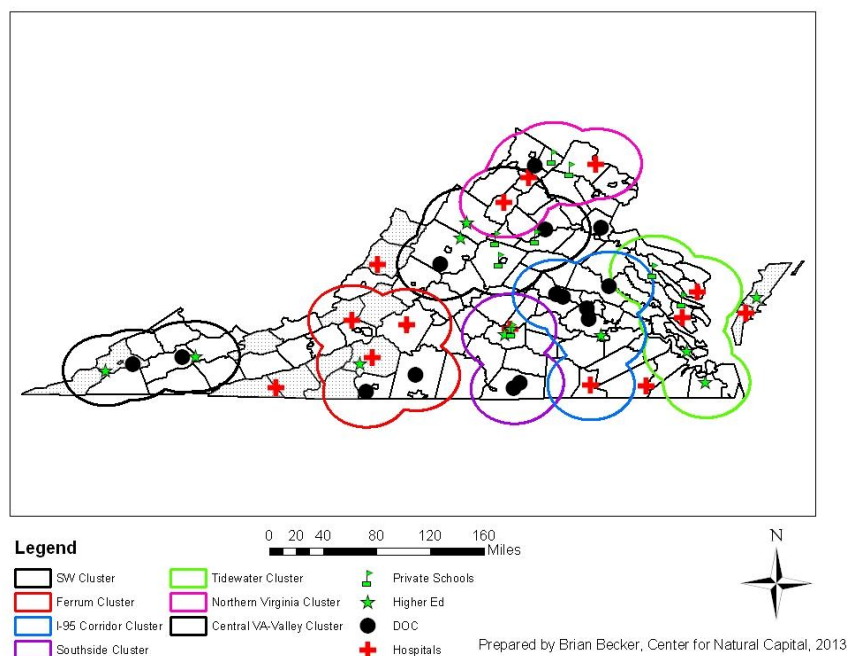
Waste-to-Energy

Virginia also hosts several Waste-to-Energy (WTE) facilities. Combustion of municipal solid waste (MSW) at plants in Alexandria, Fairfax, and Portsmouth generates over 200-megawatts of electricity. The Wheelabrator plant in Portsmouth is also a co-generation facility, providing steam to the Norfolk Naval Shipyard, in addition to electricity.

Thermal Biomass Energy

Direct thermal energy generation for hot water, hot air, and steam for space or process heat is still the most efficient application when combusting biomass. Longwood University and Piedmont Geriatric Hospital (PGH) have been producing heat and hot water with sawdust from local mills for decades. Recently, PGH has embarked on switching over to locally-grown and processed warm season grasses, diversifying their fuel supply and catalyzing a nascent bioeconomy in Southside Virginia. In 2013, Ferrum College, located in Southwest Virginia, installed a biomass CHP system to produce hot water and to meet about a quarter of the electricity demand of the campus. Over 90 other locations throughout the Commonwealth have boilers fueled by wood, wood chips, or sawdust. Significant growth potential exists for expansion of institutional-scaled thermal energy. A recent study of public institutions with active fuel oil or propane boilers in areas of Virginia without access to natural gas identified over 450 locations that include institutions of higher education, private schools, hospitals, correctional facilities, and K-12 public schools (Figure 4-20).

Figure 4-20: Biomass Thermal Opportunity Clusters in the Commonwealth of Virginia⁴⁷



Anaerobic Digestion

Anaerobic digestion, the biological decomposition of organic materials in the absence of oxygen, finds applications across sectors, primarily as a waste management technology. To date, Virginia has seen few anaerobic digestion projects for the production, capture, and utilization of methane for energy. At the industrial level, the MillerCoors Shenandoah Brewery hosts an anaerobic digester, generating a little over a megawatt of electricity from brewing by-products, and in the agricultural sector there is only one dairy farm currently with an operational anaerobic digester. While low retail electricity prices make small projects economically challenging, throughout the Commonwealth there are close to 100 farms with 200 or more dairy cows and over 40 with 500 or more swine that potentially could be suitable for anaerobic digesters⁴⁸. Benefits include odor, fly, and pathogen control and can be coupled with a nutrient management program for additional environmental benefits and financing opportunities.

Methane is also produced by organic matter decomposing under the anaerobic conditions found within landfills. Capturing and flaring the methane avoids the emission of a powerful greenhouse gas. The methane can also be run through an internal combustion engine to generate electricity. The EPA's Landfill Methane Outreach Program (LMOP) database⁴⁹ contains 20 active landfill projects in Virginia, generating over 100 megawatts of electricity, with 3 more projects under construction and another 42 candidate or potential locations identified. Another waste stream that can be anaerobically digested is sewage at wastewater treatment plants. The enclosures for creating the anaerobic condition and for capturing the methane are effective at odor control, and the collected gas can be used to offset plant operations or injected into natural gas (NG) pipelines after cleanup. The Water Resource Recovery Facility Database of

⁴⁷ Biomass Thermal Opportunity Clusters in the Commonwealth of Virginia. Center for Natural Capital, 2013,

<http://naturalcapital.us/2014/01/10/local-bioenergy-opportunities-phase-i-project-completed/>

⁴⁸ USDA Census of Agriculture 2012 Census, Virginia Livestock. <http://www.agcensus.usda.gov/Publications/2012/>, Last accessed June 30th, 2014

⁴⁹ EPA's Landfill Methane Outreach Program (LMOP) Database: <http://www.epa.gov/lmop/>

waste water treatment plants⁵⁰ contains seventeen Virginia entries where anaerobic digestion is incorporated into the water treatment regime.

Biofuels

Liquid fuels production from biomass feedstocks lags well behind total capacity. In 2013, 4.3 million gallons of biofuels (biodiesel and ethanol) were produced out of total production capacity of 17.5 million gallons.⁵¹ There are two biodiesel producers collecting and processing restaurant (yellow) grease located in the Richmond area, an operation in Southside that produces biodiesel from locally-grown canola oil, and the Shenandoah Agricultural Products Farmer's Cooperative in the Shenandoah Valley that produces biodiesel for their users.⁵²

On the ethanol side, the only commercial operation is the recent reopening of the former Appomattox Bio Energy plant by Vireol Bio-Energy, located in Hopewell, which is expected to produce over 60 million gallons a year.⁵³ There are also currently two cellulosic demonstration projects operational in Virginia: 1) Fiberright has a MSW cellulosic demonstration plant in Lawrenceville, with 0.5 million gallon capacity,⁵⁴ and 2) a new effort under development in Callaway, in Southside Virginia, by BCLF (Biomass Cellulosic Liquid Fuels) Corporation to produce 0.37 million gallons of cellulosic ethanol a year from agriculture and wood residues.⁵⁵

⁵⁰ Water Resource Recovery Facility, Biogas Data, 2013. <http://www.wrrfdata.org/biogas/biogasdata.php>

⁵¹ Virginia Alternate Fuels Report, 2014. <http://www.vacleancities.org/wp-content/uploads/Alt-Fuels-Report-Q4-2013-Final.pdf>

⁵² Virginia Biodiesel Plant Listings. <http://www.biodiesel.org/production/plants>

⁵³ Vireol Bio Energy Joins Growth Energy, <http://www.growthenergy.org/news-media/press-releases/vireol-bio-energy-joins-growth-energy/>

⁵⁴ U.S. Ethanol Plants, 2014. <http://www.ethanolproducer.com/plants/listplants/US/All/All/page:1/sort:state/direction:asc>

⁵⁵ Personal Communications, Charles Bowman, BCLF Corporation, June 30th, 2014